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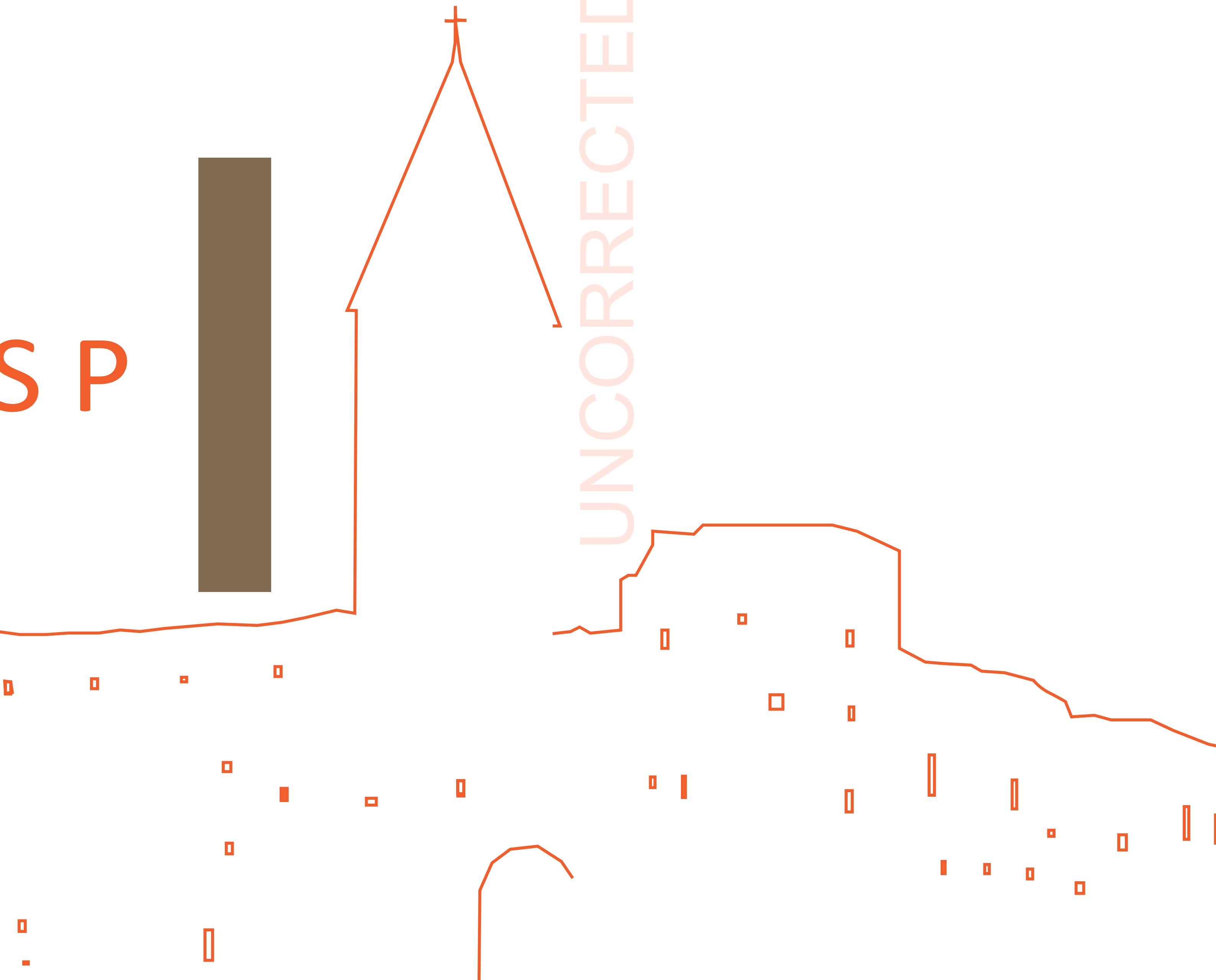

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PAPERTREAT PROJECT - PRESERVING OUR PAPER-BASED COLLECTIONS

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In the 19th century, changes in production technology gave rise to a decrease in paper quality, which resulted in a massive decay of library and archival holdings. In order to increase the useful lifetime of the vast quantities of original materials, paper collections may be deacidified and/or stored in appropriate conditions. Although preservation strategies are well known and have been used for decades, their effect on real-time ageing has not yet been evaluated. Together with the evaluation of side effects and cost estimates, these data are essential for the development of a suitable preservation strategy.

The main aims of the PaperTreat project, co-funded by the European Commission 6th Framework Programme (2005-2008), were to estimate the extension of the useful life of paper, as achieved by traditional and novel treatments as well as by storage at low temperatures, to identify the side effects of the treatments and to provide cost estimates for each treatment, thus enabling the development of the most cost-effective preservation programmes.

The main achievements of the project are the following:

- A new methodology for the determination of the condition of paper was developed. The technique (size exclusion chromatography) for the first time allows us to reproducibly determine the condition of paper which contains a significant amount of wood-derived lignin. A few fibres suffice for the analysis, which renders the methodology suitable for characterisation of historical materials. This represents a significant advantage over the traditionally used methods, where mechanical properties are determined, which require an ample amount of sample and are burdened with a high uncertainty of measurement.

- The technique was used to survey the condition of the collection of Narodna in univerzitetna knjižnica (National and University Library, Slovenia). Together with micro-pH and fibre furnish analysis, an overview of the types of the papers used and the condition of paper, manufactured between 1850 and 2000 was obtained.

Based on the results of the survey, two model papers, representative of papers made in the 19th and 20th centuries, were produced. A model paper containing a variety of inks was produced as well. These model papers will enable quality control of deacidification processes and significantly simplify the evaluation of future new or modified processes.

A database of immediate side effects together with a damage atlas was developed. This will help in the selection of materials for treatments, as well as simplifying the evaluation of side effects by the end-user institutions.

The volatile organic compounds (remaining solvents and reaction products) emitted by treated books were identified and quantified in order to determine the rate of emission under storage conditions. The health and safety regulations were consulted in order to estimate their effect on health.

The effect of a variety of deacidification methods on the stability of paper at room temperature and under cool and cold storage (15 ºC and 5 ºC) was determined. In addition, pollution ageing and light-induced degradation of treated papers were studied. The new ASTM standard on closed-vessel ageing of paper was critically evaluated. This will enable evidence-based paper preservation management in libraries and archives.

Administrative procedures, such as contracts and insurance, as well as costs of various treatments were evaluated and compared.

Results of the PaperTreat project will enable development of the most cost-effective preservation strategies for the decaying collections and thus ensure safekeeping and long term access to the endangered written cultural heritage.

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THE IMPACT OF THE PROMET PROJECT FOR PROVIDING STATE-OF-THE-ART AND SUSTAINABLE PRESERVATION FOR METALS COLLECTIONS

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Abstract

The PROMET project was a major scientific research initiative that concentrated on the preservation of archaeological metal objects and collections in the Mediterranean basin. PROMET received financial support by the European Commission, 6th Framework Programme, which enabled a consortium of 21 partners, educational, research and cultural heritage organizations, from 11 different countries in the Mediterranean basin to carry out an ambitious research program. With its completion, PROMET was successful in providing novel sustainable prototypes and protection systems that can be easily applied to any museum setting world-wide for metals conservation. Surveys of metals collections were carried at 11 museums, and survey approaches were established to identify the conservation problems and needs of the collections using state-of-art portable diagnostic techniques, such as micro-X-ray Fluorescence (μ-XRF) and laser- induced breakdown spectroscopy (LIBS). Furthermore, new and safe corrosion inhibitors, coatings, and barrier films were developed/tested for museum objects housed in the Mediterranean basin, such as linear saturated sodium carboxylates and azoles and natural extracts from Moroccan plants to name a few.

The advances achieved in the frame of PROMET guarantee that there is an audience ready for the prototypes and protection systems developed and/or tested; nonetheless, there are still several critical challenges that need to be overcome in order to effectively introduce these prototypes to the conservation market. The paper discusses the next steps required in order to take the prototypes to the market.

In brief, for the mobile diagnostic techniques, the major task is to develop easy-to-use devices with integrated analysis protocols and supportive user-friendly software tools adapted and optimized for the needs of the conservation community. For the green corrosion inhibitors, laboratory optimisation of the different formulations developed and testing with a laboratory pilot scale of the preparation of the corrosion inhibitor solutions in large quantities to evaluate the manufacturing process, the stability and the ageing of the solutions. It becomes necessary to define experimental conditions to serve as a basis for extrapolation to an industrial-scale process.

1. Introduction

Technological innovation in cultural heritage is considered as the key element to economic development in the Mediterranean region and requires cooperation. To this end, PROMET, a Euro-Mediterranean scientific research project, funded by the European Commission, Framework Programme 6 (priority INCO), represents a coherent endeavour which has brought together specialists and end-users in the field of preservation of cultural heritage so as to develop innovative strategies to protect, preserve, and interpret the material culture made of metals, which are housed in museums of the Mediterranean basin.

To fulfil this curatorial mission, a comprehensive knowledge of materials, manufacturing techniques as well as corrosion processes relevant to the objects of the collections is necessary. This information is of primary importance for improving the archaeological/historical data of the collection and for conducting a survey of the metallic collections that will allow setting up a coherent conservation policy.

Taking into account environmental data and the degradation mechanisms, the curator will need to develop and implement a coherent conservation plan. In some cases, the plan shows that conservation work must take place because of the presence of active corrosion on a metal object. At the end of the conservation treatment, a protection coating must be applied to slow down the exchange between the metal and the corrosive media. With the application of these protective coatings, a maintenance programme must be set up to prevent the degradation of the coating and to determine the time between applications.

Good knowledge of the composition of the ancient metals can be a decisive factor for their preservation, because some alloys are more sensitive to changes in the environment than others. Thus, it is often important to perform early diagnostic analysis to identify the mechanisms that lead to the degradation of collections.

Jointly, the partners of PROMET developed new strategies to monitor the corrosion of metal objects using state-of-the-art analytical techniques such as micro-X-ray Fluorescence (μ-XRF) and laser- induced breakdown spectroscopy (LIBS) implemented by means of portable prototypes developed in the frame of PROMET. Scientific studies are providing other and newer ways to obtain information about these unique collections from the past. At the same time, conservation scientists developed and/or tested new materials, corrosion inhibitors, coatings, Plasma Vapour Deposition (PVD) and Plasma Enhanced Chemical Vapour Deposition (PECVD) barrier films as alternative ways of better protecting metals collections that are safer, more effective, reversible, and longer-lasting.

The only way to establish and to promote a proper conservation strategy for the Mediterranean region is to develop prototype portable diagnostic and/or monitoring systems and protection methods, to identify each specific degradation factor for the many museum collections of precious metals, iron and copper alloys, and then carry out the preservation.

2. Survey and damage assessment

One major aspect of the PROMET project was the development of new strategies to assess the collections under study by designing technology and condition survey approaches. Surveys of metals collections housed in 11 museums throughout the Mediterranean have been carried out using a systematic survey approach, which involves using either a statistical methodology in assessing the technology and condition of a large sample of the objects and a data-mining technique to survey a random sample from the collection, or, in the case of precious metal objects, an in-depth diagnostic investigation of the chemical and mineralogical properties of a representative number of artifacts.[1,2] For the PROMET project, the 11 collections studied had different questions for their assessment and thus different approaches were developed to conduct their respective survey. The quality of the survey information depends on the analytical tools used to either identify or verify the information obtained visually. Here analytical techniques are required that are non-destructive to the bulk material and at the same time quick to survey a large collection of objects.

3. Non-destructive analytical techniques

Modern analytical techniques, such as micro X-ray Fluorescence (μ-XRF) and laser-induced breakdown spectroscopy (LIBS) are excellent tools for identifying the characteristics of metal artifacts as well as the different factors involved in metal degradation. These advanced non-destructive techniques formed the basis of two mobile diagnostic prototypes that enabled the consortium to carry out several analytical campaigns, surveying collections of archaeological or historical metal objects in *situ,* and making it possible to characterize the objects and pinpoint conservation needs without any risk of damaging the artifacts. A major advantage of the micro-XRF and LIBS mobile instruments developed is that they can overcome the huge obstacle of sampling archaeological objects or transporting them away from their site, often to a different country.

Micro-XRF spectroscopy

Basic research was focused first on the original design and optimization of the micro-XRF probe characteristics, building on the experience of previously developed successful commercial prototypes and on the know-how about milli-beam spot XRF spectrometers developed in-house at NCSR Demokritos. A systematic study of the analytical performance of the micro-XRF spectrometer was undertaken regarding the analytical description of its elemental excitation response, spatial resolution and analytical sensitivity. Optimized analysis protocols were developed and validated through various experimental methodologies towards an accurate, precise compositional analysis of the alloys composition overcoming problems that arise either from their heterogeneity (in many cases) at the micrometer scale or Bragg spectral interferences.

As a next step, the micro-XRF spectrometer was evaluated in terms of its analytical performance to identify corrosion products formed on the metal surface. Artificially corroded copper and silver coupons produced by the PROMET partner CNR-ISMN to simulate the composition and degradation phenomena of archaeological alloys, were measured exploring various experimental methodologies and data analysis procedures. The micro-XRF results were compared to the one obtained by SEM-EDX and XRD techniques so to identify and document the analytical capabilities of the micro-XRF technique.

Analytical methodologies were also developed, studied and optimized to overcome two major problems regarding the micro-XRF analysis of metal alloys; the heterogeneity that appears very often (depending on the type of the alloy) at the micrometer scale and the interfering presence of diffraction peaks in the XRF spectrum.

The experimental tools developed and the results obtained analyzing a variety of alloys at different states of degradation, proved to help significantly towards the non-destructive identification of corrosion products based on either the spatially resolved co-existence of fingerprint elements (at the range of 100 μm), or of single element distribution maps. Additional and complementary analytical tools were explored and investigated such as the elemental intensity contrast between the corrosion layer and the bare alloy and/or the competition of the element low and high energy characteristic X-ray intensities (if both detected). These experimental approaches are considered as state-of-the-art methodologies proposed and applied for the first time by the NCSR Demokritos work within PROMET.

A significant state of the art contribution of NCSR Demokritos within PROMET was the development of a novel analytical approach to describe the X-ray lens transmission efficiency and thus to predict more accurately the exciting spectral distribution in the micro-XRF analysis. The model developed was next validated in reproducing concentrations of ten (10) standard reference (SRM) glasses (NIST and BAM) with deviations less than about 10%-15%. The advantage of the proposed analytical approach is that it does not require removal of the X-ray lens from the micro-XRF setup configuration and thus it can be adapted in commercial micro-XRF spectrometers supporting crucially the quantification process in micro-XRF analysis.

LIBS spectroscopy

Also referred to as laser-induced plasma spectroscopy (LIPS), derives by time- and spectrally-resolving the optical emission of a transient micro-plasma generated by focusing a nanosecond pulse from a laser on a solid surface (laser ablation). The characteristic, sharp atomic emission peaks in the LIBS spectrum enable the identification of the elements contained in the plasma plume, reflecting the local elemental composition of the solid sample. The peak intensity or the integrated emission of individual spectral lines can be associated with the concentration of the elements in the sample, leading to quantitative analysis based on calibration curves (obtained by analyzing appropriate reference samples) or on calibration-free methods.

Starting in 1997, with an original paper by the IESL-FORTH group,[3] LIBS was shown as a potentially useful tool for analysis of works of art and archaeological findings. Since then, research that demonstrates the potential of LIBS in the field of cultural heritage has been reported in the literature describing analytical studies of materials in a variety of objects including painted artworks, icons, polychromes, pottery, sculpture, metal, glass and stone artifacts.[4-10]

Obviously in the context of dealing with art objects several of the characteristic features of LIBS are considered quite important such as for example the ability to carry out the analysis in *situ*, with no need for sampling or sample preparation. The latter, coupled to the fact that a typical measurement requires a single laser pulse and the corresponding spectrum is acquired in less than one second, offers unparalleled speed. In addition, because of the tight focusing of the laser beam the lateral spatial resolution achieved is nearly microscopic (the diameter of the area probed is on the order of 100 microns). Even though the analysis leads to material removal from the surface, the loss in a typical LIBS experiment, is minimal (in the tens or hundreds of nanograms range) and any damage to the sample surface is practically invisible to the naked eye. Thus, LIBS can be considered as a nearly non-destructive technique.

In the frame of PROMET, the research group at FORTH aimed to first design and then construct a portable LIBS instrument capable of analysing the materials and potentially monitor the degradation products on metal collection objects in Mediterranean.

Based on previous experience with a mobile LIBS system for the analysis of archaeological objects, FORTH actually developed and constructed a new fully portable LIBS system, LMNTII (eL-eM-eNT-two). This portable instrument (Fig. 1) enables rapid, multi-elemental, in *situ* analysis with minimum influence on the sample surface while in certain cases there is also the possibility for quantitative analysis (based on reference alloy standards). Furthermore, a depth profiling analysis is possible, when multilayered samples are examined.

In parallel to the instrument development efforts, research was carried out in collaboration with NILES optimizing analytical methodologies for metal analysis. Tests were performed on reference samples prepared in collaboration with PROMET project end-users (i.e. TEI, CNR-ISMN, SVUOM). To achieve this, a series of systematic and detailed tests and evaluations have been made both on model and real samples.

Overall, LMNTII indeed succeeded to take LIBS technology outside the research laboratory to real-life archaeological analysis applications as demonstrated with the PROMET campaigns at Ancient Messene, Damascus, and Yarmouk. A typical case of LIBS analysis of a decorative foil, exhibited in the Museum of ancient Messene in Peloponnese, Greece is shown in Figure 2.

Figure 1: LMNTII, the portable LIBS instrument developed in PROMET.

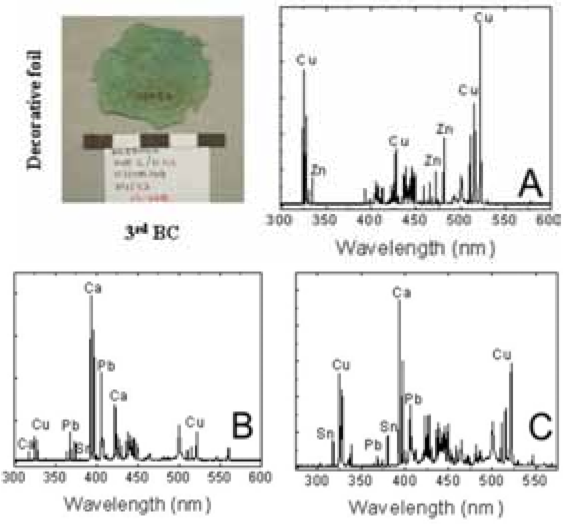

Figure 2: LIBS analysis of decorative foil from the Museum of Ancient Messene. A: Bulk metal – main elements detected; B: White corrosion – high Pb and Ca compared to the bulk metal; C: Black corrosion – high Sn and Ca compared to the bulk metal.

The synergistic and combined real time application of micro-XRF and LIBS spectrometers was carried out for the first time by NCSR Demokritos and FORTH research groups within PROMET. The analysis of a micro-spot being successively ablated by LIBS pulses may reveal and elucidate the elemental stratigraphy of a corrosion layer, whereas in addition the μ-XRF technique evaluated the micro-destructive aspect of the LIBS irradiation supporting this way the optimization of the LIBS instrumental and operational parameters for minimum risk.

The in-*situ* analytical campaigns of the micro-XRF spectrometer assessed extensively the analytical performance of the spectrometer in "real" conditions, away from the controlled conditions of the laboratory environment.

The first on site campaign at Ancient Messene in Peloponnese, Greece (September 2006), highlighted several practical issues and gave the opportunity for further development and optimization of the system (i.e. by addition of an imaging system to locate the sampling areas).[11] During the 2nd on-site campaign to Syria and Jordan (October- November 2007) the optimized portable LIBS instrument was tested on real gold, gilded and bronze artifacts from the Archaeological Museum of Damascus in Syria and the Numismatic Museum of the Yarmouk University in Jordan including copper alloy artifacts from Umm Qais.[2] In both campaigns the complementarity of the LIBS technique to μ-XRF analytical system developed by NCSR Demokritos was investigated.

In addition, the NCSR Demokritos group travelled to Malta to apply and assess the analytical performance of the micro-XRF spectrometer and another milli-XRF device in the analysis of Palace Armoury metal collections.[12]

4. Corrosion inhibitors and protective coatings

Another major innovation for this project was the search for new, safe, and effective corrosion inhibitors, coatings, and barrier films for the protection of cultural property made of metals. Safe corrosion inhibitors do exist, and new chemical agents were developed and/or validated to use on artificially- or naturally-aged metal reference alloys and, then, real metal objects.

These include: Linear saturated sodium carboxylates; Azoles and natural extracts from Moroccan plants; Salts of linear aliphatic organic acids, derived from vegetable oils and extracts (for example, cactus); Commercially available and safe corrosion inhibitor additives for synthetic waxes and varnishes.

Furthermore, innovative plasma processes for the deposition of barrier films and for suitable cleaning of the artifacts were investigated, such as PECVD of SiO_2-like thin films associated to a cleaning pre-treatment in hydrogen plasma. The SiO_2-like coatings are transparent and characterised by high chemical and thermal stability, good dielectric properties, and low gas permeability.

The challenge we are facing is to determine which protection systems are suitable for the long-term protection of objects in the Mediterranean region.

Within PROMET, we developed a strategy that meets the needs of the Mediterranean region. The aim was to determine, by means of a systematic scientific approach, the most compatible, reversible and environmentally-friendly corrosion inhibitors and/or coatings to protect objects made of copper, iron, and silver alloys within the Mediterranean region. The 'environmentally-friendly' feature was essential considering that usually there is no proper way to dispose of toxic chemicals and/or standard conservation laboratory may be nonexistent.

Within PROMET, we were interested in testing and developing temporary and permanent systems for cultural heritage objects stored or exhibited in uncontrolled conditions. Corrosion inhibitors (CIs) usually respond to the need of short-term protection, whilst coatings (synthetic microcrystalline waxes or varnishes) are believed to be more appropriate for long-term protection (5-10 years). The approach that we followed has been outlined elsewhere,[2,13] and is summarised in Figure 3 as well as some important points are highlighted below.

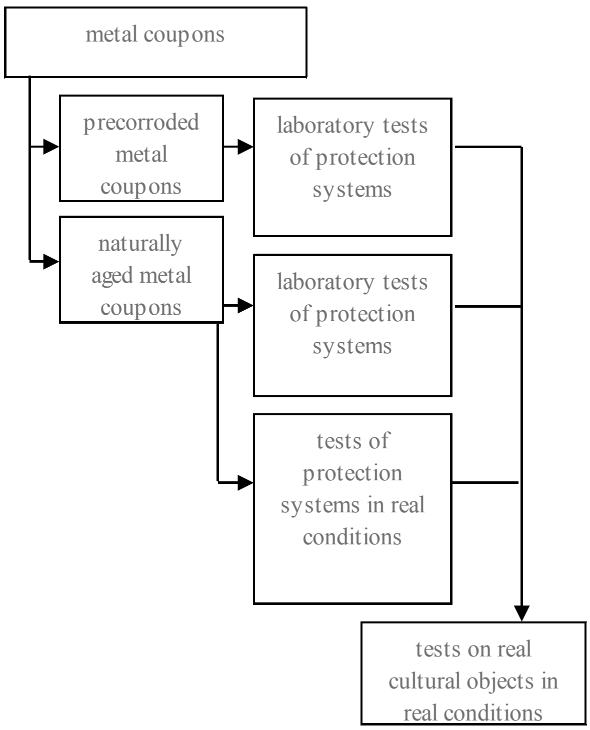

Figure 3: Methodology followed by PROMET partners for testing traditional and innovative protection systems.

To avoid initial testing of the different protection systems on real objects, it was necessary to manufacture pre-corroded metal coupons simulating real objects, which could be used all along our experimental work. Furthermore, duplicate metal coupons could be tested to ensure the reproducibility of the results. The steel (50x75x2.5 mm), bronze (50x75x5-6 mm) and silver based (Ø15 – 19 mm) coupons were manufactured by partners HM, SVUOM and CNR-ISMN respectively according to the types of metal typically encountered on objects of the Mediterranean basin.

The consortium devised several protocols for testing, examining, and analysing the protection systems selected on pre-corroded metal coupons. Short-term testing was first considered on artificially aged coupons for a preliminary selection of protection systems. Long-term testing was carried out afterwards on naturally aged coupons to assess the effectiveness of the most promising protection systems in real conditions of exposure. The products that behaved the best were finally tested on real objects.

The artificial ageing of the metal coupons aimed at reproducing the corrosion layers found on historic objects (for steel, bronze and silver based alloys) and archaeological objects (for silver objects). For steel and bronze coupons the protocols involved exposure in a humid chamber with or without a pre-chemical treatment and were carried out by HM / DMME and SVUOM respectively. For silver based coupons the protocols depended on the partners and involved exposure in a humid chamber in presence of SO_2 or immersion in chemicals ($CuCl_2$, BaS, K_2S, $CuSO_4$, $5H_2O + ZnCl_2$, $(NH_4)S$ or with alternate steps of drying in diluted Na_2S solution followed in the case of the simulation of archaeological objects by an exposure on site. The cleaning and application of protection systems was carried out by the same professional conservator-restorer (C-R) for each set of coupons (steel, bronze and silver based alloys) so to respect the original surface of the coupons.

Innovative protection systems were applied on these artificially aged coupons only by the partners who developed them before sending them to the other partners for testing in their countries, so as to limit any risk of heterogeneity based on application of protection system for the coupons tested.

For the short-term testing, the traditional protection systems used for comparison purposes were applied by the partners themselves on the artificially aged coupons sent to them by HM, SVUOM and CNR-ISMN.

Another group of metal coupons (50 per partner for steel and bronze, only a few for silver based materials) were naturally aged on site during a period of one year to simulate in a better way natural corrosion forms similar to real objects. The corrosion progress was followed during the exposure period, and after 3, 6 and 12 months binocular observations, colour change measurements, SEM-EDS investigations were carried out on the series of removed coupons.

For the long-term testing, the naturally aged steel and bronze coupons were first sent respectively to HM and TEI for mechanical cleaning carried out by a professional C-Rs that also applied the chosen traditional protection system 15% (w/v) Paraloid B-72® in acetone as a reference, which was tested at all museum sites (see Fig. 4). Both these coupons and the others (including silver based coupons) were mailed to the partners developing innovative protection systems that had to be tested. The protected coupons were finally sent back to their respective countries for another year of natural ageing under the same conditions as before.

Since it was impossible to remove real objects from one country to another, only innovative CIs and coatings that could be easily applied by any of the partners had to be considered. Poligen ES 91009 ® (with or without corrosion inhibitor additives) was considered for iron-based historic objects (arms and armours) and carboxylatation solutions from slightly to heavily corroded archaeological iron objects.[2,13] FPTS CI and silane A were considered for historic and archaeological bronze objects.[2,13] 2% nano-alumina pigmented Paraloid B72® and silane A were chosen for silver-based objects.[2,14]

Figure 4: Coatings applied to steel coupons by C-R (TEI Athens).

Our initial results after one year of testing on real artifacts found that a good replacement for Paraloid B-72® for temporary protection on partly oxidised historic steel objects was carboxylatation treatment ($HC_{10} + H_2O_2$ or $NaBO_3$). Poligen ES 91009® could be suggested for the long term protection of historic steel objects.

5. Conclusions

Still many challenges remain in order to ensure that the prototypes developed and/or tested can be applied to the conservation market.

Regarding the mobile analytical techniques, micro-XRF and LIBS, the possibility to enhance the data analysis software, the compactness and the robustness of the instruments as well as to produce low-cost, easy-to-use and reliable equipment remain important. Specifically, the tailored optimisation of the hardware components for reducing the sampled area in order to achieve a micro-beam spot of analysis that enables the investigation of typical corroding spots present on ancient degraded objects. The development of specific software tools for the appropriate calibration procedures and data handling able to provide reliable and enhanced analytical information from degraded ancient artefacts with a complex morphology and chemical composition.

For the protection systems to improve the synthesis conditions of these new safe protection systems and to identify the technological aspects that require adjustment for passage to an industrial pilot scale:

- Testing with a laboratory pilot scale of the preparation of the corrosion inhibitor solutions in large quantities to evaluate the manufacturing process, the stability and the ageing of the solutions.

- The corrosion inhibitor solutions to be tested on a large scale on real objects belonging to museum collections.

- Clear evaluation of the handling of the inhibitor solutions in the case of dilution process since products developed for the conservation market are more concentrated to reduce the size of the packaging.

- Furthermore, it still remains that for all the successful protection systems to determine their optimal efficiency, and to test the real reversibility and/or re-treatability after a long-term period.

The success of the PROMET project came from the testing and evaluating the innovative approach, monitoring tools, protection materials on real collections throughout the Mediterranean region by the end-users, namely museum and C-R professionals in order to assure their applicability to real situations. Now it remains to take the prototypes and protection systems developed further and make them readily available to the conservation market.

6. Acknowledgement

PROMET, Contract No. 509126, Developing new analytical techniques and material for monitoring and protecting metal artefacts from the Mediterranean region, Co-ordinator: Vasilike Argyropoulos, The Department of Conservation of Antiquities & Works of Art, Technological Educational Institute of Athens (T.E.I. of Athens), Ag. Spyridonos, Aigaleo - Greece 12210, Email: bessie@teiath.gr

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EUROPE AT CUSBO FOR THE ANALYSIS OF PAINTINGS: A RESEARCH INFRASTRUCTURE FOR CULTURAL HERITAGE

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1. Introduction

LASERLAB-EUROPE[1] is a Consortium of 17 laser infrastructures from 9 European countries forming an Integrated Infrastructure Initiative. The Consortium combines the majority of the largest European laboratories in the area of laser-based inter-disciplinary research, representing a comprehensive collection of modern laser technologies and laser research, and pursuing applications in sciences and life sciences through in-house research and services to the relevant communities. Integration amongst researchers of the European Community (EU) is enhanced through dedicated Networking and Joint Research Activities and through a highly coordinated trans-national access program. In fact, within the 6th and 7th Framework Programme of the European Commission, LASERLAB-EUROPE provides financial support to EU researchers desiring to obtain access to individual major research infrastructures on the basis of proposals on well focused research activities.

Amongst the 17 infrastructures, CUSBO (Centre for Ultrafast Science and Biomedical Optics),[2] located at the Physics Department of Politecnico di Milano, offers new generation fast laser sources and time-resolved spectroscopy techniques for non-invasive investigation of organic and inorganic materials, with possible applications ranging from the biomedical imaging to material processing and the analysis of materials from Cultural Heritage.

In the field of Cultural Heritage, the activities at CUSBO represent a practical juxtaposition of cutting-edge laser technology and the analysis of art. Principal research focuses on time-resolved fluorescence and reflectance spectroscopic techniques for the analysis of a variety of different types of materials; this includes protein-based binding media[3] and organic varnishes on models and real paintings. Further, in-situ measurements on wall paintings and stone sculptures, including works of Masolino[4] and Michelangelo,[5] have been carried out.

2. Laboratory equipment and research

Ultraviolet (UV)-induced fluorescence is a widely exploited tool in the analysis of works of art, which can be used to better visualize or detect retouchings, coatings, varnishes or other non-original materials on the surface of a work of art and provide information on the presence of specific compounds, such as modern fluorescent pigments,[6] natural colorants in wood and silk textiles,[7] commonly used varnishes[8,9] and organic binding media.[10,11]

Laboratory equipment available at CUSBO includes different fluorescence spectroscopy devices, comprising a continuous-wave fluorimeter, a nanosecond time-resolved fluorescence spectrometer and a nanosecond fluorescence lifetime imaging instrument. Past and on-going projects focus on the study of painting materials using fluorescence spectroscopy. Examples include the analysis of protein-based binding media[3] and of natural varnishes on models. The combined use of both spectrally and temporally-resolved fluorescence spectroscopy indicates the possibility of a clear differentiation between different types of materials, opening the way for a potential in-situ characterization of paintings on the basis of non-invasive spectroscopic techniques. In particular, time-resolved fluorescence techniques may be decisive in certain cases, since fluorescence lifetime permits the discrimination amongst some materials despite minimal differences in fluorescence spectra.

3. Fluorescence lifetime imaging for in situ investigation and case studies

In addition to point-like fluorescence spectrometers, fluorescence imaging devices are particularly attractive for in situ analysis on real paintings, since they can be used to document the presence of organic or fluorescence contaminants and compounds on large areas; further, fluorescence imaging measurements can be easily repeated in time, thus allowing the monitoring of possible changes in condition, due to fluctuations in light exposure, humidity, pollution, etc. on a work of art either prior to, during or after conservation or restoration.

At CUSBO a portable Fluorescence Lifetime Imaging (FLIM) apparatus was developed for advanced fluorescence investigation of works of art. FLIM is an experimental technique based on the measurement of the lifetime properties of the fluorescent emission at every point of a field of view. The nanosecond FLIM apparatus available at CUSBO is based on a pulsed laser emitting nanosecond UV pulses at 337 nm for fluorescence excitation on a nanosecond time-gated image intensifier for acquiring fluorescence emission from the surface. Based on the exponential decay of fluorescence intensity immediately following excitation, FLIM yields the fluorescence lifetime map of the surface, potentially differentiating between different fluorophores in the field of view.

Recently, FLIM has been successfully applied to characterize the presence of conservative treatments and organic original materials on Renaissance wall paintings as well as contaminants on the surface of marble sculptures. As an effective example of in-situ FLIM analysis, the results of time-resolved fluorescence measurements carried out on Michelangelo's last masterpiece, the Pietà Rondanini, are briefly summarized here: FLIM analysis was carried out three times (before, during and at the end of a cleaning intervention) and it was mainly aimed at identifying areas showing similar fluorescence features and, therefore, characterized by similar mixture of compounds present on the marble surface. The results provided by FLIM where further integrated with laboratory analysis on selected micro-samples. In detail, these investigations allowed us to assess the presence of two different contaminants on the surface of the sculpture: a yellow-brown patina diffused almost over the entire surface, showing a peculiar fluorescence lifetime around 4.5 ns, and a mixture of organic compounds mainly located in the concave areas, such as the carving and sculpting notches and signs, showing a higher intensity emission and a lifetime approximately 6 ns.

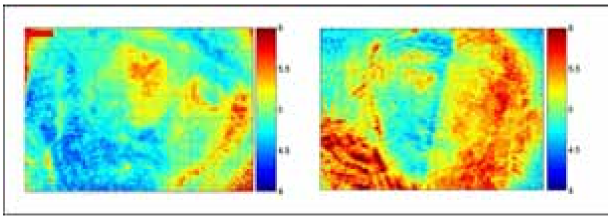

Figure 1: Fluorescence lifetime map (nanosecond scale) measured on the face of the Virgin of Michelangelo's Pietà Rondanini before (left panel) and after a distilled-water based cleaning trial on the left side of the sculpture (right panel).

In Figure 1, left panel, the potential of FLIM is demonstrated for the case of the face of the Holy Virgin, where a fluorescence emission characterized by a lifetime near 6 ns can be observed on the chisel signs located around the eyes and the oval of the sculpture, whereas a shorter fluorescence lifetime is measured on the lower part of the figure, corresponding to areas where a yellow brown patina is observable under normal visible illumination. In Figure 1, right panel, the fluorescence lifetime map measured on the face of the Virgin is shown after cleaning performed with distilled water on the left part of the face. In the cleaned area, still characterized by a detectable fluorescence emission, a uniform lifetime near 6 ns is measured. Following analysis of micro-samples, FLIM results suggests that the patina, easily removed with the cleaning, was an external layer, most probably intentionally applied after the last casting operations, whereas under it the mixture of organic compounds is still present and couldn't be removed with the distilled water-based cleaning.

4. Development of new instrumentation

In addition to time-resolved fluorescence imaging measurements, spectrally-resolved imaging analysis can provide important indications for the in-situ analysis of a work of art. In fact, emission spectra and fluorescence lifetime are the two properties that mainly characterize a fluorescence emission:[12] the fluorescence spectrum of a molecule is primary related to the structure of the vibrational levels in the ground state of the fluorophore, whereas the lifetime of a fluorophore is defined as the average time molecules spend in the excited state before returning to the ground level and both parameters can be used for discriminating between different complex fluorescent compounds.

Starting from these simple considerations, a multispectral imaging device for recovering fluorescence spectral information was developed. The new imaging apparatus is a multispectral imaging device,[13] which exploits two UV lamps for fluorescence excitation and a liquid crystal tunable filter coupled to a low-noise CCD as the image detector. A sequence of images is sequentially acquired by sweeping the transmission band of the filter between 400 and 720 nm. In this way, the fluorescence emission is sliced in multiple narrow bands within the visible region of the electromagnetic spectrum and the fluorescence spectrum is recorded at each pixel of the field of view. By simply changing the illumination source of the device from UV to visible, the multispectral imaging device can be used for recovering spectral information of the light diffusely reflected from an artistic surface. Diffuse reflectance measurements of a painted surface are extremely useful since they may provide information on color fading, alterations or changes and on the nature of pigments used by an artist. The new spectroscopic imaging system was tested in conjunction with the FLIM device for analyzing wall paintings of Masolino da Panicale in Castiglione Olona. The combined fluorescence and reflectance analysis proved extremely effective for the analysis of the organic painting materials used by the artist.[13]

5. Acknowledgements

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EU PROJECT PROPAINT - ASSESSMENT OF ENVIRONMENTAL PROTECTION FOR PAINTINGS OFFERED BY MICROCLIMATE FRAMES AND VARNISHES

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Abstract

In the ongoing EU project PROPAINT (SSPI-044254) "Improved Protection of Paintings during Exhibition, Storage and Transit" detailed study is performed of the protection effect of microclimate (mc) frames and varnish treatments for the conservation of paintings. Doses and expected degradation effects of pollutant gases inside mc-frames of different design are studied extensively. For this purpose a set of dosimeter techniques are used to determine best possible innovative combined dosimetry for the evaluation of air pollutant and climate effects on the conservation state of paintings in mc-frames. Concentrations of expected important pollutant gases in the mc-frames are measured by using passive gas samplers. In addition climate (RH, T, UV and Lux) is measured. Environmental dose-response functions are developed by using statistical methods, and dosimeter responses are evaluated against most accepted threshold levels of tolerability of environments and related effects on the objects as determined by conservation scientists. Accelerated laboratory tests and field exposures of a range of varnish samples are performed to establish air pollutant and climate degradation effects on varnishes and compare effects with measured environmental conditions observed inside mc-frames of different typical modern and traditional designs used in selected museum locations throughout Europe and in Mexico.

1. Introduction

The main aim of the EC project PROPAINT (SSPI-044254) "Improved Protection of Paintings during Exhibition, Storage and Transit" is *to provide conservation staff and stakeholders with innovative protection treatments used as a preventive conservation measure for paintings during exhibition, storage and transit.* The protective effect of microclimate frames and varnishes is studied. Mc-frames protect paintings physically, against externally generated pollutants and give climate buffering. The positive effects are assumed to outweigh the negatives of added weight, difficulty of handling, risk of breakage, trapping of internally generated pollutants and cost. The chemical composition of the air and climate was measured inside and in the rooms just outside of different state of the art microclimate frames in 7 museums in Europe and one in Mexico.

2. Experimental

Three different generic effect dosimeter technologies (Figure 1) and a range of passive air pollution samplers were used.

Figure 1: The three PROPAINT dosimeters and a microclimate frame design: A. The NILU EWO (Early Warning Organic) dosimeter. B. The Birkbeck PQC (Piezoelectric Quartz Crystal) dosimeter and C. The Fraunhofer Glass Slide dosimeter. D. A SIT-Artyd microclimate frame.

The NILU Early Warning Organic (EWO) dosimeter is a synthetic polymer sensitive to the photo-oxidising elements of the environment and climate. The EWO response to the environment was statistically derived from simultaneous measurements of environment parameters and dosimeter response in the previous EU project MASTER (EVK4-CT-2002-00093). Calibration for relative humidity levels is indirect using isoperm values for temperature and humidity. Dosimeter threshold values for the quality of environments for organic objects was determined from a comparison of environmental effects on the dosimeters and known effects on real objects.

The Birkbeck Piezoelectric Quartz Crystal (PQC) dosimeter was developed within the EU project MIMIC (EVKV-CT-2000-00040) at Birkbeck College, London, together with QuartzTec. Both resin mastic and lead coated crystals are used in PROPAINT. The environmental effect on the crystals is measured as their frequency shift. In PROPAINT the shift from before to after the exposures was measured. The frequency shift can also be measured continuously during the exposure. For comparison with effects on the dosimeters lead coupons were also exposed in PROPAINT.

The Fraunhofer Glass Slide dosimeter developed in the EU project AMECP (EV5V-CT-92-0144) is a thin wafer of calcium and potassium rich glass highly susceptible to corrosion. The dosimeter is very sensitive towards pH changes and thus acidic species and monitors the corrosivity of the atmosphere on site, quantified by FTIR-absorption measurements in the OH-band. Microscope and ATR-FTIR analysis can be performed of the corrosion products including surface crystals salts, leaching, cracking and intrusion of water into the corroded glass surface, allowing correlation with main impact factors like RH, T, or pollutant gases. Environmental impact levels, from acceptable to dangerous, for cultural heritage objects have been determined for the dosimeter.

The three kinds of dosimeters were exposed simultaneously for three months (2007/08), inside and outside of state of the art microclimate frames on 12 locations in 7 European and one Mexican museum organisations (Table 1). In addition two periods of dosimeter exposures were performed in the SIT-Artyd frame maker laboratories in Madrid. Climate (T and RH) was measured during the dosimeter exposures. two periods with standard passive samplers following the dosimeter exposures. VOCs during one week, then NO_2, O_3, SO_2, acetic and formic acid, and formaldehyde, with separate samplers during one month. The air exchange rates of the microclimate frames and light (Lux and UV Pollutants were measured in) are presently being measured.

The following test locations were used:

1. SIT-Artyd workshop (several frames), Madrid, Spain
2. National Gallery, Oslo, Norway
3. English Heritage, Apsley House, London, UK
4. English Heritage, Kenwood, London, UK
5. Tate, Tate Britain, London, UK
6. Tate, Tate Store, London, UK
7. Danish National Gallery, Copenhagen, Denmark
8. Fine Art Museum, Valencia, Spain
9. National Museum of Art, Mexico City, Mexico
10. Germanic National Museum, Nürnberg, Germany
11. National Museum of Krakow (Leonardos frame), Poland
12. National Museum of Krakow (new frame), Poland

In PROPAINT samples of different most common types of natural and synthetic *varnishes*; dammar without and with Tinuvin, mastic, MS2A without and with Tinuvin and Paraloid B72, were prepared on stainless steel foils, cured at 40 ºC and 50% RH for one month, and exposed to varying high doses of air pollutants (NO_2, O_3 and acetic acid,) in accelerated tests in an exposure chamber at T = 22 ºC and varying RH, and, ongoing, to O_3 and UV light combined. Chemical and physical analyses of the raw and exposed varnish samples were performed. Varnishes are also presently being exposed to the environment inside and outside microclimate frames in five of the end user museums. Measured oxidation effects on varnishes in accelerated tests will be compared with conditions inside microclimate frames, and with possible effects on the varnish samples exposed for long time in the museums.

Further work is in progress and, in particular, includes measurements on varnished replicas by scanning electron microscopy (SEM), Secondary Ion Mass spectrometry (SIMS) and depth profiling SIMS, Direct Exposure Mass Spectrometry (DEMS). Moreover, all the results obtained with the different techniques used will be integrated to evaluate the overall performances of varnish replicas in order to suggest a better conservation practise.

2. Results

Dosimeter response

Pairs of dosimeters, the EWO and resin mastic coated PQC (Fig. 2) and the Glass Slide and lead coated PQC (Fig. 3), showed high correlation in their responses.

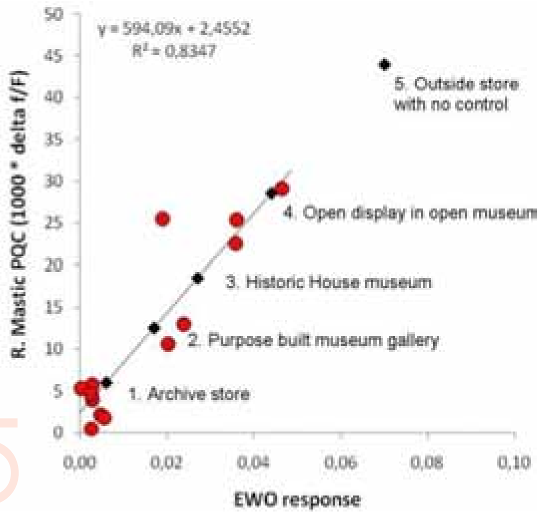

Figure 2: Correlation between EWO and resin mastic coated PQC dosimeter responses in the museum room and frame locations.

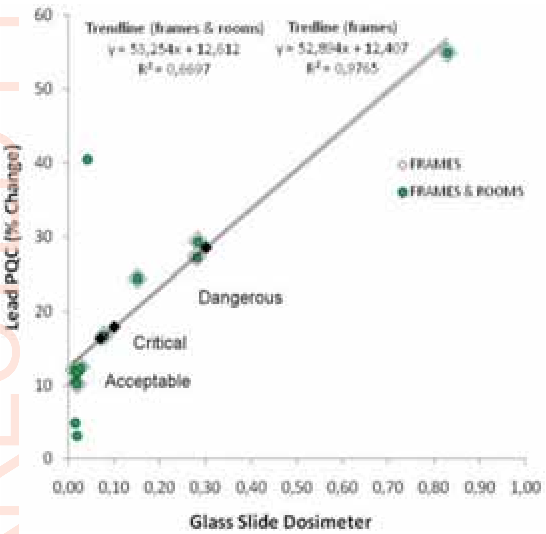

Figure 3: Correlation between the Glass Slide and lead coated PQC dosimeter responses in the museum room and frame locations. Diamonds are frame locations with R^2 = 0.98.

Levels of tolerability of environments for organic archive and museum objects in different locations have previously been determined for the EWO.[1] Environmental impact levels, from acceptable to dangerous, for cultural heritage objects have been determined for the Glass Slide dosimeter.[2,3] The correlations found for the pairs of dosimeters made possible suggestions for similar impact levels also for resin mastic coated and lead coated PQC (Figs. 2 and 3).

Environmental measurements

The measurement of pollutant gases in the frames and museum rooms showed low inside to outside of frames (I / O) ratios for inorganic gases that typically infiltrate into frames from outside, but high I / O - ratios for organic gases that typically have emission sources inside the frames (Fig. 4).

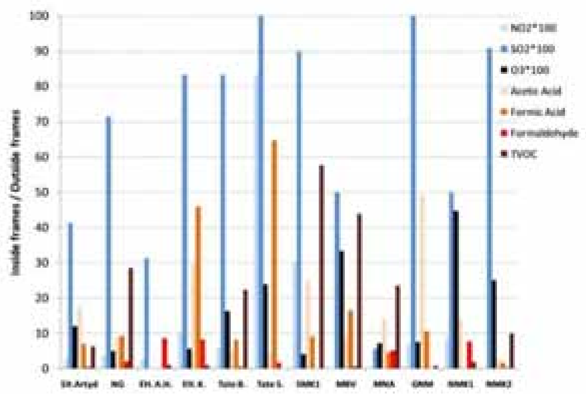

Figure 4: Inside to outside of frames (I / O) ratios for concentrations of inorganic and organic gases in PROPAINT locations. The bars for the inorganic gases are shown inside the circles.

Table 2 shows max and min values for the concentrations of the pollutant gases measured in frames and rooms for the measurement locations.

Table 2: Minimum and maximum values for pollutant gases measured in frames and rooms in the PROPAINT locations. Values in brackets were measured for a "worst case" with an oak panel, freshly prepared with natural varnish and an old white carpenters glue, installed in a frame located in a mounting room at the SIT-Artyd frame making company in Madrid.

Pollutant gas	Frames Min ($\mu g\ m^{-3}$)	Max ($\mu g\ m^{-3}$)	Rooms Min ($\mu g\ m^{-3}$)	Max ($\mu g\ m^{-3}$)
NO_2	0.5	11	1.2	43
O_3	0.5	5.9	2.0	20
SO_2	0.3	1.0	0.5	5.5
TVOC	110	5300 (28000)	39	2000 (4500)
Acetic acid	92	1800	16	300
Formic acid	0.1	510.(250)	1.9	32 (52)
Formaldehyde	0.4	5.6 (5.8)	0.2	2.4 (15)

Among the VOCs high concentrations of α-pinene and chloroform, which was identified used as a glue material, were found in a number of frames. For other VOCs the variation was large between frames, with relative high concentrations observed for a number of alkanes, alcohols, organic acids, ketones, esters and aromatic compounds. Large variation was also observed in the rooms, but with toluene high on the list in all museums. Toluene is a common solvent and ingredient in cleaning agents.

Environmental effect on dosimeters

Preliminary multiple linear regression analysis that was performed for effects of the environmental parameters on the dosimeters showed that the main explaining effect variable was NO_2 for the EWO dosimeter and resin Mastic coated PQC dosimeters, and acetic acid for the Glass Slide dosimeter and lead coated PQC dosimeter, with high explanatory power at a significance level of more than 99% (96% for acetic acid effect on lead coated PQC) for a two sided test (which is reported onwards, Figs. 5 and 6).

Part of the remaining variance for the EWO and resin mastic coated PQC dosimeters may be explained by O_3 and/or temperature. For the EWO dosimeter, O_3, by itself, explains about as much of the variance as NO_2, with a significance level higher than 99%, but only very little of the remaining variance when combined with NO_2, with significance dropping to 88%, probably due to strong correlation with NO_2. For the resin mastic coated PQC adding temperature to the correlation equation increases R^2 to 0.92, with both correlations for NO_2 and T being more than 99% significant. Adding O_3 to the equation increases R^2 to 0.98, but with a negative O_3 effect significant only on an 87% level. For the Glass Slide and lead coated PQC dosimeters formic acid had a highly significant effect (higher than 95%) about half of that of acetic acid, but gave only very little added explanation, probably due to the high correlation with acetic acid concentrations. Formaldehyde together with temperature explained much of the remaining variance for the lead coated PQC dosimeter, with inclusion of formaldehyde giving a R^2 of 0.30 and further inclusion of T a total R^2 of 0.76, with significance level higher than 98% for all three variables. For the Glass Slide dosimeter inclusion of formaldehyde did not improve R^2. Some of the remaining variance for the Glass Slide dosimeter was explained by temperature, giving a total R^2 of 0.68, with a significance level of 99% or better for both the acetic acid and T effect. However the temperature effect was estimated negative for both the Glass Slide and lead coated PQC dosimeters.

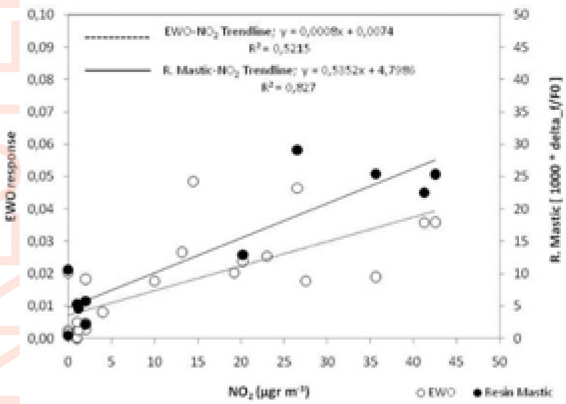

Figure 5: NO_2 single variable correlations with EWO and resin mastic coated PQC dosimeters.

The results for the environmental measurements are reflected in the very different, but complementary, dosimeter responses that were measured inside and outside of the frames, related to effects of inorganic gases (in particular NO_2), mostly infiltrating from outside, vis-à-vis organic gases (in particular acetic acid) mostly being emitted inside the frames (Fig. 7).

The PROPAINT results for the environmental parameters (climate and gaseous pollutants) and dosimeter responses are now in the process of being systemized into best possible linear or non-linear dose-response equations for the dosimeters. Based on the fully developed dose-response equations and correlations of dosimeter responses and determined levels of tolerability, the aim is to suggest a design for combined dosimeter exposures that give best possible evaluation of pollutant gases and climate effects on paintings and on archive and museum objects in general.

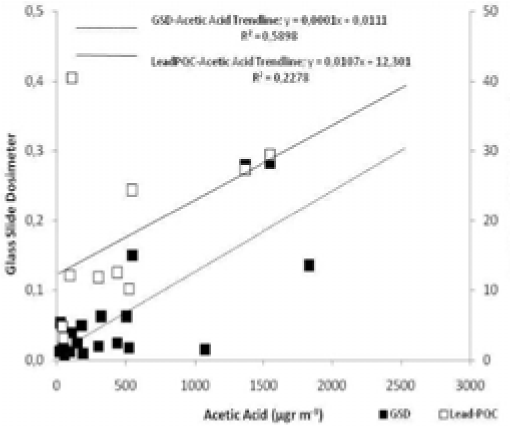

Figure 6: Acetic acid single variable correlations with Glass Slide dosimeter (GSD) and lead coated PQC dosimeter.

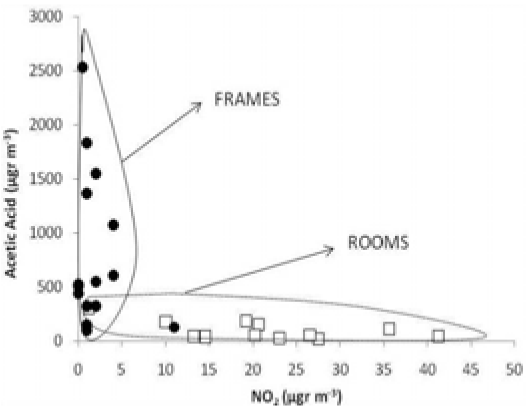

Figure 7: NO_2 and acetic acid concentrations measured in PROPAINT room and inside frame locations

Air exchange

Air exchange measurements are being performed for the frames. Results are now available for three frames (Table 3).

Table 3: Air exchange rates measured in three well sealed microclimate frames used in PROPAINT.

Location	Air Exchange (Ach day^{-1})
SIT Artyd modern frame:	0.19
Danish National Gallery classic frame adapted to microclimate frame:	0.67
Norwegian National Gallery classic frame adapted to microclimate frame:	0.39

Varnishes

From the measurement so far performed on varnish samples exposed in accelerated tests, it was observed that

- all the ageing procedures affects the varnish compositions at different degree;
- the most effective ageing procedure is that based on a simultaneous exposure to NO_2 and O_3, mostly for dammar resin;
- there is a difference in the effect of oxidising agents such as NO_2 and O_3 on natural (resin mastic) and synthetic resins (MS2A and B72); the former being more vulnerable;
- for a series of difference dose levels and /or different RH there does not appear to be a systematic trend as it was observed with light ageing of resin mastic where the response increases with the dose received;
- Tinuvin 292 reduces cross linking and polymerisation reactions depending on the ageing conditions, and is extremely efficient in preventing the oxidation of Dammar triterpenoids under all artificial ageing conditions tested. This aspect is fundamental for restoration because the use of such a stabiliser can avoid a frequent removal of the varnish layer;
- aromatic compounds present in the solvents used for varnish preparations are retained in MS2A films. Their occurrence in the varnish actually applied on a real painting could be harmful for the paint layers, because the aromatic compounds could migrate towards the paint films and act as solvents for some of the paint constitutes. This would have an effect on the paint layers stability, and it cannot be excluded that this could contribute to the well known phenomenon of the ghost images.

3. Conclusion

The resin mastic coated PQC and EWO dosimeters generally measured much higher values in the rooms than in the mc-frames, showing the protective effect of the mc-frames against photo-oxidizing agents (NO_2 and to some extent O_3) infiltrating from outside the mc-frames. The lead coated PQC and Glass Slide dosimeters generally showed the opposite result, with much higher responses inside than outside the mc-frames. This was explained by the presence of reactive species, formic and acetic acid and formaldehyde, inside the mc-frames. None of the dosimeters responded to the presence of, in some mc-frames high, concentrations of higher mass VOCs inside the mc-frames. Less observed difference in dosimeter response inside and outside of mc-frames at some sites can be explained by either less good sealing and higher air exchange, which makes the inside air more similar to the outside, - or by less well conditioned rooms possibly with internal contaminant sources, which would give the higher measured values for the lead coated PQC and Glass Slide dosimeters sensitive to acidic compounds, in these rooms.

Dosimeters are designed to mimic particular valuable materials and / or respond generically to inform about, ideally, the quality of total environment, or important parts of this. The different but complementary results obtained from the two pairs of dosimeters (EWO and resin mastic coated PQC, and Glass slide and lead coated PQC) in the same locations in PROPAINT show the importance of knowing the sensitivity of the dosimeters to the separate environmental influences, and to calibrate dosimeters responses against known influences. This makes possible the evaluation of critical loads to cultural heritage objects, such as e.g. paintings in mc-frames, based on dosimeter measurements. Different sensitivity of the pairs of PROPAINT dosimeters to photo-oxidative and acidic reactions means that simultaneous use of two or more dosimeters give added information. By using pairs of dosimeters an evaluation of the major gaseous air pollutant and climate factors, that degrade cultural heritage objects, can be performed.

Analysis of varnishes subjected to accelerated pollutant exposure tests showed that natural varnish (dammar) was degraded by oxidizing compounds (NO_2 and / or O_3) and was protected from oxidation by Tinuvin 292. The natural varnishes, resin mastic, were found to be more degraded by the exposure than the synthetic varnishes MS2A and B72. The degradation caused by the oxidizing gases was less systematic than that previously observed for light ageing.

Final results from PROPAINT are expected to be a design for more complete dosimetry of environmental influences on paintings and museum objects, more knowledge about the importance of different microclimate frame designs and of varnishes for the protection of paintings and contribution to environmental standards for paintings in microclimate frames. These are the major subjects for the scientific studies during the last year of the PROPAINT project.

4. Acknowledgements

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We will also like to thank the End User Museums and the conservators doing the mounting, measurement and data reporting work in the museums. Their co-operation and support was, and is, essential for the results obtained in PROPAINT.

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SENSOR SYSTEM FOR DETECTION OF HARMFUL ENVIRONMENTS FOR PIPE ORGANS (SENSORGAN)

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The organ belongs to the core of European culture, reflecting a diverse history of traditions and stylistic periods. The European heritage of the organ is preserved in more than 10,000 historic instruments. A major threat to this heritage is indoor harmful environments. Organic acids, also in combination with condensation phenomena, create pipe corrosion causing serious damage to the pipes. Harmful humidity conditions can create cracks in the wooden parts of the organ, making the instrument unplayable.

The EC funded SENSORGAN project (contract 022695) objectives are to make available new instrumentation for the monitoring and detection of harmful environments for organs through the development of sensors for real time measurement.

The sensors are designed in order to be placed in the organ without disturbing playing or affecting the sound. The sensors have been applied in the historic organ in the Minor Basilica of St. Andrew the Apostle, Olkusz, Poland. Data collected from the sensors will be analysed and conclusions will be drawn for publications, mitigation strategies, and to support the Committee for European Standardisation.

The system contains three different sensors:

1. Dosimeter for detection of organic acids, corrosive to organ pipes.

Many European historic organs suffer from corrosion inside the metal pipes (lead and lead-tin alloys). The aggressiveness of the corrosion is a major environmental threat against this cultural heritage assets. Results from the previous COLLAPSE project showed that emissions of organic acids in the organ wind emitted by the wooden parts in the organ is a serious corrosion factor.

When an alternating electric field is applied to a piezoelectric quartz crystal, it vibrates at its resonant frequency (e.g 10 MHz). If a coating is applied on the crystal surface the crystal frequency will decrease. Typical shifts in the resonant frequency of the crystal are of the order of 10 kHz for lead coatings of micrometer thickness and nanograms in mass.

This property is used for the development of a dosimeter for the detection of organic acids, which are corrosive to organ pipes. A coating of pipe metal and/or metal alloy (i.e. lead, lead-tin alloy) is applied to the crystal. When the coating reacts with organic acids, the mass of the coating increases and a frequency change of the crystal vibration can be detected.

2. Acoustic emission sensor to indicate risk of damage to wooden parts of organs.

Fluctuations in ambient relative humidity are considered to be one of the main factors contributing to the deterioration of wooden cultural objects. Wood responds to these fluctuations by gaining moisture when the humidity is high or losing moisture when the surrounding air is dry. Wood shrinks as it loses moisture and swells when gaining it. When wood is restrained in its movement, it can experience high stresses within the material, which can cause significant damage. Cracks in the windchests of the organ can cause serious damages, making the instrument unplayable. The organ facade, often containing invaluable art handicraft, like wood carvings and sculptures, can also be damaged by a harmful environment.

A new and innovative method of recording acoustic emission activity has been employed to trace microfracturing of wooden parts of the organ, thereby constituting an early warning for emergence of cracks in the wood. When a micro-crack develops, a sound pulse is emitted from the wood. This sound is not in the audible frequency range but it is detected by the sensor.

3. Optical fibre sensor for detection of dew or frost inside or/and outside organ pipes.

The working principle of the Dewing-Frosting Detector is based on the change in the reflectivity of the optical fibre, following the formation of a water layer on its distal end. When liquid water (either a film or droplets) or ice crystals form on the surface where the core is truncated, the external dispersion of light increases, the reflectivity decreases, and the back fraction drops.

The distal end of the fibre should be placed into contact with the target surface. It is likely that the presence of hydrophilics favours the change of phase, making the condensation earlier than the dew point is reached on contaminated or oxidized surfaces. This sensor monitors the actual, early formation of water.

The sensor meets all the goals needed for the study of what happens inside the foot of an organ pipe: Non-invasive size, no aesthetical appearance, responding both to dew or to frost, resistant to aggressive acidic environment, no disturbance to playing. The sensor could be regularly applied to organs for real time detection of unfavourable or risky environmental conditions.

PROTECTION OF CULTURAL HERITAGE AGAINST GRAFFITI VANDALISM: THE GRAFFITAGE PROJECT

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1. Summary

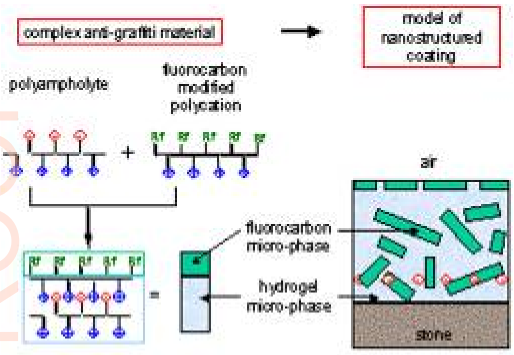
Graffiti are affecting our Cultural Heritage objects since years. Apart from its negative aesthetical aspects, graffiti damages significantly ancient porous materials since paints can penetrate into the substrates making their removal a difficult task. With the aim of protecting these valuable elements, anti-graffiti coatings are currently used. However, within the products most frequently used in Cultural Heritage, there is at present a lack of choice. Furthermore, these products are not suitable enough for this type of application causing, in many cases, further deterioration of the substrate. With the aim of solving this problem, the EC funded in 2005 the GRAFFITAGE project, "Development of a new anti-graffiti system, based on traditional concepts, preventing damage on architectural heritage materials", a European project aiming at developing a new anti-graffiti coating with specific properties for its application in Cultural Heritage materials. Within this project, a new formulation has been successfully synthesized and tested both at laboratory and field scale. According to the results obtained, this new anti-graffiti formulation presents overall improved properties with regard to four commercial anti-graffiti coatings of different chemical composition.

2. Introduction

Graffiti affects more than 3.500.000 protected monuments in Europe[1]. Graffited areas are not only considered to be less secure by most citizens, but also threaten the conservation state of the substrates, especially when these are historical[2]. The latter are often porous and already present deterioration problems due to their age. As a consequence of this, they are particularly liable to absorb graffiti paints, which makes the elimination process more difficult. In order to facilitate the graffiti cleaning, anti-graffiti products are often applied to the surfaces. However, to date, there are not suitable anti-graffiti systems for Cultural Heritage materials and the application of the currently available products often cause too many problems, leading to unsatisfactory results. Considering this situation, the main objective of the GRAFFITAGE project was to develop a novel anti-graffiti formulation suited for protecting materials of historical monuments, avoiding the disadvantages of the commercial anti-graffiti products. The new formulation was compared to a series of commercial anti-graffiti systems with different chemical composition, first in the laboratory and then in outdoor conditions.

3. Experimental method

A completely innovative approach was used to develop the new anti-graffiti system. This was based on the complexation of polyampholytes with polymeric amines that were modified by fluorocarbon residues (Figure 1), specifically suited for the protection of currently used anti-graffiti coatings. These



polyampholytes are "protein-mimics" having a structural similarity to traditional coatings, like casein, gelatine and egg-white.

Figure 1: Schematic presentation of the new anti-graffiti formulation.

There are at present two major anti-graffiti coating families: permanent and sacrificial[3,4,5]. The first type of products remains on the surface after the cleaning of graffiti has been performed. On the contrary, the second type disappears together with the graffiti, thus it must be reapplied. Two different new anti-graffiti formulations were synthesised and their properties compared to 4 commercial anti-graffiti coatings of different chemical composition, namely, a copolymer, a wax/paraffin, a polyurethane and a methacrylate (the second being a sacrificial anti-graffiti, and the rest, permanent systems).

These products were applied to 8 European substrates of historical importance which were selected according to their porosity and pore size: 4 sandstones (Spain, Slovenia, Germany), 2 limestones (Belgium), 1 travertine (Italy) and 1 brick (Germany).

The interaction between the anti-graffiti and the substrates was studied by means of scanning electron microscope (SEM) and laser scanning confocal microscope (LSCM), on untreated, treated, painted and cleaned samples.

The following properties of the substrates were studied before and after anti-graffiti application: capillary water absorption, water absorption at atmospheric pressure, water absorption under low pressure, drying behaviour, water vapour permeability, colour and gloss. The durability of the new system was also investigated by salt crystallization tests, natural weathering, UV ageing, acid rain ageing and biological growth. In all cases, the tests were carried out according to European standards.

Finally, the cleaning efficiency of the anti-graffiti was studied in the laboratory and in outdoor conditions by performing field cleaning tests. To ensure that laboratory cleaning was performed under the same conditions in all participant laboratories, a special cleaning apparatus was developed (Figure 2).

Figure 2: Cleaning machine for performing laboratory cleaning efficiency tests.

5 different common paints were applied on the treated and untreated samples prior to cleaning. The elimination of the paints was carried out by using a pH-neutral commercial cleanser. The field tests were carried out on untreated areas and areas treated with the new anti-graffiti formulation, on 5 different substrates: 2 sandstones (Spain and Slovenia), 2 limestones (Belgium), 1 travertine (Italy) and 1 brick (Germany). Two different removing methods were used in this case: brush and water, and high pressure hot water.

4. Results

The SEM images revealed that the new anti-graffiti formulation forms a 10-20 µm layer on the surface of the German sandstone, being the penetration of this coating overall low. After cleaning, paint residues were found over the anti-graffiti coating. In general, the new protective coating was not damaged. According to the LSCM figures on the same substrate, after the new anti-graffiti formulation was applied, the surface roughness decreased, improving the cleaning efficiency of the substrate. When the sample was cleaned, the smoothness decreased but this was still smoother than the untreated sample.

With regard to hydric properties of the substrates, after anti-graffiti application these were reduced in all cases. However, the lowest reductions were obtained with the new anti-graffiti formulation. In many cases, the behaviour of the new anti-graffiti was similar to that of the tested sacrificial commercial anti-graffiti.

The total colour differences of the new anti-graffiti system were again similar to the tested sacrificial commercial anti-graffiti. However, overall improved results were obtained with the new formulation on all studied substrates. With respect to the gloss results, the most porous treated substrates were not left glossy, but on the least porous substrates glossiness was observed.

The durability of new anti-graffiti system was found to be satisfactory compared with the commercial anti-graffiti. The natural weathering test revealed that drying behaviour and capillary water absorption results were satisfactory or acceptable in all cases and that colour variations were not perceptible by the human eye on most substrates.

The cleaning efficiency of the new product was acceptable in the laboratory in most cases, obtaining the best results in the least porous substrates. When cleaning was performed in outdoor conditions, results were found to be satisfactory or acceptable, depending on the surface roughness. A higher surface roughness led to worse cleaning efficiency. The cleaning efficiency was higher when the cleanser was left to react longer.

5. Conclusions

The new anti-graffiti formulation is a promising new anti-graffiti product with similar behaviour to that of sacrificial anti-graffiti coatings but with permanent properties with respect to graffiti elimination i.e. the coating is not removed after cleaning. This new formulation shows overall the best hydric and durability properties when compared to the selected commercial anti-graffiti. Acceptable results are obtained for the most critical properties, namely, water vapour permeability and drying behaviour.

6. Impact

The product developed in the GRAFFITAGE project will have an important industrial impact, having a strong influence on the market of a variety of industrial sectors like anti-graffiti manufacturers and suppliers, restorers and graffiti cleaners, architects and decision makers of monuments restoration, owners of monuments, etc. The development of the project will highly benefit the competitiveness of European SMEs with respect to large American anti-graffiti producers. The commercialisation and further application of the project will considerably reduce cleaning and maintenance costs of treated surfaces. In consequence, considering the suitability of the product for Cultural Heritage, and the reduction of maintenance costs, the application of anti-graffiti in monuments is expected to increase dramatically. The impact of the development of this project is not only addressed to economical direct aspects, but it also has an important influence on the conservation degree of our monuments, which strongly influences the economy of a region or a city.

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RECENT ADVANCES IN SMART MONITORING OF HISTORIC STRUCTURES

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1. Introduction

This paper presents the project SMooHS, Smart Monitoring of Historic Structures, which brings together scientists from 7 countries working to establish a competitive and simple to use monitoring technique based on wireless sensors.

The proposal aims to deliver novel structural health monitoring (SHM) systems capable of taking advantage of the reduction of wiring costs and, at the same time, achieving a further cost reduction by e.g. not relying on a centralized communication gateway architecture. Such novel approaches would deliver a "place-and-forget" SHM solution. Although the market offers a large number of different sensors their applicability for long-term monitoring of cultural heritage has not been validated in detail. Especially the long term stability and the reliability of the measured data might be problematic. In order to provide the practitioner in the field of cultural heritage with a tool which goes beyond the mere accumulation of data, but instead provides help in the sense of warnings and recommendations for action, data fusion and interpretation is implemented within the monitoring system.

Three main case studies (located in Berlin - Germany, Schwäbisch Gmünd - Germany, and Bologna - Italy) are planned to be used to demonstrate and to validate the work that is done in the core work packages. Three test sites (located in Jarash - Jordan, Hebron - West-Bank, Palestine, and Vienna – Austria) serve for method and system enhancement.

The proposed wireless system is user friendly, to be used by practitioners in the field, modular (modules for specific questions arising at the object to be monitored and sensor combinations), open source, for maximum transparency and open for extensions and new modules. The modularity and open source concept are most important for making a dynamic tool, which can be updated and broadened continuously with new research results, both from partners within this project team and from other research groups with their special expertise. However, the system needs to be simple, taking also the low budget available in many cases for such a system into account.

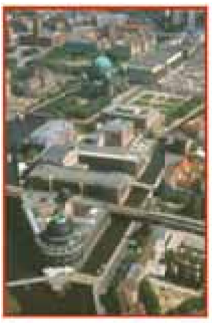
Figure 1: Wireless sensing system.

2. Methodology and technology

Developments in the proposed project are designed as smart monitoring techniques that employ permanently installed technologies addressing mainly the following aspects: competitiveness; simple application, stable long term behaviour, minimally invasive mounting and installation, open for different sensor technologies, integrated data analysis and interpretation methodologies.

Taking these aspects into consideration, the focus of the monitoring system development will be on small wireless sensor networks and autonomous wireless sensors based on platforms that could be used in combination with any kind of low power sensors (Figure 1), provide self organizing and reorganizing network functionality, have very low power consumption and achieve sufficient methodologies for data analysis, data fusion and data reduction.

However, continuous monitoring of structures is not useful if just a large amount of data is recorded and stored without further adequate analysis. There is a lack of sufficient models for material and structural deterioration that take into account the data from continuous monitoring.1-4 In order to provide the practitioner in the field of cultural heritage with a tool which goes beyond the mere accumulation of data, but instead provides help in the sense of warnings (e.g. if damaging factor values increase) and recommendations for action (e.g. window opening/closing, ventilation on/off, heating on/off, etc.) data fusion and interpretation is implemented within the monitoring system. To this aim software will be developed which is user friendly, to be used by practitioners in the field, modular (modules for specific questions arising at the object to be monitored



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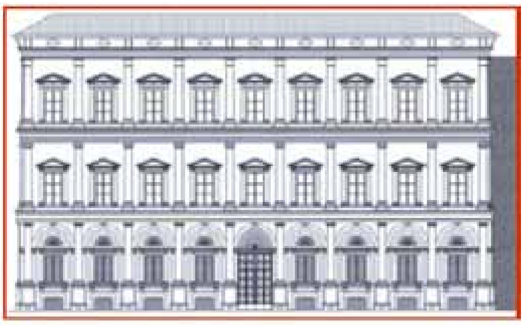

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Figure 2: The three main case studies: 1. Museum Island, Berlin, Germany. World Cultural Heritage since 1999; 2. Polychrome Portals of the Holy Cross Minster Schwäbisch Gmünd, Germany; 3.Main office of the Province of Bologna, Italy.

and sensor combinations), open source, for maximum transparency, and open for extensions and new modules, also from other research groups.

3. Measured parameters and monitored materials

A number of building materials (wood, brick and stone masonry, mortars, plasters, terracotta, pigment layers, etc.) and material assemblies typical for historic structures will be monitored for better investigation of structural damage and environmental pollution effects. With respect to the aspects of smart monitoring techniques defined above, for some applications there are presently no sufficient sensor technologies available. This is especially true for chemical attack due to gases or salts, for the measurement of moisture content inside a material and for the measurement of air flow at low speed inside buildings. For this reason new sensor technologies will be investigated and tested with these purposes (especially air flow sensors for low air speed, humidity and temperature sensors as well as acoustic emission sensors will be developed). In particular the following parameters will be measured/monitored: temperature & humidity (in environment and materials using resistive sensors air humidity sensors and miniaturized MEMS), air velocity (especially for low air speed measurement inside buildings), strain and crack opening (strain gauges etc.), acoustic emissions, vibration, inclination (MEMS), ambient light, UV light, (with regard to paintings and pigments), chemical attack due to gases (e.g. HCl, O_3, SO_2, NH3, NO_x, etc.) or salts (chlorides, sulphates etc.).

4. Case studies

There are three climatic zones (Central European, Northern and Southern Mediterranean) represented in three main and three additional case studies during the project. Those sites offer the possibility of indoor and outdoor testing. Three main case studies are used to test and to demonstrate several different methodologies simultaneously and are also used for the modelling (Figure 2).

5. Evaluation of methodology and technology

Measures of physical, chemical and mechanical material and environmental parameters during repeated monitoring on samples and specimens in varying environmental conditions are aimed to simulate and better understand structural and material deterioration processes due to environment. Based on previous experiences of authors5-8, physical models built in the lab will simulate the form of structural elements made of brick and stone masonry, with addition of plaster layers; component materials and masonry layout will be chosen in view to reproduce complex elements typical for historical structures. Specimens will be aimed at both evaluating the effectiveness of different NDT methods to quantitatively detect defects and inhomogeneities and to evaluate the capacity of the NDT methods to detect the beginning of material and structural damage and its evolution over longer periods, by measuring mechanical and physical properties. Reliability and applicability of employed techniques to the specific cases of complex historic structures will be studied.

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ADVANCED TECHNIQUES FOR SEISMIC PROTECTION OF HISTORICAL BUILDINGS

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Abstract
The seismic protection of historical and monumental buildings, namely dating back from the ancient age up to the 20th Century, is being looked at with greater and greater interest, above all in the Euro-Mediterranean area, its cultural heritage being strongly susceptible to undergo severe damage or even collapse due to earthquake. The cultural importance of historical and monumental constructions limits, in many cases, the possibility to upgrade them from the seismic point of view, due to the fear of using intervention techniques which could have detrimental effects on their cultural value. Consequently, a great interest is growing in the development of sustainable methodologies for the use of Reversible Mixed Technologies (RMTs) in the seismic protection of the existing constructions. RMTs, in fact, are conceived for exploiting the peculiarities of innovative materials and special devices, and they allow ease of removal when necessary. This paper deals with the experimental and numerical studies, framed within the EC PROHITECH research project, on the application of RMTs to the historical and monumental constructions mainly belonging to the cultural heritage of the Euro-Mediterranean area. The experimental tests and the numerical analyses have been carried out at five different levels, namely full scale models, large scale models, sub-systems, devices, materials and elements, and they give an important contribution for the use of RMTs in the seismic protection of historical constructions.

1. Introduction

The cultural heritage of Mediterranean and Balkan area is strongly at risk of severe damage or even collapse due to earthquakes, since the area is greatly exposed to seismic hazard. The historical and monumental constructions are the mostly exposed ones to seismic risk because, in many cases, they are not engineered, that is not endowed with basic anti-seismic features and/or any seismic retrofit has never been applied to them. The effects of earthquakes occurred in the area in the last decades prove the extremely unsatisfactory degree of seismic protection characterizing there the historical and monumental constructions. Degradation in material quality, lack of appropriate maintenance and, above all, absence of elementary anti-seismic provisions are the clear reasons of the very large number of the collapses, particularly in old masonry structures, occurred during earthquakes.

The extreme seismic vulnerability of the historical constructions is confirmed by this evidence and, consequently, urgent strategies for the seismic protection of the cultural heritage are strongly required. In this perspective, the main objective is improving the global behaviour of the construction considered as a system, by setting up innovative technological systems, rather than providing solutions to specific structural or architectural problems. The new intervention methods must be not only reliable and durable, but also, if required, easy to monitor and remove, the latter aspect corresponding to the widely shared policy of safeguarding existing buildings from inappropriate restoration interventions, with particular reference to historical and monumental constructions. Good seismic performances have been achieved by the use of modern constructional systems, which allow to strongly limit the damage and completely prevent collapses. Consequently, a slow but continuous increasing in the sensitivity to the use of more advanced technologies in the earthquake protection policy has started. The excellent performance of innovative materials has been acknowledged and the potential advantage of using special techniques for seismic resistant structures has been recognized, in a step by step process. Although initially referred to new buildings, this trend represents an important study field in seismic rehabilitation of existing buildings, with particular interest for historical and monumental constructions.

In this framework, this paper illustrates the experimental and numerical parallel campaigns aimed at studying and developing Reversible Mixed Technologies (RMTs) for the seismic protection of historical and monumental buildings. RMTs are based on the integration of structural members of different materials and/or construction methods into a single constructional organism. The basic feature of RMTs is that their application should be always completely recoverable, that is reversible, if required. This is considered as an essential design requirement in order to prevent historical and monumental buildings from unsuitable rehabilitation operations. The main aim of RMTs is the best exploitation of material and technology features, in order to optimize the structural behaviour under any condition, including very severe limit states produced by strong seismic actions.

The activity described in this paper has been carried out within the PROHITECH ("Earthquake protection of historical buildings by reversible mixed technologies") project, a scientific research project involving sixteen academic institutions coming from twelve Countries belonging to the Euro-Mediterranean area (Italy, Algeria, Belgium, Egypt, Macedonia, Greece, Israel, Morocco, Portugal, Romania, Slovenia, Turkey). The PROHITECH research project is framed within the INCO thematic areas, devoted to "Protection and conservation of cultural heritage", and its duration is of four years, since October 1, 2004 to September 30, 2008. The scientific activity is subdivided into four parts, and the object of this paper mainly belongs to the third part of the research. Details on the whole PROHITECH project can be found in Mazzolani, and on the website www.prohitech.com.

2. Experimental activity

General

The experimental analyses described in this section have been carried out with the objective of giving a suitable experimental contribution to the assessment and set-up of new mixed techniques for repairing and strengthening of historical buildings and monuments belonging to the Cultural Heritage of the Mediterranean basin. The experimental activity has been developed at five different levels, namely full scale building, large scale models, sub-systems, full devices, materials and elements, and it is dealt with in the following sub-sections.

Full scale tests

The full scale experimental tests are referred to the following constructions: a reinforced concrete building located in the Bagnoli area in Naples (Italy); the Mustafa Pasha Mosque in Skopje (Macedonia); the Gothic Cathedral in Fossanova (Italy); the Byzantine St. Nicola Church in Psacha, Kriva Palanka (Macedonia); the Beylerbeyi Palace in Istanbul (Turkey).

The experimental studies carried out at the University of Naples "Federico II" on the Bagnoli r.c. building (Fig. 1 top) have been extremely exhaustive and detailed. This building, in fact, is not an "ad hoc" built model but it is a "real" construction, actually representative of a large part of the building stock present in many Countries during the 20th Century, and so it represents a unique occasion of knowledge of wide interest.

After preliminary tests on the materials, aimed at characterizing them from the mechanical point of view, the dynamic identification of the structure has been carried out[10]. In order to perform inelastic cyclic tests under lateral loading conditions, a special steel structure has been designed and realized (Fig. 1 bottom), which allows to alternately push and pull the construction up to reach pre-fixed horizontal displacement values. The experimental tests have been carried out in three phases. In the first phase, the original structure has been strongly damaged by applying a seismic input corresponding to a return period of more than three thousand years (Fig. 2 top). In the second phase, it has been repaired by means of FRP bars placed in the mortar joints of the external walls (Fig. 2 middle) and damaged again[11]. At last, in the third phase, an intervention by means of buckling restrained braces (BRBs) has been carried out (Fig. 2 bottom), with subsequent further tests[12].

The full scale experimental work on the other above mentioned buildings, say the Mustafa Pasha mosque, the Gothic Cathedral in Fossanova, the St. Nikola Church in Psacha, Kriva Palanka, and the Beylerbeyi Palace in Istanbul (Fig. 3), have been non-destructive tests, mainly focused on the characterization of the structural materials and on the dynamic identification of the constructions.

Figure 1: The r.c. building in the Bagnoli area, Naples, Italy: top - the original building; bottom - the reaction structure for carrying out the push-pull cyclic tests on the building.

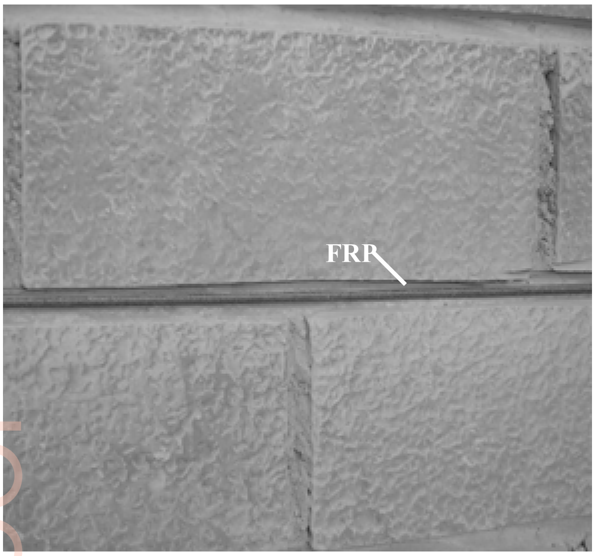

Figure 2: Top - Damage in the full scale building after the test on the original structure; Middle - First repair intervention, by means of FRP bars; Bottom - second repair intervention, by means of BRBs.

Large scale tests

The programme of large scale tests includes experiments on the following models: Mustafa Pasha Mosque in Skopje; Fossanova Gothic Cathedral; Greek Temple; St. Nikola Byzantine Church in Psacha. The large scale model of the Mustafa Pasha Mosque (scale 1:6) has been tested on shaking table (Fig. 4) at the IZIIS Laboratory in Skopje, Macedonia.[13,14] The seismic shaking table testing was performed in three main phases:

1. Testing of the original model under low intensity level, with the aim to induce damage in the minaret only;
2. Testing of the model with strengthened minaret under intensive earthquakes, with the aim to provoke the collapse of the minaret and damage to the mosque;
3. Testing of strengthened mosque model until reaching heavy damage.

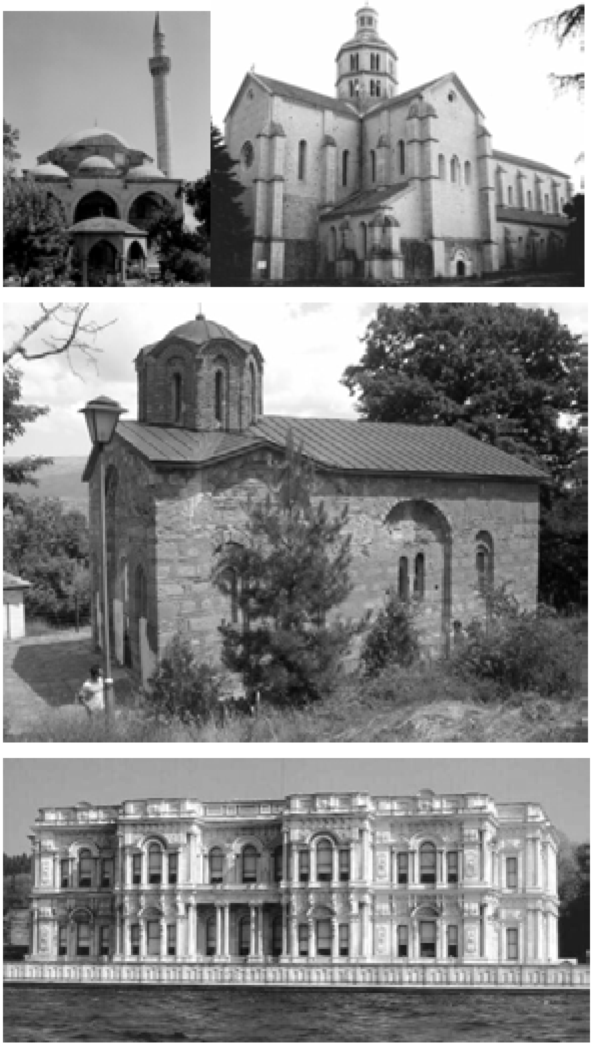

Figure 3: Top left - Mustafa Pasha Mosque in Skopje, Macedonia; top right - Gothic Cathedral in Fossanova, Italy; middle - St. Nikola Church in Psacha, Kriva Palanka, Macedonia; bottom - Beylerbeyi Palace in Istanbul, Turkey.

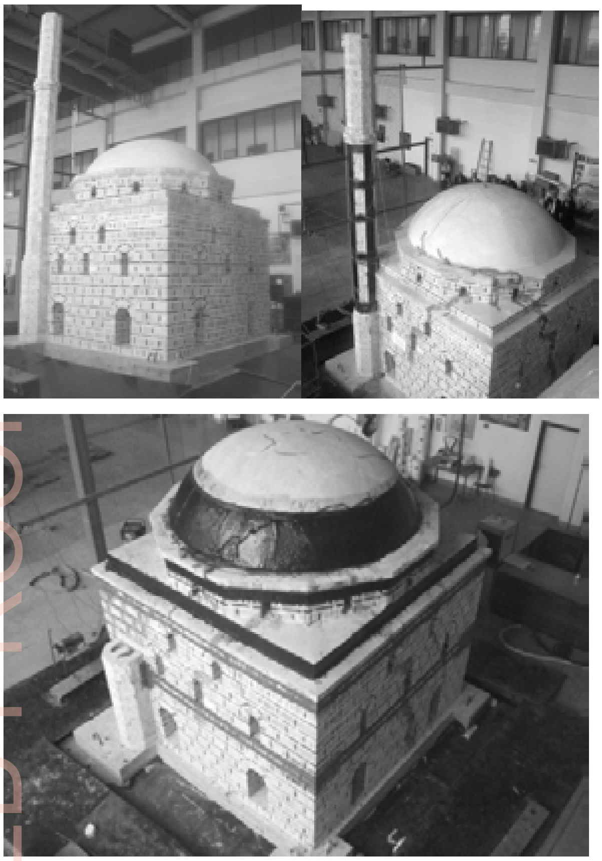

Figure 4: Shaking table tests on the Mustafa Pasha Mosque large scale model (Skopje, Macedonia): top left - before testing; top right - after the consolidation of the minaret; below - after the consolidation of the mosque.

Tests on sub-systems

A large number of experimental tests on sub-systems has been carried out within the project. The tests are mainly related to the application of Reversible Mixed Technologies to masonry, timber, reinforced concrete and iron structures.

With regard to masonry panels, two main groups of experiments have been carried out. The first group, at the "Politehnica" University of Timisoara (Romania), deals with the behaviour of masonry panels consolidated by means of metal (steel or aluminium) sheeting plates or steel wire mesh, which are applied at the external faces of the panel. In this case, the connection of the metal sheet plates to the masonry wall can be realised in two ways, namely by means of chemical anchors or pre-stressed ties; the wire mesh is glued to the masonry wall by using epoxy resin. The second group, at the University of Naples "Federico II" (Italy), deals with the behaviour of masonry walls strengthened by FRP bars, which are located in the mortar joints. These tests are aimed at investigating the behaviour of such masonry walls in three conditions, namely in absence of the retrofitting system, in presence on the FRP bars at one side of the wall only, and in presence of the FRP bars placed at both sides of the masonry wall.

Also to the experimental activity on timber sub-systems has been developed in two main groups of tests. The first group is related to the tests carried out on timber composite beams and floors, at the University of Naples "Federico II" (Italy) and at the Istituto Superiòr Tecnico of Lisbon (Portugal), both systems being based on an innovative technological system useful for connecting timber elements and concrete slabs (Fig. 6 above).[15] The second group of tests is carried out at the Boğaziçi University of Istanbul and it is related to the study of the behaviour of timber frames equipped by means of metal shear panels (Fig. 6 below).

At last, experimental tests on reinforced concrete columns retrofitted by means of three techniques, namely r.c. jacketing, the FRP jacketing, and steel jacketing, have been carried out at the Technical University of Bucharest (Romania), whereas tests on iron elements retrofitted by means of FRPs have been developed at the University of Liège (Belgium) and at the University of Naples – Architecture Faculty (Italy).

Tests on devices

The experimental investigation of the innovative devices has been aimed at characterizing the cyclic performances of the Reversible Mixed Technologies developed within the project, in order to optimize their use in the seismic protection of historical and monumental buildings.

A wide campaign on the cyclic behaviour of pure aluminium shear panels has been developed at the University of Naples "Federico II" (Italy) and at the University of Chieti-Pescara "G. D'Annunzio" (Italy).[16,17] The experimental tests have been carried out on both full bay and bracing type pure aluminium shear panels (Figs. 7 above). In particular, four full bay and four bracing type specimens have been considered. For both groups of experiments, the main differences among the tested systems are related to the presence of adequate stiffening ribs on the panels and to the connection (bolted or welded) between the ribs and the panels.

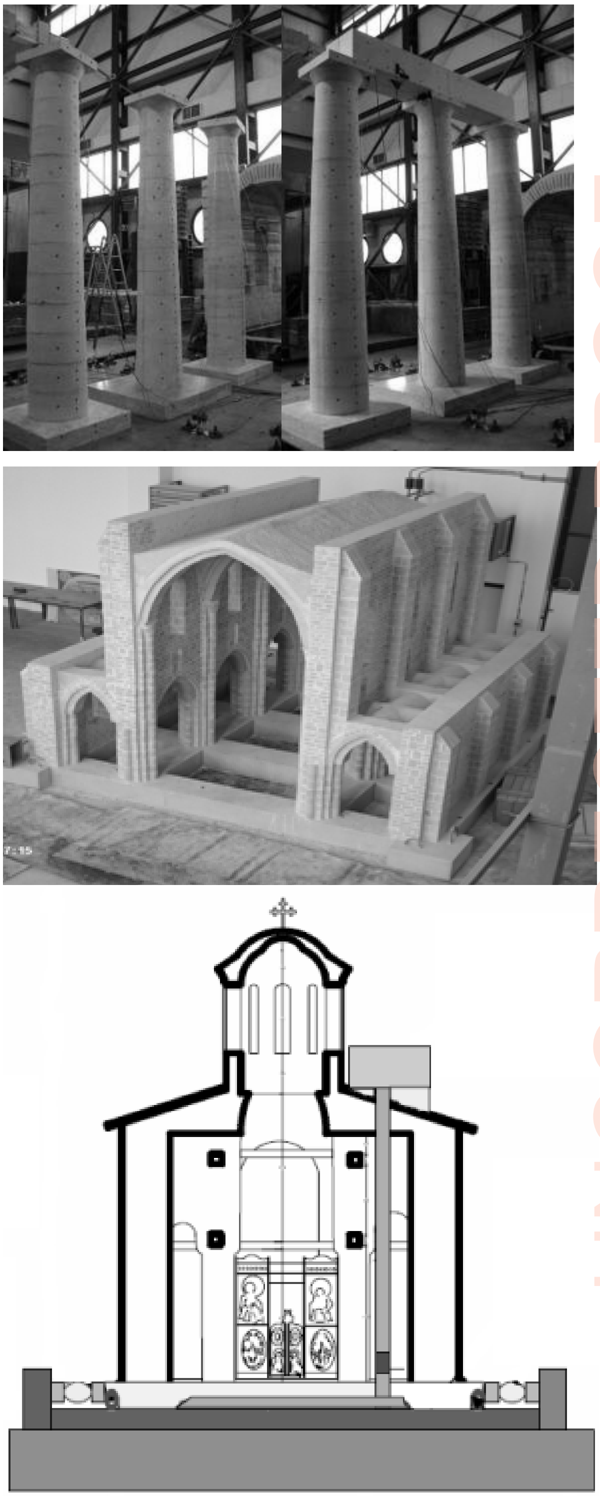

Figure 5: Experimental set-up in Athens (Greece) of three columns in a row: top left - freestanding columns, top right - with architraves; middle - large scale model of Fossanova Cathedral in Skopje, Macedonia; bottom - design of the experimental model of St. Nikola Church.

The basic innovative devices used for the realization of composite timber-steel-concrete elements, have been subjected to extensive experimental investigations (Figs. 7 below left and middle) at the University of Naples "Federico II" (Italy) and at the Istituto Superiòr Tecnico of Lisbon (Portugal).

A special dissipative beam-to-column node has been conceived at the University of Naples "Federico II" (Italy), and it has been subjected to experimental investigations devoted to evaluate the node capability to dissipate the input seismic energy by a torque mechanism in metal elements placed in the nodal area (Fig. 7 below right).

For the connection of marble elements, special steel anchors in marble have been studied at the Technical University of Athens (Greece), by performing pull-out tests on threaded reinforcement bars which are installed in drilled holes and connected to the marble by means of a suitable cementitius material. Moreover, special metallic devices for the connection of marble architraves have been tested at the University of Ljubljana (Slovenia), in order to assess the effectiveness of such innovative system in linking marble blocks each other.

Further experiments on devices are referred to iron connections (University of Liège, Belgium, together with University of Naples-Architecture Faculty, Italy), to magneto-rheological devices at the Second University of Naples (Aversa, Italy), and to DC90 dampers at the University of Ljubljana (Slovenia).

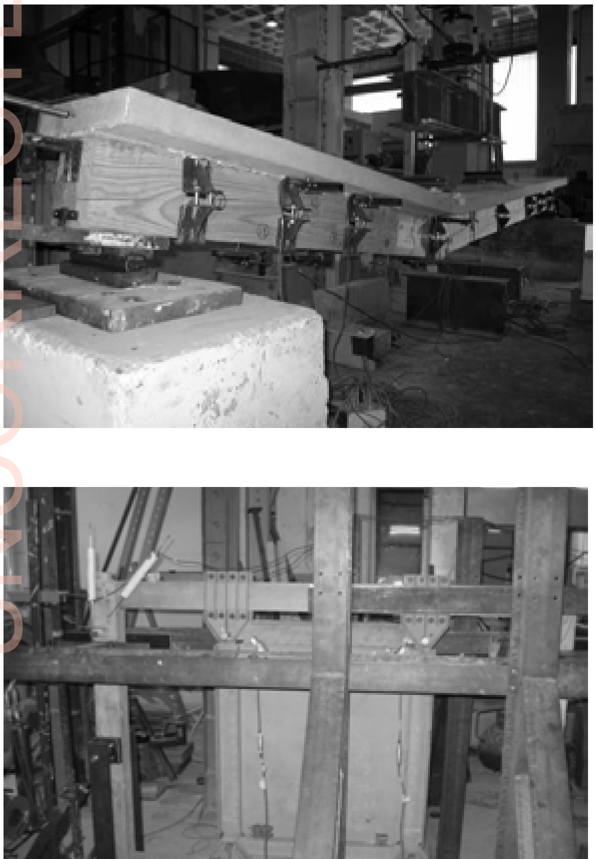

Figure 6: Tests on timber sub-systems: above - composite timber-concrete beam (Lisbon, Portugal); below - timber frame retrofitted by a metal shear panel (Istanbul, Turkey).

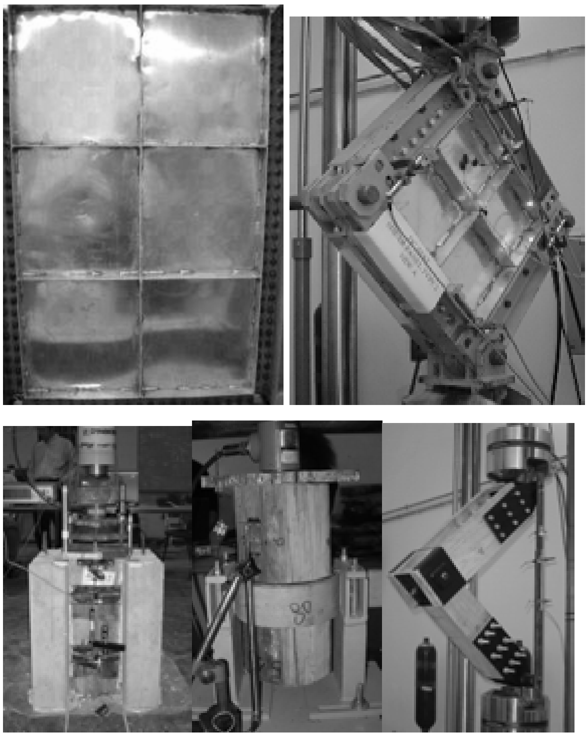

Figure 7: Tests on devices: above left - full bay type, and above right - bracing type pure aluminium shear panels (Naples, Italy); below left - timber-steel-concrete connections in the presence of concrete elements (Lisbon, Portugal), and below middle - in the absence of concrete (Naples, Italy); below right - dissipative beam-to-column wooden connection (Naples, Italy).

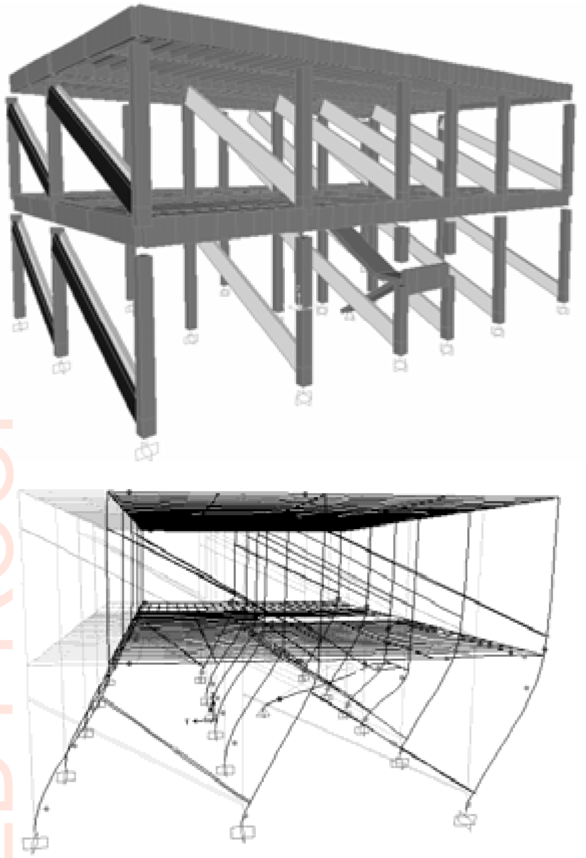

Figure 8: The numerical model of the full scale building: above - geometry; below - column-sway mechanism.

Tests on materials and elements

The tests on materials and elements have represented the basis for all the experimental analyses carried out at different scales, as previously described. Simple elements and materials have been characterized from the mechanical point of view, so allowing the correct interpretation of the experimental results coming from the tests at larger scales.

Experimental campaigns have been performed, in particular, on elements made of: adobe (Rabat, Morocco), bricks with mortar (Skopje, Macedonia), stone (Rabat, Morocco and Algiers, Algeria), marble and limestone (Ljubljana, Slovenia and Athens, Greece), iron (Liège, Belgium and Naples, Italy), aluminium (Naples, Italy), timber (Istanbul, Turkey and Naples, Italy), and concrete (Bucharest, Romania).

3. Numerical activity

General

The numerical analyses represent the counterpart of the experimental tests described in the above section, since most of them are focused on models of the experimented test specimens. Consequently, also for the numerical analyses, the activity has been developed at five levels, from full scale building to materials and elements. The clear aim of this activity has been the set up of reliable numerical investigation tools, useful for both studying aspects difficult to catch in the experimental tests and providing the basis for the set up of calculation models adequate for historical buildings retrofitted by Reversible Mixed Techniques.

Full scale model

The whole Bagnoli r.c. building, already described in the section on full scale experimental tests, has been modelled by means of the non-linear finite element program SAP2000 at the University of Naples “Federico II”.[12] In the numerical model (Fig. 8 above) the presence of the innovative BRB retrofitting system has been taken into account, and the numerical results, from the static non-linear analysis of the building, have well matched the experimental ones.

Large scale models

Pre- and post-experimental numerical analyses, devoted to support the development of advanced analytical models, have been performed for the large scale models interested also by the experimental tests. The Mustafa Pasha Mosque has been modelled in cooperation between the University of Naples “Federico II”-Architecture Faculty and the University of Skopje “Sts. Cyril and Methodius”[18] (Fig. 9 above). The Gothic Cathedral of Fossanova has been modelled at the University of Chieti-Pescara “G. d’Annunzio” (Fig. 9 below). The model of the St. Nicholas Church in V. Psacha has been set up at the University of Skopje “Sts. Cyril and Methodius” (Fig. 10 above) and the Greek Temple has been modelled at the National Technical University of Athens (Fig. 10 below).

Models of sub-systems

Numerical models aimed at investigating the behaviour of subsystems endowed with RMTs have been set up. Several retrofitted sub-systems have been considered in the study, namely: masonry walls and metal panels (Fig. 11 above) (“Politehnica” University of Timisoara – Romania and University of Chieti-Pescara “G. d’Annunzio” – Italy),

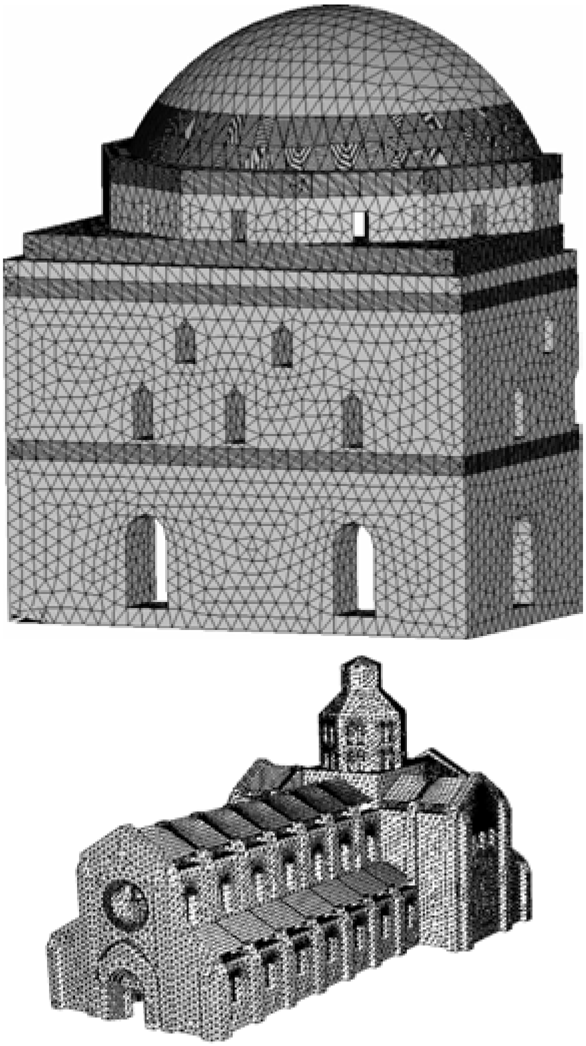

Figure 9: FEM models: (a) Mustafa Pasha Mosque; (b) Fossanova Gothic Cathedral.

masonry walls and FRPs (University of Naples "Federico II" – Italy), timber frames and metal shear panels (Boğaziçi University of Istanbul – Turkey and University of Chieti-Pescara "G. d'Annunzio" – Italy), timber composite floors (Fig. 11 below) (University of Naples "Federico II" – Italy and Istituto Superiòr Tecnico of Lisbon – Portugal), iron elements and FRPs (University of Liège – Belgium).

In all cases, pre- and post-experimental analyses are carried out. The pre-experimental analyses are used for setting up the models and carrying out preliminary studies. The post-experimental analyses are developed in five phases, namely: the numerical simulation of the original specimens, the modelling of the strengthening devices, the simulation of the strengthened specimens, the comparison with the experimental results, and the calibration of numerical procedures for the analysis of the strengthened structural systems.

Models of devices

The activity concerned with the numerical modelling of innovative devices has been subdivided in several steps, following the same approach of the numerical analyses on sub-systems. In fact, after the pre-experimental analyses aimed at setting up adequate numerical models and carrying out preliminary investigations, the post-experimental analyses have been focused on the modelling of the devices, on the comparison of the numerical results with the experimental ones and, as a final step, on the calibration of numerical procedures for the analysis and the design of the devices.

The devices modelled numerically are: iron connections (University of Naples "Federico II" – Italy), architrave connections (University of Ljubljana – Slovenia and National Technical University of Athens – Greece), wood-to-concrete connectors (University of Naples "Federico II" – Italy and Istituto Superiòr Tecnico of Lisbon – Portugal), wooden node dissipative device (University of Naples "Federico II" – Italy) (Fig. 12), pure aluminium shear panels (University of Chieti-Pescara "G. d'Annunzio" – Italy),[19,20] magnetorheological devices (Second University of Naples – Italy), and DC90 dampers (University of Ljubljana – Slovenia).

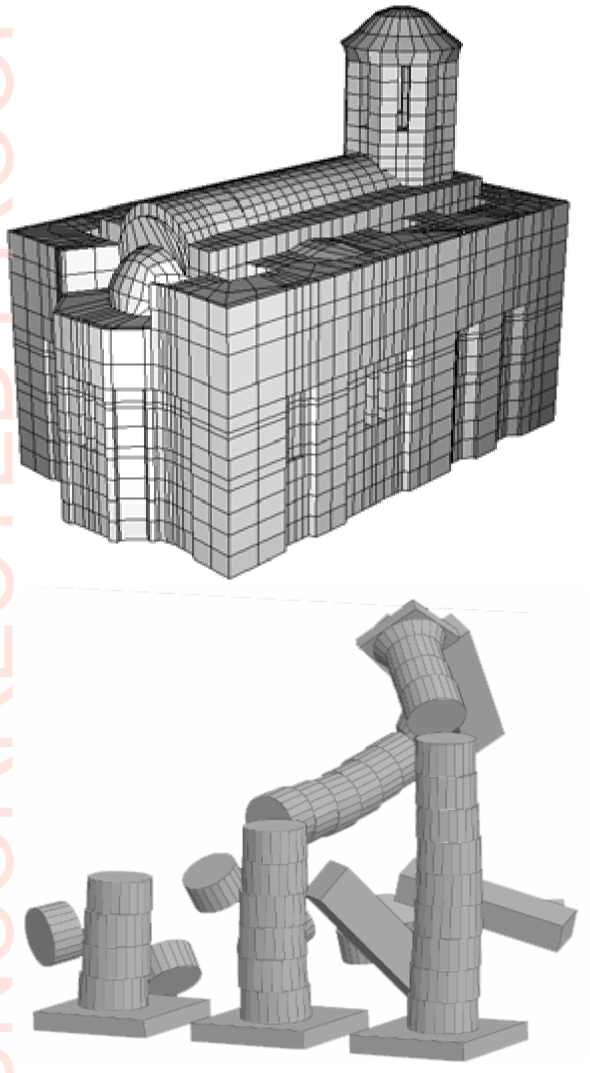

Figure 10: FEM models: above - St. Nikolas Church; below - Greek Temple.

Models of materials and elements

The characterization of the behavioural features of the materials and the elements used for the construction of the models of devices, sub-systems, large scale and full scale systems has represented the basic issue for carrying out the numerical activities. In fact, the calibration of material and element simple numerical models is essential for the set up of more complicated models, from the modelling of the single devices to the numerical investigation of the complex behaviour of the full scale building retrofitted by reversible mixed systems.

In this perspective, numerical models of adobe, stone, marble, iron and aluminium have been set up. The models have preliminarily been used for carrying out pre-experimental numerical analyses; then, after the experimental tests, the numerical models have been calibrated, and numerical post-experimental analyses have been carried out with the aim of calibrating the numerical constitutive laws to be used in the models at larger scales.

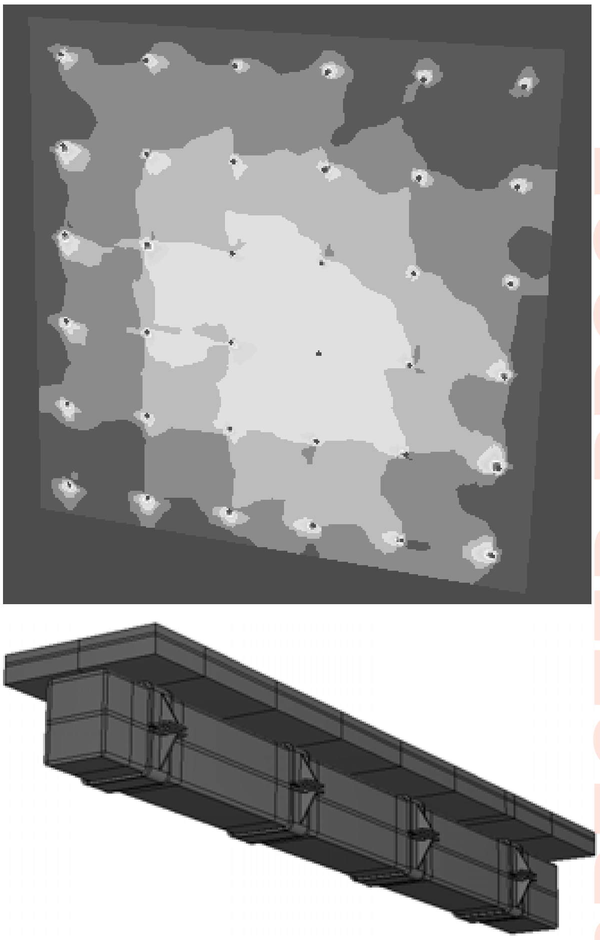

Figure 11: Numerical models: above - masonry wall reinforced by metal panels; below - timber composite floor.

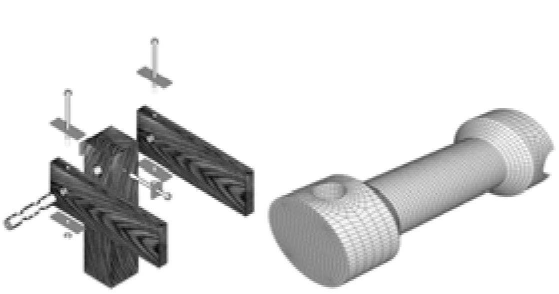

Figure 12: Left - dissipative beam-to-column wooden connection: geometry; right -FEM model of the nodal metal element.

4. Conclusive remarks

This paper presents a comprehensive overview of the experimental and numerical activities carried out within the PROHITECH research project. This project, which involves sixteen academic institutions coming from twelve Countries belonging to the European and Mediterranean area, is focused on the seismic protection of historical and monumental buildings by means of Reversible Mixed Technologies. Such research field is being looked at with more and more interest, since the Reversible Mixed Technologies can be conveniently used for the seismic upgrading of constructions by matching the following important objectives: (1) exploitation of the advantageous features of different materials and devices used together; (2) preservation of the cultural value of the protected construction, thanks to the possibility of removing the protection systems, if required. The experimental and numerical investigations obviously represent the core part of the PROHITECH research project. Two preliminary parts already produced are related to the traditional intervention strategies in the field of seismic protection[21] and to the collection of information referred to innovative materials and devices[22], these two parts being preliminary to the experimental and numerical ones. The final part deals with validation criteria illustrated also by selected study cases and a proposal of codification for the use of Reversible Mixed Technologies in the seismic protection of historical buildings (this part being the effective general output of the whole research project).

The relative novelty of the above mentioned research field implies the necessity of creating a background of knowledge on the behaviour of both the innovative protection systems and the whole constructions equipped with them. At this aim, a large number of experimental and numerical investigations has been carried out. The studies have been planned so that the experimental and numerical activities could be developed in a parallel way, each of them being the basis and the term of comparison for the other one. So, the pre-experimental numerical analyses have been used for collecting information useful for the realization of the experimental tests. Then, the experimental results have been used for calibrating and updating the numerical models, with the final goal of developing ad-hoc calculation models for the study of historical constructions retrofitted by Reversible Mixed Technologies.

The parallel experimental and numerical activities have been developed at different levels, in order to clearly understand the behavioural characteristics of all the structural parts involved in the protection by Reversible Mixed Technologies. In this perspective, both numerical and experimental studies have been carried out on materials and elements, devices, sub-systems, large scale systems and full scale systems.

The experimental and numerical analyses summarized in this paper represent an important contribution in the field of the seismic protection of historical and monumental constructions by Reversible Mixed Technologies, due to both the encouraging results obtained during the work and the comprehensiveness of the whole activity, which will lead towards the set up of a proposal of codification well framed into the international standards for the seismic protection of constructions.

5. Acknowledgments

The support of EC for the development of the PROHITECH research project is gratefully acknowledged.

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CULTURAL HERITAGE PROTECTION AGAINST FLOOD (CHEF) – A EUROPEAN FP6 RESEARCH PROJECT

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1. Abstract

For the protection of Cultural Heritage from environmental damage and in particular against flood, a research project has been proposed under the 6th European Framework Program to support policy-oriented research. The project CHEF contributes to the call area "8.1 B.3.6 The protection of Cultural Heritage and associated conservation strategies, Task 4: To help protect Cultural Heritage from environmental damage particularly in relation to flooding*"*. In the project different aspects are considered varying from historic significance and context of an object, building structure or landside to technical problems like lack of documentation, unknown structural condition and assembly, unknown material properties and characteristics and unknown parameters of exposure.

The main aim is the development of preventive conservation strategies and the identification of appropriate measures. Clear recommendations for mitigating or removing damage from Cultural Heritage objects will be provided through the project results. CHEF proposes the integration of multidisciplinary research as scientific support to European policies. In this frame the necessary technological basis and cost efficient and effective tools for the development of new and innovative strategies will be provided.

2. Introduction

The European Community has suffered from disastrous floods in recent years, which caused enormous damage (Fig. 1) and left hundreds of people dead in several European countries. The flooding occurred across regional borders and involved neighbouring states along the rivers Elbe (2002), Odra (1997), Rhine (1993 and 1995) and many more. Floods can not be prevented. Europe will have to face further flood catastrophes due to the change of climate and due to further building activities in flood-prone regions.[1-3]

Although very comprehensive, projects, strategies and further administrative measures, which started after the recent flood events, do not include the particularities of movable and immovable Cultural Heritage like objects in museums and libraries, historic buildings, parks and sites (historic cities), which are threatened by flood catastrophes. For protecting the common European Cultural Heritage against flood hazards and environmental conditions related to flood, a focus has to be put on the mapping of the above mentioned risk-areas including the objects worthy of protection.

It is required to assign a high protection level to particular monuments or to areas where valuable historic sites are located.[4]

3. Project objectives

The strategies to be developed in the project can help to make protection and repair of Cultural Heritage against flood and related hazards far more effective and allow carrying out these measures on a large scale. This knowledge will help to take precautions against it and will thus reduce the impact of environmental damage on historic structures. In particular the project aims at:

- Classification of movable and immovable Cultural Heritage in the countries of the project partner according to their vulnerability and sensitivity to flood
- Analysis and classification of damage processes in different materials (soil, brick, stone, wood, metal, textile, paper, etc), structures (buildings, bridges) and sites (cities, gardens, archaeological sites) induced by flood and flood related environmental impacts in close cooperation with museums and further stakeholders
- Validation and evaluation of methods and sensors for non-destructive testing and monitoring of material and structural parameters; environmental technologies will have to be provided
- Definition of threshold levels for exposure and damage before restoration, also in relation to the use of the objects/buildings
- Analysis of preventive measures before flood and temporary (emergency) measures during and soon after flood for movable and immovable Cultural Heritage. The influence of these measures on material and structure will be addressed
- Assessment of restoration and repair techniques after flood
- Assessment of running and new case studies on different objects concerning infrastructure, buildings, parks, cities
- Generation of practical recommendations by definition of strategies for the protection, conservation and repair of movable and immovable Cultural Heritage

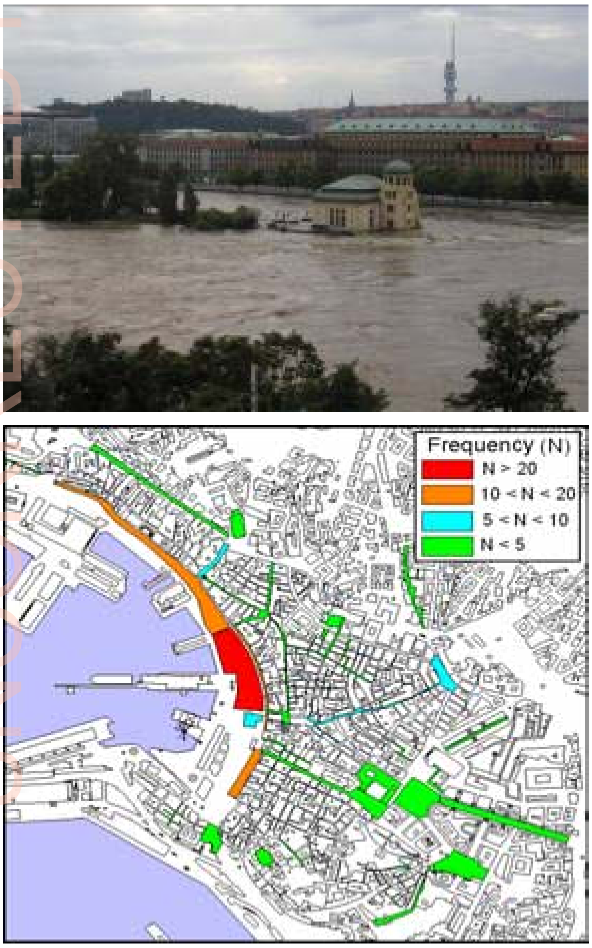

Figure 1: Top: historic power station in Prague (Czech Republic) during flood in 2002. Photo: V. Herle. Bottom: observed frequency of flood events in the historic centre of Genova, Italy.

4. Work plan

The scientific and technological approach aims at identifying characteristic parameters for flood and flood related hazards, which have an impact on movable and immovable Cultural Heritage depending on their vulnerability. The understanding of damage processes in materials and structures by using environmental technologies will provide the basis for evaluation and further developing strategies for preventing, mitigating and repairing damages at Cultural Heritage related to the objectives and policies of the European Community. The research will be carried out in eight work packages.

5. Partners

The consortium includes members from 7 different European countries. These institutes provide a lot of experience on different skills related to flood protection of Cultural Heritage:
- BAM, Federal Institute for Materials Research and Testing, Berlin, Germany
- ITAM, Institute of Theoretical and Applied Mechanics ITAM ASCR v.v.i., Prague, Czech Republic
- IDK, Institut für Diagnostik und Konservierung an Denkmalen in Sachsen und Sachsen-Anhalt e.V., Dresden, Germany
- CRUIE, University of Genova, Italy
- ZAG, Slovenia National Building & Civil Engineering Institute, Ljubljana, Slovenia
- UIBK, University of Innsbruck, Austria
- TUD, Technische Universität Dresden, Germany
- ECOLAND, UNESCO Chair ECOLAND, University of Bucharest, Romania
- POLIMI, Department of Structural Engineering (DIS), Politecnico di Milano, Italy
- IMSL, Industrial Microbiological Services Ltd., United Kingdom

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COHERENT METROLOGY IN IMPACT ASSESSMENT OF MOVABLE ARTWORK: THE MULTIENCODE PROJECT

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1. Abstract

Europe's works of art are the lifeblood of Europe's cultural heritage. Museums put them on display and, increasingly, loan them out to other institutions. However, repeated handling, the need for conservation treatments, and exposure to sudden environmental and climatic changes can all take their toll on old or delicate objects. Art in transit is also under threat from mishandling and fraud. Conservators need to monitor the condition of artwork in a way that responds to these issues. The MultiEncode project creates this new approach to monitoring the condition of artwork. It introduces an innovative method and tool which allows conservators to assess the conservation state of an object and the need for any treatment; illustrate new damage; monitor the impact of transport; and confirm a piece's authenticity. Distinct features of an artwork are encoded with undisclosed information that will be used to assess the impact of handling, treatment, and authentication of an object in the future.

2. Introduction

Ever since the invention of lasers and optical coherent techniques as non-perturbing tools, they have maintained a competitive profile towards modern applications in art conservation1-6. A thorough presentation of these techniques is not among the priorities and the context of this paper, however, a short description of the advantages offered include the non-contact nature of the laser source used to produce the signal of interest, a non-destructive approach in procedures including an examination process free of sampling or artwork preparation and the use of non-deleterious procedures throughout the examination of the artwork in terms of intensity and power of the pump and probe beams6. Therefore, ethical parameters essential for safe art handling during examination are satisfied with optical coherent inspection, and this inspection is independent of the exact geometry setup7. A recent demand that has emerged from the increased interest and transport of cultural objects forces the conservation community to seek special methods, strategies, and eventually instruments capable of performing repeated assessments of handling, transportation, climate, and restoration effects. This demand is the reason why the MultiEncode project was formed—to introduce a new overall approach towards information retrieval and archiving the assessment of an artwork throughout its entire life to safeguard it for future generations. The key word is inspection; the encoding of distinct features invisible to the human eye and to analytical tools but visible to specialized laser interference techniques. A specially-developed procedure of repeated inspection over time has been developed as has software to handle the data and process the information in a portable, user-friendly, system. The results have successfully proven this instrumental approach and it has been named as an Impact Assessment Procedure. The field of applications is broad and may expand to routine monitoring of indoor and outdoor cultural treasures as well as to periodic assessment of collection maintenance, loan constraints and in planning environmental storage, display, or shipping strategies.

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EFFECTS OF ARTIFICIAL AGEING PROCEDURE ON CANVAS MODEL PAINTINGS MONITORED IN MICRO SCALE

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1. Introduction

Over time the materials which constitute our cultural heritage may slowly deteriorate in response to environmental factors. Detecting change and monitoring degradation is critical if preventive conservation strategies are to be improved. Digital Holographic Speckle Pattern Interferometry (DHSPI) is based on the principles of holography and allows the detection of various minute defects or structural heterogeneities in surface movement in paintings. For example, cracking and delamination of paint can give rise to changes in interoferometric patterns. The technique requires no direct contact with the paint surface and can be applied to monitor paintings in real time. Paintings on canvas supports are highly sensitive to RH changes and their slight but continuous movement is of particular interest[1].

In this paper a specially developed portable instrument incorporating holographic interferometry is described that records speckle patterns. Canvas samples have been thermally aged and as a result paint has become more brittle and prone to cracking on the flexible canvas. Within the laminar structure, comprising two or more paint layers over a canvas, tension and stress may develop between layers due to uneven shrinkage, and pre-existing cracks may extend. The DHSPI images acquired illustrate the potential of the device. Very few examination methods are able to measure the rapid microscopic movement of the paint surface and thus DHSPI is uniquely suited to monitoring canvas paintings especially with regard to changes in RH and temperature. Furthermore, the technique can be employed to detect cracks and their propagation.

1.1 Digital Holographic Speckle Pattern Interferometry

For the measurements described in this paper DHSPI has been used. With this non-invasive method, based on the principles of Double Exposure Holographic Interferometry, it is possible to observe the micro-displacements or movements in the structure of the painting, before and after the application of some kind of load (e.g., thermal or heat). By measuring the surface reflected optical path variations caused by intentionally induced dimensional deformations a structural response of an object under test is obtained. This is achieved by the superposition of two temporally separated coherent wave fields which are capable of producing interference on a photosensitive recording medium, representing two different states of the object usually in relaxed and excited states. In order to excite the surface, infrared lamps (175 W) are used to produce a temporary change in the object. In our case the recording medium was a CCD camera. The resulting displacement is numerically processed by specially developed algorithms based on phase-shifted images which have been acquired by a piezoelectric transducer. As a result, information on object deformation associated with the generation of visible interference fringes is provided[2].

1.2 Canvas sample

Canvas samples (Fig. 1) constructed at the TATE gallery were prepared by stretching canvas over a wooden expandable stretcher with mitred corners and metal turnbuckle expansion systems. The canvas was sized twice with a rabbit-skin glue solution, allowed to dry, and then primed with a white chalk and glue ground applied by brush in two layers. It was decided to include several types of "defects" beneath the paint surface in order to observe them using DHSPI and to monitor their possible alterations and effects on the paint surface following artificial ageing. As shown in Fig.1 the canvas was divided into 25 different squares (9x9cm); each square was examined using the same experimental settings. For this paper, the area marked with the green square was analysed (Figure 1b).

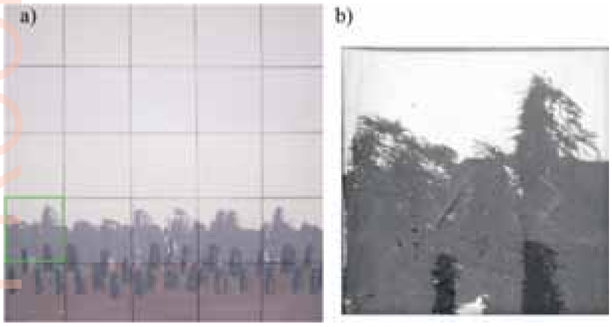

Figure 1: (a) Canvas sample separated in 25 parts, (b) detail examined with DHSPI

1.3 Experimental Procedure

The canvas sample was examined using DHSPI before the ageing process. Then the sample was aged (at the TATE Gallery) at 60°C and 55% RH for six weeks. This process provided a simulation of ageing equivalent to 50 years. The sample was examined again using the same experimental settings. In order to obtain the thermal excitation of the canvas, IR lamps of 175 W were used in two combinations of direction: 1) both IR lamps on the front side of the sample and 2) one lamp in front and the other on the back side of the canvas. The duration of excitation in all sets of measurements was 3 sec.

2. Results

The interferograms presented here correspond to measurements obtained with the frontal direction of excitation and concern only one square of the 25 (Figure 1b). The defect included in this part corresponds to a packing tape placed beneath the painted surface. With the front direction excitation a new defect has been revealed after the ageing process and it is indicated by the red square in Figure 2b. This defect corresponds to a newly generated crack in the painting surface. By superimposing the images of the interferograms before and after the

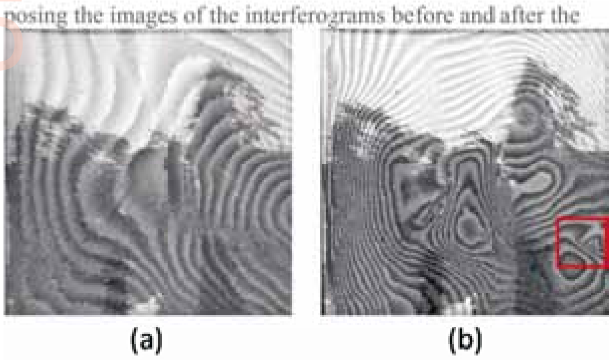

Figure 2 : Overlapping of investigated area and interferogram before (a) and after (b) the ageing process.

artificial ageing process an image of the difference of the area investigated has been created and presented in Figure 2a,b.

3. Conclusions

DHSPI provides full field information of the surface movement of an artwork. Hidden defects under the painted surface can be easily detected and the technique can offer valuable information concerning the effects of ageing processes in canvas paintings. In addition to this, new microscopic cracks that arose following ageing and can not be observed with other methods can be rapidly detected with DHSPI.

4. Acknowledgements

Authors would like to thank the Multi-Encode project [006427 (SSPI)].

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OPTICAL SPECTROSCOPY FOR THE NON-INVASIVE ANALYSIS OF COMMONLY FOUND PAINT VARNISHES AND BINDING MEDIA

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1. Introduction

The analysis of paint varnishes and binding media is critical for both conservation and treatment of works of art, as well as for understanding both original technique and historical context. Varnishes and binding media may strongly influence the appearance of paintings,[1] and their identification will determine the choice of cleaning methods, as well as other conservation recommendations. Media, including drying oils (linseed, poppy and walnut oil, for example) and protein-based binders (including isinglass and other collagen-based glues, egg white and egg yolk, milk and derivatives), often mixed with pigments, may adhere material and are consolidants used in conservation. Varnishes comprise tree resins (for example mastic (from *Pistacia lentiscus*), dammar (from trees of the *Dipterocarpaceae* genus), amber and copal) and insect excretions (like shellac, from *Kerria lacca*) dissolved in solvents. Although most often analysed using mass spectrometric techniques,[2] various non-destructive techniques have been proposed for the analysis of binding media and varnishes, and include optically-based methods ranging from spectrofluorimetry,[3-5] Laser Induced Fluorescence,[6,7] Raman spectroscopy,[8,9] Elipsometry,[10] Terahertz spectroscopy,[11] and Multiphoton microscopy.[12] In this work, selected novel non-invasive optical techniques for the analysis of varnishes and binding media are presented. Fluorescence excitation emission spectra of a range of different commonly found varnishes and media have been recorded, as have spectrally and temporally resolved fluorescence measurements using a portable laser system. Multi-photon spectroscopy has been used to analyse multi-layer structures, complementing spectrofluorimetric analysis.

2. Materials and Methods

Samples were prepared using a range of different binding media and varnishes, and included the following: copal, amber, mastic, dammar, shellac, linseed oil (cold pressed and cooked), walnut oil, poppyseed oil, isinglass, ox bone glue, egg white and egg yolk; materials were supplied by Zecchi (Firenze, Italy) or purchased at local markets, for preparation see Nevin, et al.[9] Samples were painted out on quartz disks in single layers, and combinations of different varnishes in multiple layers were also prepared and naturally aged in ambient lighting conditions for one year. Artificial ageing of samples was carried out under fluorescent lamps to an equivalent of 50 years under museum conditions.[13] Analysis of samples was performed using a Jobin-Yvon Fluorolog Spectrometer equipped with a double monochromator with slits of 1 nm. Fluorescence excitation emission spectroscopy was carried out from 250-500 nm excitation and 380-750 nm emission. Laser induced fluorescence spectroscopy of monolayer samples was undertaken using a 1 ns nitrogen laser emitting at 337 nm and at other wavelengths using suitable dyes. Spectrally resolved fluorescence lifetimes were determined as described elsewhere.[14] Multiphoton fluorescence microscopy was carried out using a 1084 nm fs source; both third harmonic generation (THG, in transmission) and three-photon fluorescence (TPF, collected in reflectance) of multilayered samples were measured.[12] For reference, confocal micro-Raman spectroscopy on layered samples was carried out.

3. Results and Discussion

Due to different chemical compositions of binding media and varnishes, which is the basis for their differentiation using MS techniques and Raman spectroscopy, fluorescence excitation emission spectra of media are also distinctly different from one another. This is due to the presence of different fluorophores within the materials, which may include amino acids in protein-based binding media,[4] saturated aromatic molecules in natural resins,[3] and the accumulation of conjugated cross-linked fatty acids in oils.[4] Although it is not generally possible to ascribe individual species which are responsible for the broad fluorescence observed in many of the samples studied, more important for the discrimination between materials is that different excitation emission spectra are observed for different materials, as exemplified in the spectra of amber, linseed oil, shellac and mastic (Figure 1)

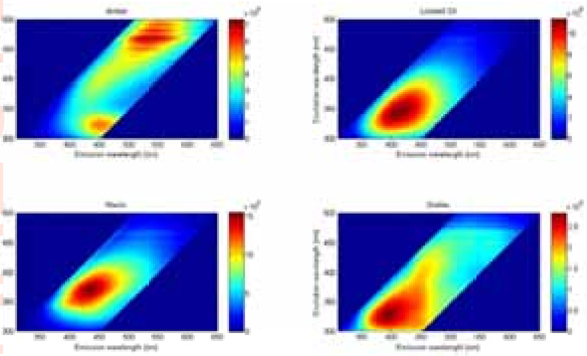

Figure 1: Excitation Emission spectra of binding media and varnishes.

Statistical analysis of fluorescence spectra can be particularly powerful for the identification of binding media, as differences in spectra may be subtle but significant. Therefore, methods including synchronous fluorescence spectroscopy, principal component analysis and cluster analysis have been employed for the discrimination of a large group of samples.

Fluorescence lifetime spectroscopy is particularly sensitive to differences in the environment of similar fluorophores, and materials studied have significantly different fluorescence emission and lifetime profiles.

Due to the similarity of fluorescence emissions when excited at 337 nm (Figure 2a), lifetime spectra may provide complementary means for discriminating materials (Figure 2b).

Fluorescence of media is usually recorded from the surface of samples; another method for the analysis of multiple varnish layers involves the use of confocal microscopy.

With a 1028 nm fs laser source the thickness of layers is probed through the detection of THG at 343 nm which occurs at the interface between different materials, and depends on small discrepancies in the refractive index between different layers. In some cases, it is also possible to differentiate between layers on the basis of the intensity of TPF as shown in Figure 3a.

The detection of different layers and fluorescence in samples is complicated by absorption of the third harmonic as well as that of fluorescence emissions (Figure 3a). By measuring samples in both transmission and reflectance from the front and back faces, an estimation of the layer structure is obtained (Figure 3b); a 15 µm layer of shellac is observed over an 8 µm layer of linseed oil.

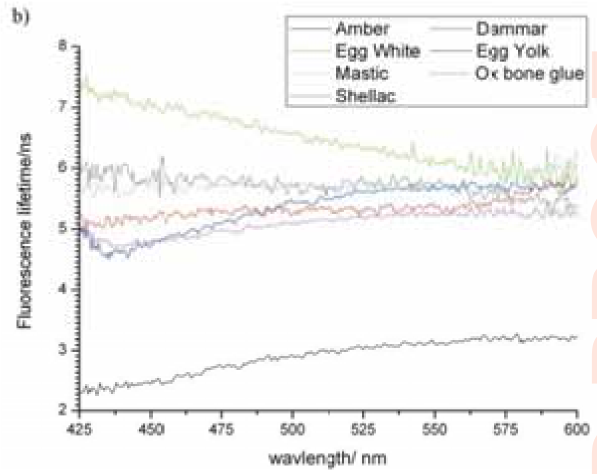

Figure 2: (a) emission spectra (b) and temporally resolved fluorescence lifetimes of varnishes and binding media excited at 337 nm.

4. Conclusions

While the characterisation and identification of organic binding media and varnishes used in paintings is commonly carried out using invasive techniques, recent advances in non-invasive instrumentation are promising; however, further research and applications on real cases are necessary. With portable instrumentation and fibre optic fluorescence spectroscopy, however, applications on real paintings have been carried out.[3] Statistical methods may be particularly useful for discriminating between broad fluorescence spectra, and time resolved spectroscopy can effectively complement results, especially in the case when fluorescence lifetimes of materials are different. Multiphoton and confocal Raman spectroscopy may provide an alternative method for examining multi-layered structures including varnished wood and paintings.

5. Acknowledgement

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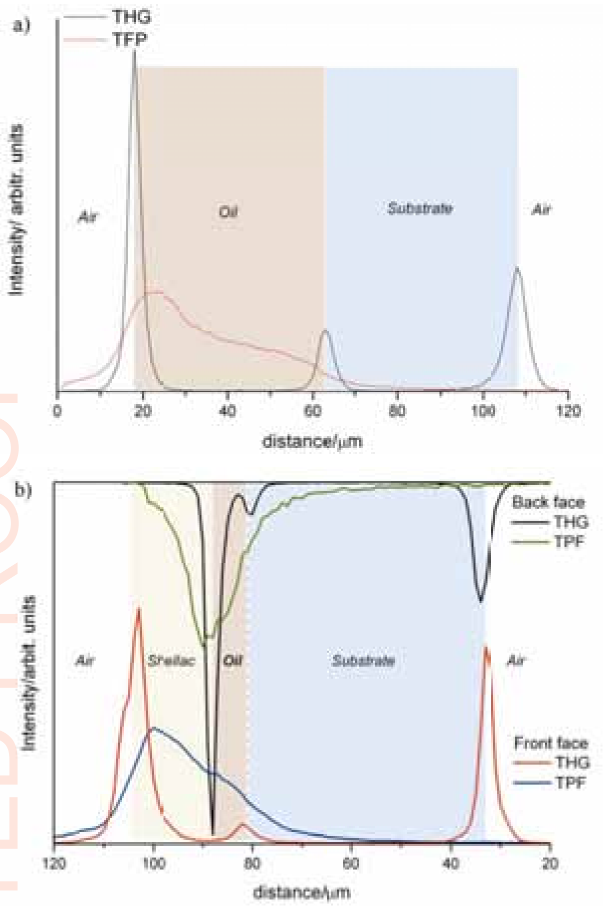

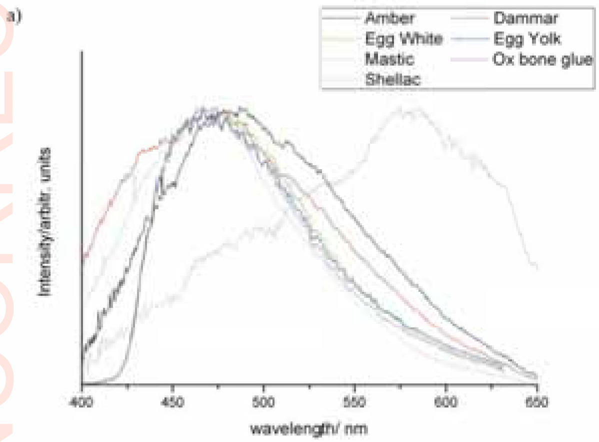

Figure 3: (a) film of Linseed oil and (b) film of Shellac and Linseed oil.

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DEFECT GROWTH IN MODEL PANEL PAINTINGS MONITORED BY FULL FIELD INTERFEROMETRY

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Abstract

Full field interferometry has the capability to be used as a means of structural diagnosis for the detection and record of non visible and new born defects in artefacts. The high sensitivity under low loading conditions allows the performance of non-destructive analysis, giving a strong advantage to the technique for the art world, where sampling an artifact can be problematic since it may affect its integrity.

For the case of panel paintings, this technique can offer invaluable information concerning the evolution of a defect and its reaction to conservation and restoration treatments. A typical panel painting structure consists of a number of layers of egg tempera paint, a gold leaf layer and gesso ground on a wooden substrate. The multilayered structure creates the opportunities for complex stress development due to the variety of materials present; a typical example among these is the wood expansion or contraction at different rates to the paint and priming layers under changes in humidity and temperature and thus the creation of a series of internal non-visible defects. For conservators, the monitoring of the defects present in an artefact is of paramount importance since they can test the adequacy of the treatments and the materials used. This paper focuses on the investigation of panel paintings in order to obtain information about the dynamics of a defect in an artwork. In this study a series of model panel paintings fresh, artificially aged and restored were investigated using high resolution full field interferometry.

1. Introduction

A typical panel painting structure usually consists of gesso ground on a wooden substrate, a layer of fabric, a number of layers of egg tempera paint, a layer of gilding consisting of a layer of bole and a gold leaf and finally a layer of varnish (Fig. 1). This multilayered structure comprising different materials creates the opportunities for layers to detach from one another or crack due to the variety of interfaces and materials present. When, for example, the artefact is exposed to unstable environmental conditions then each layer reacts at a different rate, leading hence to a number of internal non-visible defects. The detection and monitoring of this type of defects is very important for the preservation of the object and the selection of the suitable conservation method and materials. However, quite often internal defects are not being monitoring on time due to the lack of structural diagnosis techniques and they are only being detected when they have developed to such an extent that they are visible, or when they have produced a serious or irreversible damage. Furthermore, the lack of a tool that would monitor the conservation treatment suitability results many times in unsuccessful treatments and thus in the further deterioration of the artwork.

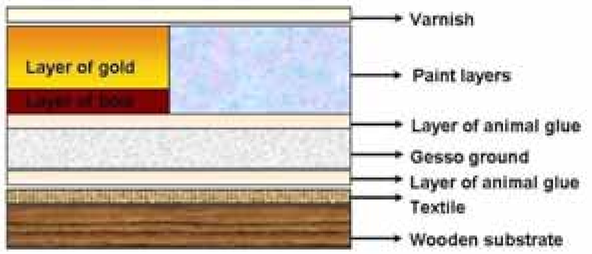


Figure 1: Cross section of a panel painting showing the different materials used.

To study defects produced on panel paintings, a series of model panel paintings, following the traditional techniques, were produced and subjected to a specific cycling process comprised of: artificial ageing, interventive restoration treatment and further ageing.[1] During all stages the samples were recorded by means of full field interferometry.[2]

Figure 2: Example of a panel painting examined with non-contact, non-destructive full field interferometry.

The high sensitivity under low loading conditions of full field interferometry inspection offers the capability of recording and detecting, from surface illumination, subsurface non-visible and/or inborn defects in wood panels. In addition, it permits the collection of remote non-contact and non-destructive analysis in realistic museum exhibition environments to trace growth and expansion of previously detected detached regions (Fig. 2). Thus full field interferometry provides strong advantages for art conservation of panel paintings where detection of detachment growth and deterioration is invisible by most known tools and practices or requires extensive physical contact and removal of the artwork to a conservation lab.

This paper focuses on the procedural investigation with full field interferometry of characteristic defects of panel paintings in order to obtain information about their growth, progress and reaction to conservation and restoration treatments. The aim of the research was achieved by construction of model panel paintings with known defects which were systematically investigated in fresh, artificially aged and restored condition. The results allowed the authors to communicate in this paper interesting observations directly visible to the eye of the conservator for a better understanding of the artwork.

2. Experimental

Construction of model panel paintings

The development of structural diagnosis techniques requires artificial samples that satisfactory simulate original objects. Thus, the Conservation Department of the National Gallery of Greece in the framework of the MultiEncode European Research Project [006427 (SSPI)] produced a series of artificially-made samples to imitate original panel paintings. The protocol for the construction of model panel paintings included:

- The study of the typical structure of the paintings to be simulated,
- The determination of the deterioration factors that *can* be reproduced,
- The definition of the defects that *have to be* reproduced,
- The construction of the samples,
- The documentation and characterization of the artificial samples,
- The ageing of the model panel paintings.

Taking into consideration the typical structure of a panel painting (for example, a Byzantine icon), the factors of deterioration and the types of defects that usually occur, a strictly definite series of 18 artificially made samples was produced (Table 1). The aim was to cover all possible combinations in the structure of a panel painting and to produce all the typical types of defects, such as cracked wood, detached ground and paint layers, etc.

Table 1: The stratigraphy and the defects produced on a model panel painting.

Technique	Layer Structure	Defects
Byzantine (with textile)	Wooden substrate Textile	1. knots 2. partial loss of gilding
	Preparation layer	3. loss of ground layer
	Bole	
	Layer of gold	
	Paint layer	
	Varnish	

Ageing protocol

For the accelerated ageing, it was decided to follow the oxidative type of ageing through thermal treatment of the samples. Due to the lack of standards on accelerated ageing of painting on wooden panels, original experimental protocols were produced. According to previous papers and publications,[3] the kinetic properties can be used to estimate the rate of degradation of materials containing cellulose, employing the Arrhenius equation:

$$F = \exp\left[-Ea/\mathrm{R}(1/T1 - 1/T2)\right],$$

It should be noted that the other deterioration mechanisms of cellulose, lignin and other wood components, i.e. hydrolysis and photo-oxidation, were not stimulated by the procedure followed. However, this accelerated ageing procedure is satisfactory serving the holographic experiments since its aim was the cause of remarkable defects on the samples more than the controlled cause of a chemical phenomenon.

All the samples underwent the accelerated ageing procedure in an oven (Memmert Company) with maximum air recycling. The indoor relative humidity varied from 45 to 50% during the whole procedure. The samples were heated at intervals at 102 ^{o}C for 66.5 h. The short cycles of high temperature exposure cause shock to the sample, leading, apart from the decomposition of the wooden substrate, to rapid deterioration of the coatings.

Restoration of model panel paintings

The samples were treated with conventional restoration methods. Among those was: the consolidation of the detached areas and the bulges with an acrylic polymer (Fig. 3); the adhesion of the ground and paint layer to the substrate with an acrylic adhesive (Fig. 4); the infill of the areas of loss with the use of an acrylic gesso putty and finally the weakening of the knots by opening small holes around its centre.

Figure 3: Detail of the model panel painting before and after the consolidation treatment and the gesso putty infill.

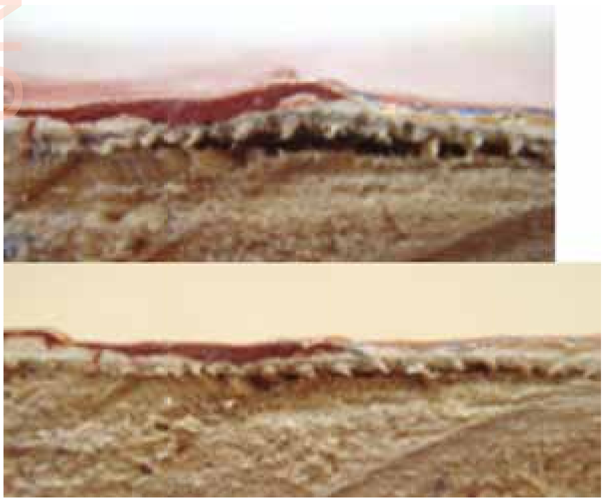


Figure 4: Detail of the model panel painting before and after the adhesion of the ground and paint layer to the substrate.

Ageing of restored model panel paintings

The treated samples were further aged by following the same protocol of the heating at intervals at 102 ºC for 66.5 h.

Full field Interferometry

Optical holography is an imaging method, which records the amplitude and phase of light reflected from an object as an interferometric pattern on a film or, for Digital holography, on a CCD. It thus allows reconstruction of the full 3-D image of the object. In double exposure holographic interferometry the artwork under test is interferometrically compared in two different states, relaxed and stressed (stressed state is achieved after thermal excitation by IR lamps). The resulting interference pattern contours the deformation undergone by the artwork under test in between the two recordings. Local discontinuitites in the overall distribution of the resulted pattern witnessing the defected regions and the possible effect in neighbouring areas and defects.

Digital Holographic Speckle Pattern Interferometry

DHSPI is a digital interferometric imaging technique that records changes of surface topography caused by thermal expansion. Hidden defects are also revealed by the inhomogeneity on the deformation fields. They are revealed by locating any sudden change in the fringe density, thickness, deviation and as long as the fringe discontinuity expands that size corresponds to a hidden discontinuity either well localised or expanded. DHSPI belongs to NDT testing, is thus a fully non contact and non invasive method that provides a double source of information being: observation of micro-displacements or movements relevant to the structural integrity of paintings and the localisation of failure due to defect. The procedure implies some kind of load (traditionally a thermal load, or heat) before or during the recording process. The technique can monitor in real time the location and the size of a wide variety of defects which give rise to precise information of the structural condition through the interpretation and post processing of the visual systems of fringe patterns.

3. Results

The model panel painting has been examined with Digital Holographic Speckle Pattern Interferometry before and after the artificial ageing process, after the restoration treatment and after the second ageing process. Defects included in the panel painting have been detected.

The purpose of those measurements is to check whether the dimensions of the detected defects have been altered through the ageing cycles and the restoration treatment. After the measurements of the defects in each state the following results arose and these are presented in Table 2. The dimensions of defect no_2 have been measured only in the "x" direction because the limit of the defect in the "y" direction is not clear enough.

Defects have been measured manually with the help of image processing software. The defects dimensions have been measured according to their fringe patterns. We consider as defect starting point the point where the regularity of whole body fringe patterns is interrupted (Table 3).

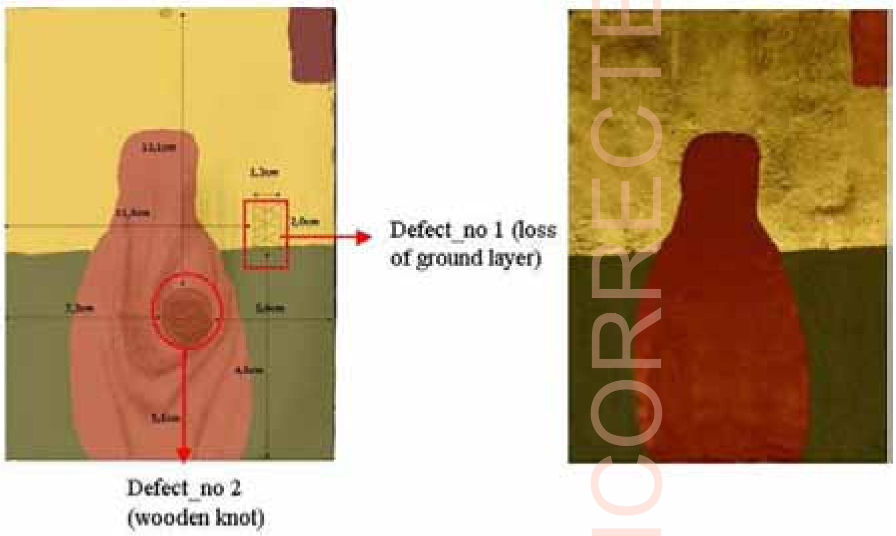


Figure 5: The model panel painting.

Table 2: Measurements of the defects.

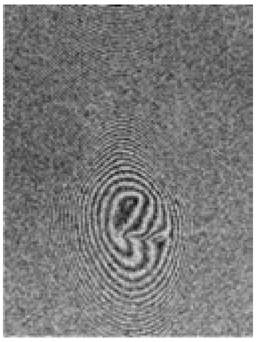
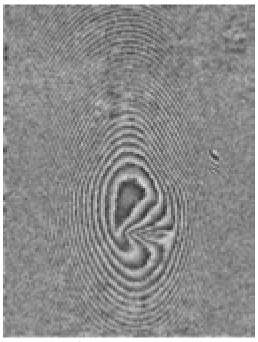
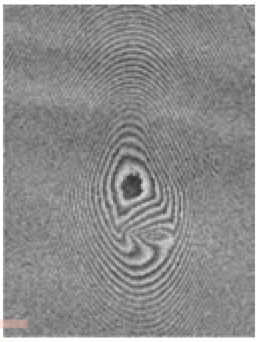
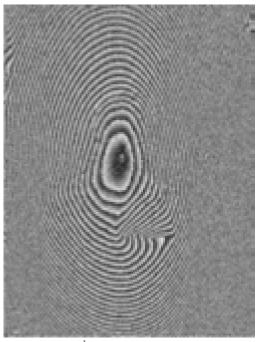
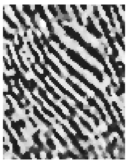
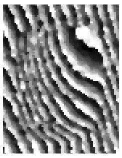
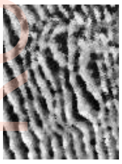
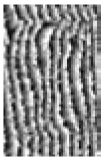
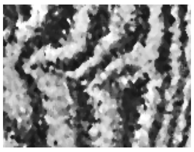
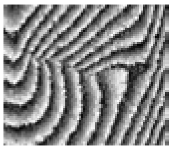
 Before ageing process after 28 s.	 After 1st ageing process after 28 s.	 After restoration process after 28 s.	 After 2nd ageing process after 28 s.
 Defect no_1 (Loss of ground layer)	 Defect no_1 (Loss of ground layer)	 Defect no_1 (Loss of ground layer)	 Defect no_1 (Loss of ground layer)
 Defect no_2 (Wooden knot)	 Defect no_2 (Wooden knot)	 Defect no_2 (Wooden knot)	 Defect no_2 (Wooden knot)

Table 3: Measurements of the defect size.

Defects	Before ageing	After 1st ageing	After restoration	After 2nd ageing
No_2 (x direction)	3.05 cm	3.24 cm	3.51 cm	3.44 cm
No_1 (x direction)	1.48 cm	1.51 cm	1.37 cm	1.42 cm
No_1 (y direction)	1.7 cm	1.81 cm	1.8 cm	1.8 cm

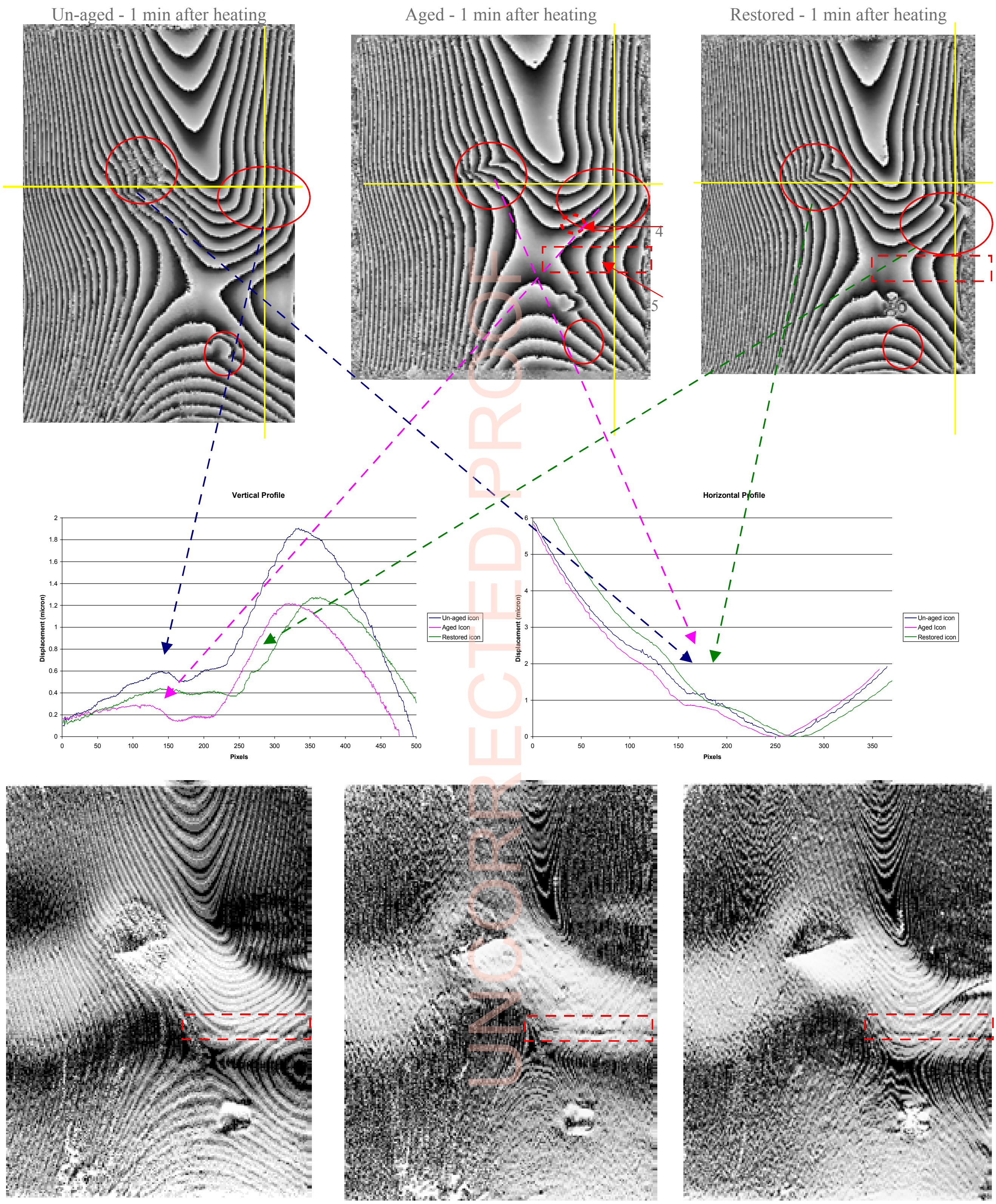


Figure 6: Location of selected defects and their holographic differentiation.

Table 4: Size measurements of defect no_1.

Size before ageing (cm)	Size after 1st ageing (cm)	% change
x: 1.48	1.51	2%
y: 1.7	1.81	6.5%
Size after 1st ageing (cm)	Size after restoration (cm)	% change
x: 1.51	1.37	-9.3%
y: 1.81	1.8	-0.55%
Size after restoration (cm)	Size after 2nd ageing (cm)	% change
x: 1.37	1.42	3.6%
y: 1.8	1.8	0%

Table 5: Size measurements of defect no_2.

Size before ageing (cm)	Size after 1st ageing (cm)	% change
x: 3.05	3.24	6.23
Size after 1st ageing (cm)	Size after restoration (cm)	% change
x: 3.24	3.51	8.33
Size after restoration (cm)	Size after 2nd ageing (cm)	% change
x: 3.51	3.44	-1.99%

As it is easily observed in Table 4 the defect no_1 has been expanded as far as it concerns the "x" direction with a percentage of 2% and as far as it concerns the "y" direction with a percentage of 6.5% after the 1st ageing process. After the restoration process the defect demonstrates shrinkage of 9.3% for the "x" direction and of 0.55% for the y direction. After the 2nd ageing process there has been an expansion in the "x" direction of 3.6% while in the y direction there has been no change.

As it can be observed in Table 5 the defect no_2 has been undergone an expansion of 6.23% after the 1st ageing process and an expansion of 8.33% after the restoration process. This can be explained by the fact that this defect corresponds to a wooden knot and the treatment had to do with the opening of wholes, hence the expansion of the defect. After the 2nd ageing process the specific defect went through shrinkage of 1.99%.

Another example of the importance of full field holographic interferometry is the monitoring of the model panel painting through the same cycle (fresh-aged-restored-further aged) by Dynamic holographic interferometry (DyHI).

Dynamic Holographic Interferometry

DyHI is an interferometric imaging technique that has similar principles as DHSPI. It records changes of surface topography caused by thermal expansion. The model panel painting has been examined with DyHI before and after the artificial ageing process, after the restoration treatment and after the second ageing process. Defects included in the panel painting have been detected.

The first point to notice is the similarity between the fringe patterns, the profiles and the sheared images before and after restoration.

The fringe density in the restored sample is about the same as in the aged sample, while the restoration does not seem to have changed the fringe density. The signature of defects 1, 2 and 3 is still detected in the restored sample. However the signature of defect 3 is more pronounced after restoration due to the strong restoration treatment (weakening of the knot). This is also obvious confirmed at the phase and sheared images.

Another observation is the fact that the signature N°5 corresponds to the limit between the green and the gold paint which is still present after restoration. Furthermore the signature N°4 that appeared after ageing is no more detected after restoration.

As a general remark, it can be observed that the defects produced at the construction of the model panel painting evolved during the ageing process. Furthermore, after the restoration some defects disappeared completely (defect No.4) while others (defect No.3) increased after the treatment.

4. Conclusions

As it was demonstrated above, the monitoring of an artefact by full field interferometry can offer invaluable information about the preservation state of an artwork and its course through time. Moreover, unique information concerning the suitability of a conservation and restoration treatment can also be obtained.

The application of this type of non-contact structural diagnosis technique on model panel paintings showed that even minor changes in the structure of an object can be recorded. Specifically, the evolution of defects and their reaction to conventional conservation methods, along with details about the exact size of a defect and its expansion or shrinkage were achieved.

Optical holography and particularly DHSPI is a sensitive interferometric imaging technique that records and reveals hidden inhomogeneous deformations in the structure of a panel painting. This allows the conservators to minimize the evolution of a defect, to stop the progress of a new-born defect and to conserve the object by choosing suitable materials and treatments.

5. Acknowledgements

The authors would like to thank the Multi-Encode project [006427 (SSPI)]. Thanks are also due to Eleni Kavalieratou, Maria Gerasimina Trompeta and Agni Vassileia Terlixi from the National Gallery – Alexandros Soutzos Museum. Finally, thanks are extended to the following project partners for their invaluable contribution: Cedric Thizy from CSL-Belgium, Stephen Hackney and Tim Green from the Tate-UK, Roger Groves from ITO-Germany and Yannis Orphanos, Kostas Hatzigiannakis, from FORTH/IESL-Greece.

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IMPACT OF CO_2 AND PRECIPITATION CHANGE ON THE BUILT CULTURAL HERITAGE

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1. Introduction

Although climate change is currently attracting interest at both research and policy levels, it has only recently been addressed as a factor threatening cultural heritage by the European Union within the Noah's Ark Project (Global Climate Change Impact on the Built Heritage and Cultural Landscape, SSPI-CT-2003-501837).

Among the effects climate change may have on built heritage deterioration, its impact on the chemical dissolution of carbonate stones is here considered, as it is one of the main damage processes occurring on monuments and buildings located in both urban and rural areas. Rainwater degrades marble and limestone through three processes: (1) a clean rain effect due to rain at pH ~ 5.6 in equilibrium with atmospheric CO_2 (karst effect), (2) an acid rain effect, caused by rain with additional acidity due to the presence of sulphuric and nitric acid, and (3) the dry deposition of gaseous pollutants, especially SO_2 and NO_x, occurring between precipitation events.[1]

While the damage on cultural heritage caused by atmospheric pollution has been extensively explored,[2,3] here for the first time Europe-wide maps show the quantitative evaluation of surface recession on carbonate materials for three 30-year periods selected within the period 1961 - 2099.

2. Methods

The models and damage functions quantifying the surface recession on marble and limestone have been reviewed,[4-9] focusing on the comparative effects due to pollutant and climate parameters. Among the damage functions present in the literature, we took into consideration the Lipfert function, which recognises the three mechanisms for material loss; i.e. karst effect, acid rain effect and dry deposition, in the three terms of the equation:

$$L = 18.8 \cdot R + 0.016 \cdot [H^+] \cdot R + 0.18\,(V_{dS}\,[SO_2] + V_{dN}\,[HNO_3])$$

where: L = surface recession per year (µm/year); 18.8 = solubility of $CaCO_3$ in equilibrium with 330 ppm CO_2; R = precipitation (m/year); 0.016 = constant valid for precipitation pH in the range 3-5; $[H^+]$ = hydrogen ion concentration (µmol/l) evaluated from rain yearly pH; 0.18 = conversion factor from (cm/s) (µg/m^3) to µm; V_{dS} = deposition velocity of SO_2 (cm/s) ; $[SO_2]$ = SO_2 concentration (µg/m^3) ; V_{dN} = deposition velocity of HNO_3 (cm/s) and $[HNO_3]$ = HNO_3 concentration (µg/m^3).

This function has been chosen because it is postulated for generic calcite and it is valid for low-to-medium porosity marble and limestone, rather than a specific carbonate material, and has the advantage of allowing the estimation of surface recession on the basis of data from air quality monitoring networks.

Climate parameters used for future projections have been extracted from the output of two widely used models from the Hadley Centre (UK): HadCM3 and HadRM3. HadCM3 is a general model with a grid resolution of 2.5° □ 3.75° (i.e. 295 □ 278 km at 45° N latitude), while HadRM3 is a regional climate model, which encompasses Europe at a higher resolution (a grid of equal-area cells, 50 □ 50 km), but spans only the years 2070 to 2099. The model outputs employed are based on the A2 scenario (IPCC SRES Emission Scenarios – Version 1.1 – July, 2000) and the selected geographical area is centred on Europe. Three 30-year periods have been taken into account: 1961-1990 (baseline), 2010-2039 (near future) and 2070-2099 (far future). In addition projected air pollution concentrations for SO_2, HNO_3, O_3 and the pH of precipitation have been estimated under future scenarios. The simulation of present conditions makes use of the grid emission data for 1990 taken from the EMEP (Co-operative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe) database. For future European greenhouse gas emissions, use is made of the projections for 2020 and 2085 developed as part of the Noah's Ark project (http://noahsark.isac.cnr.it/).

3. Results

As a first step we took the yearly mean precipitation amounts from the HadCM3 general model for the three periods (1961-1990, 2010-2039 and 2070-2099) and the yearly mean concentrations of SO_2, HNO_3 and pH of precipitation from the above described pollution scenarios, to estimate the mean annual surface recessions for the terrestrial grid squares of Europe, applying the Lipfert function.

Recession rates were calculated for the three periods considered on the basis of the various terms of the Lipfert equation, showing that most of the recession arises from the karst effect, which is expected to remain the dominant contributor in the future. This justified the use of a simplified Lipfert function ($L = 18.8 \cdot R$) to produce maps charting surface recession on the European scale.

As explained above, in the Lipfert function 18.8 is a constant related to the solubility of $CaCO_3$ in equilibrium with 330 ppm CO_2. Since it is known that there will be a significant rise in both carbon dioxide concentrations and temperatures over the coming century that may influence calcite solubility, the constant has been recalculated on a daily basis correcting for the predicted temperature and the pCO_2 ranging from 330 in 1961 to 750 ppm in 2099. Moreover, as the Lipfert function assumes that precipitation (R) arrives only in liquid phase, the snow effect has been taken into account by allowing no recession for days with daily mean temperature less than 0 °C. This assumption is particularly important in evaluating surface recession in northern Europe.

Daily precipitation and temperature values from HadCM3 and HadRM3 have been used in combination with the critically modified Lipfert function for mapping surface recession of carbonate stones on the European scale for the 21st century.

The results demonstrate that among the different parameters critical to cultural heritage, precipitation and CO_2 trends in this century play an important role in producing change of surface recession threatening the built heritage.

The map presented in Figure 1 visualizes the mean annual surface recession of carbonate stone for the thirty-year period 2010-2039 (near future) showing that a maximum value of 30 µm year^{-1} is forecast for central Europe and some parts of northern Europe. A general increase of surface recession with a maximum value of 6 µm year^{-1} is predicted across the century throughout Europe, particularly noticeable in high rainfall areas.

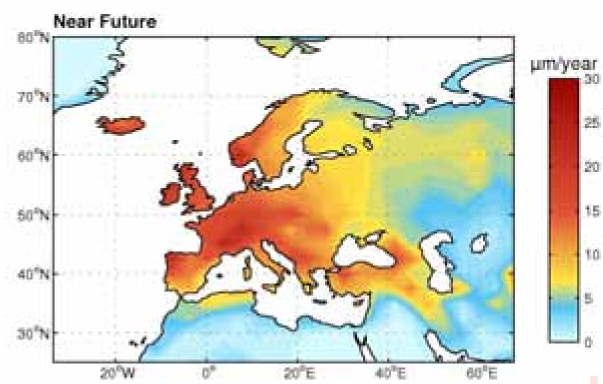

Figure 1: Estimated change in annual surface recession of carbonate stone for 2010-2039 under the A2 scenario derived from HadCM3 output.

4. Acknowledgments

This work forms part of the EC Project "Global climate change impact on built heritage and cultural landscapes - NOAH'S ARK, supported by the European Commission, within the 6th Framework Program on research (Contract nr. SSPI-CT-2003-501837-NOAH'S ARK).

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KNOWLEDGE EXCHANGE AND BUILDING SIMULATION TO OPTIMISE AN ARCHIVE REPOSITORY ENVIRONMENT

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The National Archives UK (TNA) is reviewing its provision of current storage environments and HVAC systems with the view to exploring the potential of imaginative and appropriate preservation environments for TNA's collections. The Departments of Conservation Research and Estates & Facilities Department are reviewing current environmental conditions, the Building Management System (BMS) and plant-room operation and maintenance. The latter seeks to provide a system that is responsive, flexible, energy efficient, controllable and environmentally responsible. In order to provide the evidence to support reappraisal of current practices, specifications and preservation strategies, particularly within the context of regional climate change and UK Government sustainability targets.

To provide the necessary evidence a two-year collaborative research project is underway between the University College London, Centre for Sustainable Heritage (CSH) and TNA to apply building simulation to understand the current environmental performance of TNA's repositories. Significantly, this research project will meet business critical needs and also exemplify knowledge and technology transfer from research to industry.

The earlier (1978) part of TNA's building, known as Q1, includes 3 of TNA's largest repositories that occupy the entire floor space of the 2nd, 3rd and 4th floor of the building. The environment inside the repositories has always been controlled with a mechanical system (HVAC) serviced by plant-rooms that reside in the basement of the building. Given the building is now over 30 years old, the efficiency of the environmental control system has inevitably declined over time compounded by successive changes in the internal configuration and a changing climate. To compound this situation, the resource requirements for maintaining such systems have increased, and will continue to do so, in tandem with rises in energy cost. In addition UK Government sustainability targets have made it imperative to seek environmentally responsible solutions and to reduce energy consumption. Equally, current standards and guidelines for storage environments are being scrutinised and their efficacy and long-term sustainability reviewed both at UK national and European level.

Therefore, since the HVAC system in Q1 has now reached the end of its service lifetime, it is essential that the development of a programme of upgrades or even complete re-commissioning by Estates & Facilities Department is informed by the outcomes of this research project. This will ensure that the proposed solution is not more costly or resource intensive than necessary and that it delivers the appropriate preservation environment.

Against this background, the project endeavours to construct a computer model of the three repository floors in Q1. Using the simulation programme EnergyPlus, the heat and moisture transfer properties of the building and the resulting conditions of internal temperature and relative humidity will be modelled. Once completed and tested, the model will be a valuable diagnostic and predictive tool. The parameters used to construct the model can be altered and the outputs of internal RH and T to be recomputed for a number of 'what if' scenarios. The scenarios may include changes in the building fabric, building and systems operation, occupancy, external climate and mass of material stored in the repositories. The model will be applied by the researchers to investigate the scenarios and evaluate them in terms of appropriate conditions for the care of collections, energy use and the degree of mechanical environmental control required with the aim of optimising the sustainability of stewardship of TNA's collections.

In the EC 6th Framework project NOAH'S ARK (2004-2007), a new Heat and Moisture Transfer Module (HAMT) software module was developed for the software EnergyPlus.1 This module couples the modelling of moisture exchange between air and the building fabric and modelling the moisture profile of walls and other solid materials. The research within the frame of the TNA Building Simulation Project will represent an innovative application of the HAMT model, modelling not only temperature and relative humidity inside the repository environment, but also the profiles of temperature and relative humidity in bulk archival materials themselves. This will allow us to examine a variety of environmental scenarios of HVAC system operation and different climate change scenarios. The risk of increased material degradation will be assessed against the costs of energy for HVAC system operation.

TNA staff is collaborating with researchers to gather data on the local external environment, building construction, services, collections and use that are needed to calculate these conditions.

Within TNA, the project has been the catalyst for a collaborative relationship between the Departments of Collection Care (CCD) and Estates and Facilities (E&F). A timely synergy between the two is crucial for the success of the project itself, but also for the accomplishment of their common aim to provide sustainable preservation environments for TNA's collection.

The presentation will describe the methodology for the model development, present first results and demonstrate the dynamic exchange between researchers and collection managers.

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RGB-ITR APPLICATION FOR CULTURAL HERITAGE: A PRACTICAL CASE APPROACHED IN THE CHURCH OF SS. TRINITY IN HRASTOVLJIE

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1.Introduction

Since 15 years in the Artificial Vision Laboratory of C.R. ENEA – Frascati opto-electronics systems has been developed. The first High Definition – Amplitude Modulated Laser Range Finder[1] was developed for the vision inside radioactive environments and in the next years the technology was adopted also by fine-arts world[2]. In this field, laser 3D digitisation can significantly improve current preservation and restoration practices, especially when combined with other imaging diagnostic techniques[3]. Most currently available laser scanners[4], though, are only able to produce purely geometric output, which is not enough for great part of cultural heritage applications. It is common practice to combine the "naked" 3D models generated by such devices with independently acquired digital photos, that supplement colour in the form of superimposed textures, but this technique has many drawbacks and limitations in terms of attainable visual quality and accuracy. In order to meet the demanding requirements posed by restorers and conservators, new systems with both accurate range finding and intrinsic colour imaging capabilities are needed.

Differently than the first monochromatic system, which contemplates a single amplitude modulated laser source, a new amplitude-modulated three stimulus machine has been developed. The main feature of the new generation of ITR systems is to digitalize real world scenes, producing a real high fidelity colored 3D models without the aid of textures, removing all problems this type of technique produces (registration, shadows, etc.).

2.General description

A RGB-ITR system is composed by:

An optical head equipped with a scanning device to move the laser across the scene.

Three laser sources of 450nm (blue) 532nm (green) 650 nm (red), connected with the optical head by three single-mode fiber optics of suitable wavelength.

Three separated detectors for revealing the three optical signals reflected, connected with the optical head by three multi-mode fiber optics.

Electronic devices for estimating the optical head's distance from the investigated pixel of the scene to be scanned and for acquiring the amplitude of reflected signals

A computer for acquisition and manipulation of data collected by the system.

The RGB-ITR system was designed to be separated into a passive optical head, mainly constituted by mirror and lenses, and an active opto-electronic system, which includes the laser sources and the detectors along with the dedicated electronics, so to have the capability to use it in hostile environments (i.e. radioactive environments).

Differently from triangulation laser scanning systems, the optical components (lens, mirrors, etc.) inside the RGB-ITR systems are placed so to have a monostatic configuration: this feature permits to eliminate self-occlusions during the scanning process.

Figure 1: Optical head with the six fiber optics.

As in Figure 1, the three fiber optics are kept together by a patented mechanical device called FERRULA placed at the input and output ports of the optical head. A transmission optical system, which is able to focalize the three sources on the target, is positioned on the input port. The signals reflected by the target come out with the following configuration: the red channel strikes the scanning mirror exactly in the center (the nodal point of the scanning system); the blue and green channels strike the scanning mirror with an angle of 6.045 mrad as compared to the red beam. This configuration is shown by Figure 2.

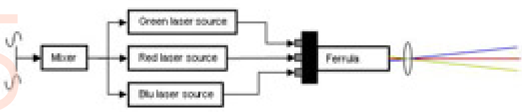

Figure 2: *Ferrula scheme*

As mentioned before, the three laser beams move across the scene through a scanning mirror. The signal reflected by the target is captured by receiving optics, composed by mirrors and focalizing lenses. The Cooke triplet, placed at the end of the receiving optical chain, is able to focalize the three separate lasers in three different receiving fibers located in the FERRULA, which bring the signals to three separated detectors. The FERRULA system is suitable for acquisition at very long distances (15-30 m).

Presently for mixing the three laser sources together we introduced dichroic filter optical combinator: in this case the three laser sources come out from a single fiber optic and the resulting spot is the superimposition of the three red, green and blue spots. The advantage of this system respect the FERRULA is that the three laser sources strikes at the same time the same point on the scene: no registration of the three RGB layers is required. The disadvantage is that due to power losses inside dichroic filters, the working range of ITR systems in this configuration is 3-15 m.

The launching and receiving fibers connect the electronic system with the optical head.

The transmitting section of the electronic system is composed by three lock-in amplifiers which amplitude modulate at suitable frequencies the laser sources.

The receiving section of the electronic system is composed by three detectors, which receive the signals reflected by the target through the receiving fiber optics. The detectors convert the optical signals into electronic signals, that are transferred to the lock-in amplifiers, which calculate phase (distance) and amplitude (color) for each channel.

All data are transferred from lock-in to a standard laptop via GPIB: a patented on purpose developed software is able to storage, reconstruct and manipulate the 2D/3D data.

In Figure 3, a general view of a complete field version of the optical head and the electronic system is shown.

Figure 3: On the left, the electronic system; on the right a panoramic view of RGB-ITR system

3.Software

The software expressly planned and developed features two main modules and is able to control the scanning process (module SCANSYSTEM) from the beam launch until the creation and manipulation (module ITR_ANALYZER) of the 2D/3D models. The software permits the 2D/3D commercial software interoperability: in fact, it is able to export the high detailed laser pictures not only in the Photoshop file format – in order to have the capability to apply its filters – but also in the 3D file formats for CAD/CAM commercial software, in order to perform direct 3D data manipulation.

Figure 4: *ITR Scan-System user interface*

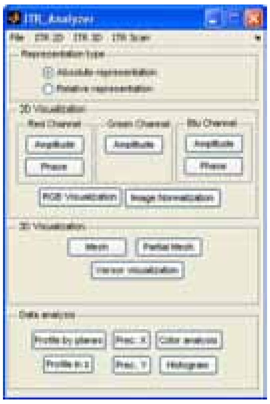

Figure 5: *ITR_Analyzer user interface*

4. Rgb-itr imaging characteristics

Before the detailed characterisation set forth in the next section of the 3D digitisation capabilities of the RGB-ITR, we first focus on the system's pure imaging potentials, by outlining a qualitative comparison with ordinary (analogical as well as digital) cameras.

Such a comparison is intrinsically problematic, due to the different characteristics and usages of the two categories of sensing devices. While e.g. an ordinary camera can instantly acquire snapshots of highly dynamic subjects, a point-scanning laser system like the RGB-ITR can only be used for the acquisition of static scenes, due to the inherent slowness of the measurement process, as well as to the fundamental requirement that the signal-to-noise ratio is high enough to enable an accurate range determination. On the other hand, the RGB-ITR provides considerable advantages in terms of self-illumination capabilities, independence from external illumination conditions, absence of shadows and off-axis aberrations, long-distance operation, production of undistorted images etc[5].

A most remarkable property of the RGB-ITR, as compared with ordinary cameras, is related to colour depth. The dependence of the current signal-to-noise ratio on the integration (or pixel sampling) time τ is given in eq.

$$SNR_i = \sqrt{\frac{P\eta\tau}{h\nu}} \qquad \begin{cases} P \rightarrow \text{collected power on the detector} \\ \eta \rightarrow \text{detector quantum efficiency} \\ F \rightarrow \text{optics merit factor} \\ \tau \rightarrow \text{integration time} \end{cases}$$

which equally applies to any of the three colour channels. As a consequence, the colour depth in any given channel is also indirectly dependent on τ , through the relationship

$$N = \frac{SNR_i}{2J}$$

which links the current signal-to-noise ratio to the number of levels that can be measured with a confidence level J ($J > 1$).

In shot-noise dominance regime, the photocurrents generated by the RGB-ITR, for typical values of τ comprised in range from 1 to 10 ms, are characterised by a very low noise level. This means that colour depths of 16 bits or more can - at least theoretically - be obtained, that is, more than 65000 levels per colours channel can be discriminated. This result must be compared with the colour depth of ordinary digital cameras, which, in typical conditions, is limited to 8-12 bits, and can only be increased by using multi-exposition techniques and dedicated post-production software.

Similar qualitative considerations also apply to the maximum attainable lateral resolution. For a system like the RGB-ITR, in the optimal yet realistic case of diffraction-limited performances, the lateral resolution can reach, in each colour channel, the limit determined by the point spread function. Once transposed in terms of standard photographic resolution - expressed e.g. in lines pairs per mm - the values that can be obtained by a topological radar may in principle outclass conventional film or CCD cameras.

The previous qualitative analysis suggests that, even in terms of pure 2D imaging performances, the RGB-ITR has the potential to produce colour images with characteristics of colour depth and resolution beyond the possibilities of the best photo cameras currently available.

For mere indicative purposes, we report in fig. 2 an example of a digital photo shot by a Nikon D-70 (6 mexapixels, objective zoom f18-70mmDX) and an image of the same subject at the same distance (5 metres) obtained by using the RGB-ITR and a scanning time of about 15 minutes. A better signal-to-noise ratio and an improvement of the spatial resolution of the laser image over the photography can immediately be appreciated.

5.Results

In the framework of the European Union Culture 2000 Community Programme, an Italo-Slovenian collaboration was set up with the objective to realise an accurate, colour 3D model of the interiors of the Romanic Holy Trinity church in Hrastovlje (Slovenia), to be used for monitoring, restoration and cataloguing purposes.

Figure 6: *Digital photo made by Nikon D70*

Figure 7: True color laser image made by RGB-ITR.

All the walls and vault of the church are decorated by frescos dating back to the XV century and representing scenes from the Old and New Testament. The paintings, remained hidden under plaster for a long time and rediscovered in 1949, are considered a masterpiece of Slovenian medieval mural artwork. During a five-day campaign in September 2007, 60% of the church's surface was 3D digitised by means of the RGB-ITR, for a total of 11 scans and almost 90 data recording hours. In fig. 3 a snapshot of the 3D model of the central apse is shown, representing the Throne of Grace. The model, reconstructed from data recorded in a single 12.5 hrs scan, consists of 3,240,000 vertices and 6,472,802 triangles.

Figure 8: Laser color Dance of Death.

Figure 9: 3D laser scanned main chapel in Hrastovljie's church.

To summarize The purpose of this campaign was to collect data for:
- monitoring church's structure and frescos' pigments
- cataloguing this important Slovenian monument for historical archive
- realization of a virtual tour inside the church

Data collected in different periods permit to reveal possible degradation in the wall structure, making a point-by-point submillimetric distances comparison, and possible modifications in frescos' pigments due to some biological attack or humidity. For a deeper analysis of color modification, LIF data were mapped on ITR data so to obtain a multispectral analysis of a portion of the church.

Speaking about cataloguing purposes it's important to underline also the aspect of making different acquisitions before and after a monument restoration: in this way it's possible to have an overview of all the aspects of operation made on the monument and it's also possible to give a wide vision to the end user of the state of the art of the monument.

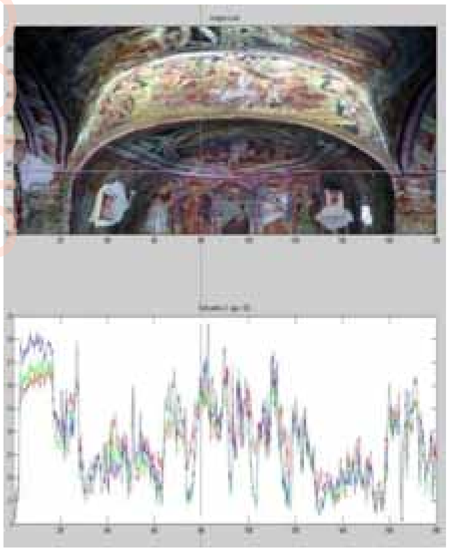

Figure 8: User interface for color analysis. It is possible to observe the three color components per each pixel.

3D game technology can be applied to the ITR scans of the church for a full immersive virtual tour: the high quality of the images permits to observe details difficult to see directly in the church. In the next figure the possibility of color analysis of the software ITR_ANALYZER is illustrated in which is possible to observe the three stimulus components for each image pixel.

6.Conclusions and future expectations

A characterization of a system RGB-ITR has given along to some important results acquired in situ. In the next years a lot of efforts will be driven to ITR color characterization and communication interfaces (software) and to an improvement of the optical transmission system (hardware) to increase the instrument accuracy and finally a more suitable and dedicated electronic wil be projected After Hrastovljie campaign algorithms for color correction and calibration have been improved.

An underwater 3D laser scanning is under investigation and in the next months a prototype will be developed in our laboratory.

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VIRTUAL RECONSTRUCTION OF A MEDIEVAL SCULPTURE

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The Germanisches Nationalmuseum in Nuremberg ranks among the most important museums of German-speaking countries. It houses an outstanding collection of medieval sculptures such as Veit Stoß, Adam Kraft and Tilman Riemenschneider. The collection of 14th century sculptures contains a nearly life-size limewood sculpture of St. George in battle with the dragon (Figure 1). Clearly it belongs to the artistic circle of the Emperor Charles IV. in Prague. It dates from the year of 1365. The sculpture's outstanding importance is underlined by its polychromy. On traditional gesso priming we find poliment silver and gold for shaping the armory and clothing. But many sculptural details have been formed by gilded tin applications conveying the imitation of a goldsmithing work. Through aging processes and partial loss, the treasure of the polychromy is no longer perceivable. Furthermore, even a restoration will not gain back this precious appearance.

The aim of this project is to visualize the previous shine of the sculpture, by a realistic three-dimensional virtual computer simulation of the surfaces. The observer in the museum should be given the impression of the original appearance of the sculpture at the time of its creation. So this project is a feasibility analysis for the complete virtual reconstruction of a sculpture by which we develop and evaluate the procedures needed for such a process. Since an important part of the realistic impression is the surrounding of the sculpture, we reconstruct an assumed surrounding and create the environmental context for the sculpture

To ascertain the suitability of the laser-scanned models for the virtual reconstruction, more specifically the simulation of the surfaces in their assumed original state, trials have been carried out on the scanned 3D model of the sculpture. The scanning was done with a state of the art 3D scanner and delivered a 3D model with a resolution of nearly 3 million polygons. The exceptional high detailed surfaces of the polychromy must be regarded as one of the significant feature of the sculpture of St. George. Its fine punched ornaments on the garments proved to be far too detailed for the possible resolution of the 3D Laser Scanner and the fine details of the surface of the metal applications could not be transported to the 3D model. On the other hand is a resolution of 3 million polygons fairly high for the planned computer graphic workflow. The scanner delivers too high resolution in areas that don't really need it but on the other hand too less in fine detailed areas. The solution could be the development of adaptive tessellation procedures that deliver the high resolution only there were it is needed. Our approach to the problem was to test procedures, which we have formerly successfully developed and used for our work in visualization, character animation and 3D game design. We completely rebuilt parts of the sculpture, using the 3D scanned model only as guidance and so we were able to define the grade of resolution needed for the desired purpose. This manual work proved to be an even faster way gaining a reliable 3 D surface than overworking the scanned model. Another advantage is the implementation of methods like displacement mapping to accomplish the fine details in the surface.

Figure 1: St. George, actual state.

Initially, the gilded and silvered areas of the leg have been reproduced in their stratigraphy with simulated craftsman tooling marks and then computed. Procedural texturing techniques were used, in order to be independent of the resolution during the image computation. The method of lighting is an important factor as is the environment of the model. HDRI (High Dynamic Range Imaging) lighting and rendering techniques were used to achieve highest realism. The results of the first tests show, that this is an encouraging prospect enabling to compute even more complex surfaces.

Apart from reconstructing the surface of the polychromy we will reconstruct the artistic work of the polychromy's painter. Layer by layer, starting with the gesso priming on a virtual limewood sculpture and ending with the tin applications, the rise of the painting will appear. Those reconstructions are done so far only by drawings. This new method of representing aged and destroyed surfaces will convey a new and more convincing inside into the rise of a polychromy and artistic work. In the prospect of the project we also plan to cast an eye on the possibility of presenting the animation in the environment of a museum. We are testing to use the high detailed and photorealistic model of the sculpture to generate a low resolution real time model for the use in a 3D game engine. Our aim is to transfer the high detailed surfaces by methods like normal mapping from the high resolution model to the game engine qualified model. So photorealistic interactive real time walkthroughs, showing the sculpture in its assumed original surrounding will be possible.

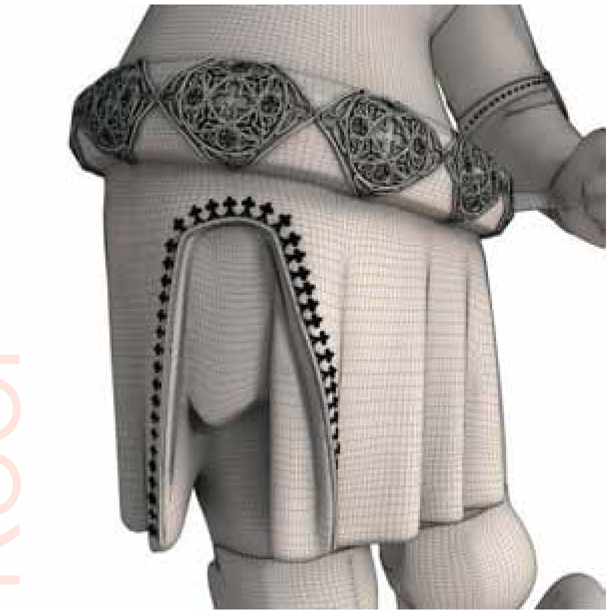

Figure 2: Process of remodelling the sculpture.

Figure 3: First test of the material simulation.

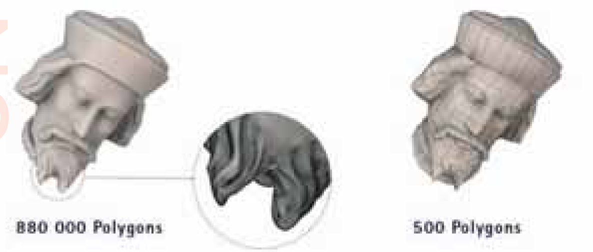

Figure 4: Polygon reduction for real time applications.

SPECTROFLUORIMETRIC CHARACTERIZATION OF BIOLOGICAL ATTACK IN ARTWORKS

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1. Introduction

It is of primary interest for Conservers and Restorers to have fast, accurate and reliable tools for cultural heritage diagnostic, applicable to a number of different materials and surfaces as for example stones, plasters, wall paintings, etc.. Surfaces like these might currently show damages from transformations caused by external deposits, internal transport of salts and biological attack as well. As the last point is concerned, the identification of microorganisms is indeed an important part of the restoration and conservation process, having its main reasons in the selection of the appropriate treatments to kill and prevent new growths and artworks' colonization. Until recently, the identification of living organisms has been done by standard biological and/or molecular methods. To complete the analysis, the classical methods require a long time, expensive tools, well equipped laboratory together with long trained personnel.

On the other hand innovative approaches based on the use of optical and spectrofluorimetric methods are very promising. these having well defined advantages of being fast, non invasive, cheap, also requiring modest skill [1]. Development of integrated optoelectronic and biological techniques and methods including materials, optical system, spectrometers and critical components to the realization of integrated and user-friendly biological and biochemical sensor systems, is then a subject of huge potential interest to be pursued by multi-disciplinary approach.

In the frame of international cooperation at the ENEA laboratories, an innovative optical instrumentation has been designed and used for the remote and local analysis of artworks, having as main goal the bio-deterioration assessment: here the focus will be concentrated on the spectrofluorimetric characterization of selected microorganisms strains.

2. Experimental

In the present measurements ultraviolet (UV) and visible (VIS) light is used to induce fluorescent emission from different biological sample, with the purpose of reveal those characteristics - invisible to the naked eye - which may be related to the early alteration caused by biological attack. The samples under study were mycelium and spores of fungi strains having a widespread diffusion as biodeterioration agents; the following strains were analyzed: *Alternaria*, *Paecylomices*, *Chaetomiumm*, *Cladosporium*, *Hromodendron*, *Schizophyllum*, *Trichoderma*, *Ulocladium*. The experiments were aimed to get the spectral signature for each investigated biodeteriogens by means of spectral tools only. To this end fluorescence was induced on (1) pure cultures at different age; (2) on spores and mycelium suspension in water and (3) on methanol extractions. Since the prepared samples come in different size and aspect, it was necessary to use more than one single instrument for local and remote spectral analysis, although the same kind of measurement, i.e. LIF, was performed.

To have the most complete conceivable spectrofluorimetric characterization of the samples under study, isolated strains were grown as pure culture in Petri capsules, then a water suspensions of spores and mycelium were put in a fused silica couvette for measurement. A time variable from few days to several weeks was needed to grow the cultures, then they were measures either locally in water suspensions or remotely by means of the hyperspectral LIF scanner. The time for preparation of water suspension was of the order of few minutes. In case of water suspensions the samples were excited with UV and VIS light, while the induced fluorescence was revealed with a PTI spectrofluorimeter. This instrument is equipped with two computer controlled monochromators allowing for selection of both the excitation and the emission wavelength: the excitation can be continuously selected in the range from 250 to 600nm, while emission is detected by a photomultiplier (Hamamatsu mod. R928) in the range from 250 to 900nm. Spectral resolution was selected by setting the monochromator's slit width to 5nm both for the excitation and the emission. To keep the acquisition time in the order of few minutes, the excitation wavelengths was limited to those few wavelengths having a real significance for practical application. Since the local experiments need to be replicated remotely with field transportable instrumentation based on a Nd:YAG laser working at third and fourth harmonic emission, the excitations for PTI spectrofluorimeter were set at 250nm, 300nm, 350nm and 400nm, while the induced fluorescence was acquired in the full usable spectral range from 250 to 700nm. The total time elapsed since the sample preparation to the end of the acquisition, was not more than 10 minutes; it was then supposed that no change in

Table 1 – First and second prominent emission band of the fungi strains under study for excitation with ultraviolet and visible light respectively at 250nm (second subheading), 300nm (second subheading), 350nm (third subheading).

Sample	Excitation wl 250nm		Excitation wl 300nm		Excitation wl 350nm	
	First prominent LIF emission band (nm)	Second prominent emission band (nm)	First prominent LIF emission band (nm)	Second prominent emission band (nm)	First prominent LIF emission band (nm)	Second prominent emission band (nm)
Alternaria		400	400		400	
Paecylomices	320	430	360	430-500	500	
Chaetomiumm	320	390	400	420	450	500
Cladosporium	320		400	420		
Hromodendron	320	420	400		420	500
Schizophyllum	330		400			
Trichoderma	320	450	450		450	
Ulocladium	300	400	390		420	

spectral feature is expected due to deterioration of water suspended mycelium and spores.

Additionally several fragments of fresco replicas were purposely prepared and used as a substrate on which grow micro organisms to simulate the situations effectively encountered in real scenarios; the resulting samples were excited with UV light while the induced fluorescence was revealed with the ENEA scanning hyperspectral LIF formerly developed; this instrument is described in detail by Colao et al. [2] and in the references therein cited.

3. Results

Main results are summarized in Table 1, where prominent peaks and/or fluorescence emission bands are reported for fungi strains under study and for some of the excitation wavelengths. It is possible to notice a strong UV protein-like fluorescence with maximum at 310-330 nm for all samples, with excitation at 250 nm, although simple phenols can contribute to this band as well. It is worth to notice the exception of *Alternaria* strain surprisingly not having any distinctive emission band in the region of protein–like bands. A second band having blue fluorescence is found around at 400-450 nm; maximum position varies from sample to sample, possibly because it results from the contribution of several overlapping peaks and band occurring in the blue spectral region. Blue fluorescence was observed for all measured samples including those containing only spores, or mycelium only.

It is also interesting to nothe that 300nm and 350nm excitation were no more able to excite the protein-like fluorescence, while apparently shifting the UV peak towards longer wavelengths around 400-420nm. In these cases green fluorescence with maximum at between 550 nm was observed mainly as a shoulder at the band of blue fluorescence. It was prevailing at excitation with wavelengths longer than 350 nm. In our experiments, none of the samples had any fluorescence peak within 600-650 nm spectral range.

From a quantitative point of view, some samples are more intensively fluorescent than others, while few ones have only a marginal fluorescence intensity when excited at 355 nm: this is probably due to several concurrent mechanisms contributing to quench the fluorescent emission, namely the absorption of excitation by the very outer superficial layers and the absorption of the fluorescence emitted by structures occurring hidden inner layers. In real situation the influence of substrate must also be taken in account, it might be shown that it is high in the UV/blue part of UV-excited spectrum and must be eliminated by appropriate instrument settings and also by suitable data processing on retrieved spectra[3].

For microorganisms detection the excitation at short wavelength, like 250nm and 266nm - both of them tested in the present experiment - is recommended because due to the higher excitation efficiency the resulting spectra are intense and show distinctive spectral features. Although the 355 nm can be used as well, its use results in a less efficient identification and discrimination capability. As the classification of organisms is concerned, the experimental findings suggest a suitable choice of the excitation wavelength, so that an appropriate data processing with optimal use of multivariate analysis tools, makes possible to distinguish among different strains also when using the remote scanning hyperspectral system.

4. Acknowledgement

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STABILISATION OF IRON GALL INK: AQUEOUS TREATMENT WITH MAGNESIUM PHYTATE

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1. Introduction

For several centuries, iron gall ink induced decay, referred to as ink corrosion, has been acknowledged as one of the major threats to the written cultural heritage.[1] The most effective aqueous stabilisation method developed to date is a so called "Calcium phytate" method, which involves inhibition of oxidative decay with complexing agent *myo*-inositol hexaphosphate (phytate) and subsequent deacidification using an aqueous solution of calcium bicarbonate. The use of phytate for stabilisation of iron gall inks was first proposed by Han Neevel in 1995.[2] Due to the use of highly alkaline sodium phytate, paper yellowing was observed. To overcome this, sodium hydroxide was replaced by calcium carbonate. As the solubility of calcium phytate is quite low at pH above 5, ammonia was added to raise the pH of the aqueous solution to the recommended 5.0-5.8.[3-5] While the treatment presents a significant advance in stabilisation of iron gall ink, there is still room for improvement, in view of which our present research focuses on the following:
- pH of the phytate solution has been set quite broadly (5.2–5.8),
- solubility of calcium phytate decreases as the pH approaches 5.8, which is demonstrated by its precipitation.
- it requires the use of aqueous solution of ammonia, which may cause severe burns, may irritate eyes, skin and respiratory system, poses danger of very serious side effects, including serious damage to eyes, may cause cancer etc. The objective of our research project is to offer an alternative phytate treatment, which would overcome some of the discussed shortcomings.

2. Experimental

Paper used in the study was Whatman paper no.1 (Maidstone, UK, 86.0 g m^{-2}, degree of polymerisation (DP): 2630 ± 20), concentration of Fe 0,191 ± 0,001 mmol g^{-1}_{paper}
Ink used in the study was produced by dissolving the following components in 0.1 L of deionised water: 3.14 g of gum arabic, 9.84 g of tannin (puro, Carlo Erba), 8.34 g of $FeSO_4 \times 7H_2O$ (Riedel-de Haën).

Selected ink was applied to the paper using a Roland DXY plotter, with the pen 0.6 mm in diameter at a speed of 3 cm s^{-1}. The papers containing the ink were pre-aged at 70 °C and 65% relative humidity for 24 h. After the treatment, the paper were exposed to 80 °C and 65% RH for up to 11 days.

Calcium phytate solution was prepared according to the ICN recipe.[6] To prepare magnesium phytate solution, 2.88 g of 40% phytic acid and 0.4 g (4.74 mmol) of Magnesium carbonate, basic (Fluka) was added to 1 L of deionised water. The mixture was stirred until the desired pH (4-6.5) of the solutions was reached, after which the solution was filtered.

The paper (3 g of paper per 1 L of solution) was immersed into the phytate solution for 15 min, after which it was deacidified by immersion into two consecutive baths of 0.01 mol L^{-1} $Ca(HCO_3)_2$ for 20 min. Deacidification using $Ca(HCO_3)_2$ was performed by immersing the sample into two consecutive baths containing 0.01 mol L^{-1} of $Ca(HCO_3)_2$ for 20 min (3 g of paper per 1 L of solution). Samples containing iron gall ink were then subjected to accelerated degradation at 80 °C and 65% RH in a Vötsch VC 0020 ageing oven (Vötsch Industrietechnik, Balingen-Frommern, DE).

The standard viscometric method was used (ISO 5351/1) to determine DP of the cellulosic fraction of paper. DP was calculated from intrinsic viscosity using the Mark-Houwink-Sakurada equation.[7]

3. Results

The results presented in Figure 1 demonstrate that the optimum pH of calcium and magnesium phytate solutions is between 5.8 and 6.0. Also, calcium and magnesium phytate solutions, when used in this pH interval, stabilise paper to a similar extent. While CaPhy treatment results in paper, which is 12 ± 2 times more stable than the untreated control, this factor of stabilisation is 12.8 ± 0.7 in case of MgPhy, demonstrating that there is no significant difference in their effectiveness.

4. Conclusion

The presented research demonstrates that magnesium phytate is equally effective in inhibiting ink corrosion as the traditionally used calcium phytate. However, when magnesium phytate is used, pH can be raised to the desired level using MgO or $MgCO_3$ without the use of ammonia, as magnesium phytate is soluble in the range of concentrations and pH values used in conservation. The step involving additions of harmful aqueous solution of ammonia is avoided. MgPhy, which is a solution, can be prepared as a stock solution in advance, while this is not advised in the case of CaPhy, which is a suspension and may form additional precipitate during storage. It is also demonstrated that pH of the magnesium phytate solution should be adjusted to 5.8-6.0, where the stabilising effects of treatment are optimal.

5. Acknowledgement

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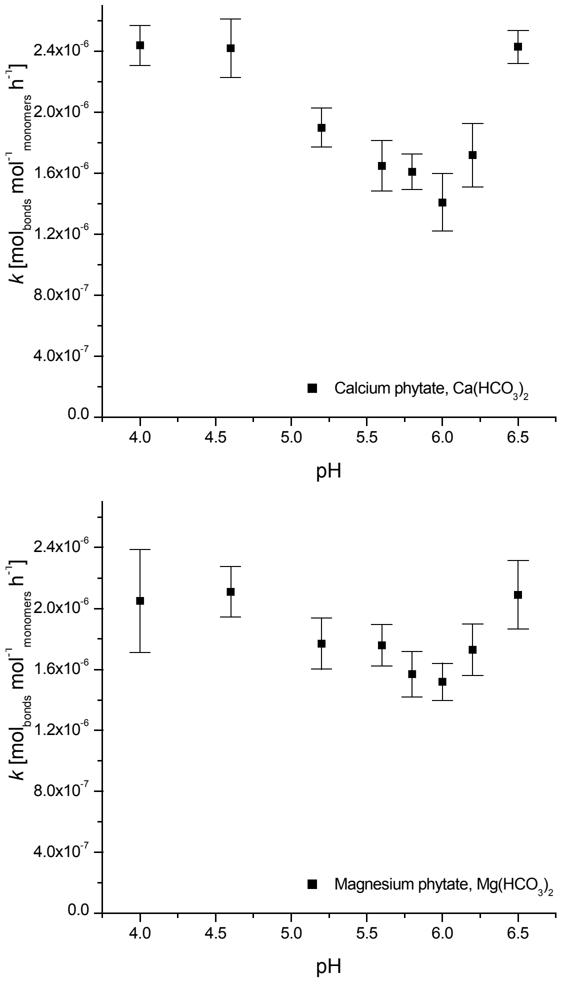

Figure 1: Rate constants of cellulose chain scission in Whatman paper containing iron gall ink, treated with solution of calcium (above) and magnesium (below) phytate and deacidified using calcium bicarbonate, at 80 ºC, 65% RH.

PAPERTECH: NEW POLYMERIC MATERIALS AND INNOVATIVE TECHNOLOGIES FOR PAPER CONSERVATION

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Abstract

At the current time, the research of materials and technologies to consolidate and preserve degraded paper artworks has not provided a final solution. Therefore the study of restoration methodologies suitable for paper artworks is deemed necessary. In the period 2004-2007 a European project entitled Papertech on the development of materials and methods expressly studied for paper conservation has been ongoing. The two main goals of this project are the development of new diagnostic techniques to evaluate the degradation level of the aged paper and developing innovative products and technologies for its conservation. In this paper attention is focused on the development of new polymeric materials and technologies for paper conservation. Two different approaches in particular have been followed: the first deals with the synthesis and the applications of waterborne polyurethane, and the second concerns the set-up of grafting polymerisation of acrylic monomers onto the cellulose chains.

1. Introduction

The world's libraries, archives and museums are faced with the immense problem of preserving countless documents, books, etc. damaged through the centuries. Paper artworks are complex materials consisting of an intricate web of cellulose fibres and, depending on their purpose, other components such as sizing, inorganic fillers, coatings, dyes, pigments, inks etc. Because of this intrinsic heterogeneity, studies on paper degradation and conservation require a broad and complex experimental investigation, including a multidisciplinary approach.

Several factors affect paper stability and mainly concern cellulose degradation, as the production processes (such as low pH values, presence of metal ions) and the environmental conditions (temperature, humidity, light, dust, presence of fungi and bacteria). Usually, four main degradative mechanisms occurring on paper artworks can be identified: acid hydrolysis, photodegradation, oxidation and biodeterioration.

It is well known that the traditional methods currently used for paper conservation consist of two phases: the deacidification and the manual mounting and consolidation of sheets and bookbindings. The use of polymeric materials for paper restoration is uncommon and only a small number of studies have been carried out until now, essentially only on the laboratory scale.[1] In a few cases, when the traditional restoration methods were not sufficient to improve the mechanical resistance of the degraded artworks, polymers have been applied, but the materials employed were commercial products, with properties not tailored for paper conservation. Therefore, their effect was limited only to a slight improvement of the mechanical resistance of the degraded artworks, without taking into account the drawbacks linked to low weathering resistance.

Taking these considerations as a starting point, the study of restoration methodologies suitable for paper artworks has been undertaken. The main goal of the European Union project Papertech (Sixth Framework Programme for Research, Technological Development and Demonstration, Innovative Materials and Technologies for the Conservation of Paper of Historical, Artistic and Archaeological Value (INCO-CT-2004-509095; July 2004–June 2007)) has been to develop innovative materials and technologies for paper conservation.

Within the framework of the project, two different approaches have been followed. The first one concerns graft polymerisation of acrylic monomers in the vapour phase onto the cellulose chains, to improve mechanical resistance and to induce water repellence in the paper. The second one is focused on the synthesis and application of waterborne polyurethanes: they seem suitable for paper given their good adhesion properties and the absence of any organic solvent in the formulation.

Among the various treatments used to improve the properties of natural fibres, synthesis of graft copolymers seems a suitable method to reduce the ageing phenomena of cellulose. The properties of the grafted copolymer can be tailored by means of the chemical structure of the monomers, the length of the grafted segment and the grafting level[2]. Graft polymerisation can induce chemical changes in cellulose, and the introduction of polymer chains can confer different structural characteristics to the raw material. In this way new cellulose-based products can be obtained with better mechanical properties than conventional cellulose. Graft copolymerisation of vinyl monomers onto cellulose has previously been investigated;[3,4] acrylic monomers appear particularly suitable because of their characteristics, such as water repellency, transparency and good film-forming ability. Grafting directly from the vapour phase onto cellulose results in enhanced mechanical resistance of the degraded paper, without altering the typical flexibility of cellulose and, importantly, no superficial coatings are formed on the grafted samples.

Previous studies showed that monomers such as methyl methacrylate (MMA) and ethyl acrylate (EA) were not suitable for cellulose based materials.[5] In the former case, due to the high glass transition temperature (T_g) of the grafted poly(methyl methacrylate) (PMMA) chains, the treated materials were brittle and stiff, while in the latter the samples were sticky due to the low T_g (-24 °C) of poly(ethyl acrylate) (PEA). Based on these results, the synthesis of new copolymers with characteristics suitable for cellulose consolidation was deemed necessary, along with further research into the graft polymerisation itself. In a previous paper a detailed investigation regarding the optimum acrylic copolymer for grafting onto cellulosics was reported[6]. An EA/MMA copolymer 75/25 wt%, because it has a T_g (10 °C) appropriate to the service temperature and it is resistant to biological attack, was selected.

In the present research, graft polymerisation of ethyl acrylate/methyl methacrylate 75/25 wt% onto the weathered model samples was performed. To initiate grafting, the creation of free radicals on the cellulose chain is necessary, and in this study polymerisation is induced by ultraviolet (UV) light. Because of its low energy, UV radiation offers advantages such as reduced degradation of the polymer backbone and better control over the process compared to other type of radiation, such as γ-rays or X-rays.

The grafting reaction requires photosensitive sites (carbonyl groups) on the cellulose in order to allow the formation of radical sites. These were formed by artificial ageing through reaction with a specific oxidising agent (sodium metaperiodate) or by accelerated ageing. In this way the glucoside units are oxidised to dialdehyde groups which then act as photosensitive agents. UV radiation transforms the carbonyl groups at these sites where radical polymerisation subsequently starts. It is evident that the amount of photosensitive sites formed on the cellulose chains depends on the type of ageing carried out on the samples.

In the framework of the Papertech project, the synthesis of waterborne polyurethanes (PU) has been also carried out, aiming to consolidate and protect the paper against degradation agents. Two series of waterborne polyurethanes have been employed, from ICAP-SIRA Industries, Milan (Italy): polyester-based and polycarbonate-based. Waterborne polyurethanes can be formulated into coatings and adhesives containing little or no co-solvent; they form films at ambient temperature and exhibit excellent adhesion to many surfaces. Films obtained from waterborne polyurethanes show high toughness, remarkable mechanical resistance and water repellency. By modulating these properties and choosing suitable reagents, it is possible to achieve a product able to consolidate and protect the paper.

2. Experimental

First, paper model samples to be used throughout the project were selected. In particular, some commercial papers were chosen:

- Whatman paper for chromatography (Carlo Erba, Italy), made only from pure cellulose, from cotton linters.
- Newsprint paper and paperboards (Murillo and Watercolour, Fabriano, Italy), made using cellulose from pulpwood and containing significant amount of fillers (5–10%), essentially calcium carbonate and kaolin[7].

Also some naturally aged paper samples (Austrian book 1903, L'Illustrazione Italiana 1919, Rivista di Diritto Commerciale 1942) with different provenience, age and composition were selected to have the possibility to investigate the effect of the natural weathering at various level of degradation. All these printed samples present evident traces of photodegradation and oxidation (yellowing and browning), due both to the additives used in the production (inks, sizing, fillers, etc.) and to the storage conditions.

In order to simulate the natural ageing of paper artworks, different types of artificial weathering have been performed: oven, climatic chamber, accelerated light ageing and chemical oxidation with sodium metaperiodate. The difficulty of using short-term experiments to simulate long-term behaviour is well known, as are problems due to natural ageing. The conditions chosen for each ageing method are as follows:

- In an oven at 100 °C for 500 h in the dark.
- In a climatic chamber Angelantoni Challenge 250 E at 60 °C (RH 70%) for 500 h, under ultraviolet light (150 W/m^2).
- In an accelerated light ageing unit Angelantoni SB3000E at 65 °C (RH 25%) for 500 h, under a xenon arc lamp (1000 W/m^2).

Chemical oxidation with sodium metaperiodate ($NaIO_4$). The ratio sample/solution was retained for all experiments as 1 g of sample for 100 ml of water. The samples were mixed in a closed vessel with the 0.1 M metaperiodate solution and the mixture was stirred gently at room temperature in the dark for two hours. At the end of the oxidation process the samples were filtered, washed with deionised water up to neutral conditions (pH 7) and dried. Oxidation leads to the cleavage of the C2-C3 bond in the glucoside ring of cellulose and the transformation of the hydroxyl groups into aldehyde groups. These latter are the active sites in which the graft polymerisation of acrylic monomers starts[8].

Two series of commercial waterbornes coming from ICAP-SIRA Industries, Milano (Italy) have been considered for the consolidating treatments: polyester based (PES 954, PES 995, PES 990) and polycarbonate based (PC 954, PC 990, PC 982) polyurethanes. Their application has been performed by brushing on Whatman paper, newsprint paper and an Austrian book after dilution (1:4) with water at 25 °C.

During the starting of grafting polymerisation, monomers are in the vapour phase; moreover, no any solvent is required. Both these factors are essential, looking at the possibility to apply grafting polymerisation for consolidating inked and/or dyed papers, since, working in absence of any solvent and with gaseous monomers, any alterations in the objects is avoided.

Experimentally, first at all, the paper is swollen in deionised water for 10 min to open up the fibrous structure of cellulose and encourage the homogeneous uptake of monomers during grafting.[1,2,5,8,9] The wet sample is placed in the reaction vessel, which is evacuated for a short time (5 min) so that the paper is still damp. The reached pressure is sufficient to ensure the complete vaporisation of the monomers. Then the liquid monomers mixture EA/MMA 75/25 wt% is loaded in the monomer storage place, and after the opening of the membrane valve is vaporised and diffuses into the reactor. Subsequently the UV lamp is switched on, with the cooling system running. The polymerisation is stopped after the chosen time by stopping the illumination and by bringing the reactor up to room pressure. The non-reacted monomer that can be remain on the sample surface is removed by washing with a mixture methanol-water (30/70 vol.), a good solvent for acrylic monomers but not for the corresponding polymers. After, the sample, containing grafted cellulose and homopolymer, is washed and brought up to constant weight. The drawback of the graft polymerisation is the simultaneous and inevitable formation of homopolymer, removed from the grafted material by extraction with acetone for 72 h at room temperature.

3. Results

The amount of applied waterborne polyurethane on both Whatman paper and Austrian book was 7-10 %; in the case of newsprint paper, being this support very thin, a dilution of 1:6 has been necessary to achieve a good aesthetical effect, with amount of coated PU equal to 10-12%. Looking at the final appearance and handling of treated papers, it has been possible to decide that PC 954 and PES 995 were the most suitable waterborne polyurethanes to be used for paper conservation.

The first step in the study of the grafting process has been the set up of the best work conditions for the reactor, from the point of view of the reaction time and the monomer/cellulose ratio employed in each experiment. It is important to note that it is not necessary to reach elevated grafting yields, because if too much grafted polymer is present in the paper, it loses its typical flexibility and handling. Therefore, the choice of the best grafting conditions is essential in order to obtain grafting yields that ensure the improvement of the mechanical resistance, without modify the typical characteristics of paper. From the experimental work, the best conditions to graft EA/MMA 75/25 on samples of oxidised Whatman paper[8] with small dimension (10x10 cm) are:

- monomer/cellulose ratio: 8,
- reaction time: 30 min.

In this case the grafting yield is 42% with a percentage of formed homopolymer equal to 27%.

Once the grafting reaction has been set up on small samples of Whatman paper, experiments on bigger specimens became essential, looking at the future application of the method on documents coming from books, journals, magazines, etc. The A4 format has been chosen for all the artificially aged model samples, because in this way the sample holder could be completely covered. Some experiments have been carried out to determine the monomer/cellulose ratio ensuring a good compromise from the point of view of working conditions and the resulting grafting yields; finally a ratio of 4 has been identified as the best one.

Results indicated that EA/MMA 75/25 wt% copolymer can be successfully employed in a grafting reaction onto artificial aged model papers and also on naturally weathered samples. It is important point out that the grafting process does not modify the aspect of paper and this is one of the main aspects for a future application of this method for the restoration of artworks with historical and artistic interest. Results collected on the oxidised model paper show the grafting percentages decrease in the presence of fillers because these additives interfere with the polymerisation process. In newsprint paper and in the paperboards the percentage of cellulose is less than in the Whatman paper, made by pure cellulose. Thus, fewer sites on the cellulose matrix are available for the grating reaction and the yields noticeably drop, in function of the amount of fillers (Table 1). Also the adhesive added during the paperboards preparation[2,7] interferes with the grafting process at an extent greater than the fillers. Finally, it is worth to note that no grating occurred on papyrus, probably due to its particular morphology[9].

Once the new materials and technologies have been set up, the evaluation of their efficacy in the preservation of writing materials became essential in order to establish if the grafting polymerisation and/or the coating with waterborne polyurethanes could prolong their life time. Several tests have been carried out to assess both the consolidating and the protective effects of both the treatments, also when the writing materials have been submitted to the degradative effects of enzymes.

From the point of view of the mechanical characterisation, the stress-strain behaviour of original, oxidised and grafted Whatman paper has been measured by tensile deformation; all samples have been tested to breaking, in order to evaluate the effect of grafting polymerisation of the mechanical resistance of paper. In table 2 the values of the maximum load and of the elongation % for the original, oxidised and grafted Whatman are collected. Oxidised Whatman exhibits a reduction in both the load and the elongation at break. By grafting with EA/MMA, the sample becomes more flexible, as evidenced by the elongation at break value. Therefore, the grafting process induced a recovery in the mechanical resistance of the aged paper, particularly elongation at break which increased up to values meaningful from the point of view of the mechanical behaviour. EA/MMA 75/25 is a rubber-like amorphous copolymer; therefore its choice for grafting polymerisation has been suitable, in that the paper retain its typical flexibility after the treatment.

Regarding the efficacy, grafting polymerisation seemed to impart a good compromise between consolidating and protective action, without induce relevant variation in the aspect and handling of paper. Moreover, this methodology must be preferred to the coating with waterborne polyurethanes, because any contact of paper sheets with liquid products is avoided, excluding possible damages of paper itself. For what concerns durability, both acrylics and polyurethanes showed a low stability when submitted to accelerate ageing by temperature, moisture and light. Therefore, looking at both the efficacy and the durability of the investigated conservative treatments, grafting polymerisation appears as the most promising method to be applied in paper conservation. Clearly, modifications and improvements concerning the nature of grafted polymers and the experimental conditions will be needed to allow the experimentation of this technology on real paper artworks.

Table 1: Summary of the grafting yields for the oxidised model samples and the naturally aged papers reached after 50 min of polymerisation.

Sample	Grafting Yield (%)
Papyrus	-
Whatman	87
Murillo	2
Watercolour	15
Paper for Conservation	9
Newsprint paper	4.5
Austrian book (1903)	13
“L’Illustrazione Italiana” (1919)	2
“Rivista di Diritto Comm.” (1942)	4

Table 2: Values of Gurley porosity and mechanical parameters for Whatman paper before and after grafting polymerisation.

Sample	Gurley Porosity (seconds)	Load at break (N/m2)	Elongation at break (%)
Original	1.63 (SD = 0.26)	2.38 ± 0.5	2.0 ± 0.3
Oxidised	1.54 (SD = 0.19)	2.02 ± 0.4	1.7 ± 0.1
Grafted	0.57 (SD = 0.13)	1.30 ± 0.2	2.3 ± 0.6

An enzymatic attack has been carried out onto the consolidated writing materials to evaluate the efficiency of both grafting and coating treatments in preventing the biological degradation. All the coating materials led to a decrease of the biodegradability of the consolidate papers; particularly, the treatments giving the strongest paper protection are the coatings with PES 995 and PC 954. Grafting of EA/MMA copolymer onto cellulose gave to the paper a very good protective action against the enzymatic attack.

4. Conclusions

To summarise, the main conclusions concerning the study on innovative materials and technologies for paper are:

Both grafting polymerisation and the coating with waterborne polyurethanes showed a consolidating and protective effect onto writing materials, in different extent, depending on the paper grade and composition and on the conservation state.

Acrylics showed a better efficacy, durability and resistance to the enzymatic attack in respect to polyurethanes.

Considering the coating treatment with diluted solutions of PU, the best treatments appeared to be those with PES 995 and PC 954.

Grafting polymerisation of EA/MMA onto cellulose can be considered as the most promising and suitable method for paper consolidation and protection.

5. Acknowledgement

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USE OF PAPER MATS PREPARED FROM THE AROMAS OF NEEM AND NEGUNDO LEAVES IN PRESERVATION OF ARCHIVAL AND LIBRARY MATERIALS

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Abstract
Use of the dried leaves of Neem (*Azadiracta indica*) and Negundo, (*Vitex negundo*) for protecting valuable textiles, books and manuscripts is still being prevalent in India but this practice cannot be applied to art works because of their staining property in the presence of moisture. Therefore, the attempts are made here to develop suitable method to use neem and negundo leaves for preserving artworks. Volatile fractions (aromas) from the leaves were extracted using Clevenger apparatus. The extracts in alcohol were fixed on paper mats , prepared in the laboratory from the handmade paper pulp adding appropriate quantity of aroma-fixers; sodium stearate, sodium lauryl sulphate and zeolites. Fungal inhibition activities of these aroma laden paper mats was assessed following standard methods against 14 fungal strains, commonly occurring in museums. Aroma retaining property and insect repellency of the mats were tested by the method devised in the laboratory. It is concluded that the developed paper mats from the aromas of Neem and Negundo leaves are natural, non-toxic, easily prepared in the laboratory, cost effective which could be safely kept inside the storage and display cases to prevent the library and archival from biodeterioration.

1. Introduction

Despite of rapid growth in science and technology, many conservation problems relating to cultural heritage have no solutions. This led us to look back at our traditions, where peoples were successfully preserving their heritage. India is known for its rich traditions and culture in rural India, people still use dried neem leaves to protect textiles, books and also to preserve food grains. Agrawal[1] narrated an interesting episode that on opening the sealed huge crate in the personal collection of the Maharaja of Jaipur found full of dry Neem leaves and very beautiful, intact woollen Mughal carpet, about 150 year old, was found inside the Neem leaves. Senior author of this paper has seen many folk objects kept covered with Neem twigs in the tailor made baskets in Janpadaloka, Ramnagaram, Bangalore. The sun dried leaves of *Vitex negundo* is reported to be inserted between bundles of palm leaf manuscripts to prevent them from insects.[4] Burning the leaves of this shrub to keep away mosquitoes from houses has been found common in south India.[5] There is not much research available on the elucidation of these traditional practices but, many plants have been investigated to understand their biochemistry and use them as medicine, pesticides etc. To mention some like, recent doctoral thesis of Farhana Afsana, Karachi University in 2002 where he isolated and identified 19 pure constituents from Neem leaf extract and studied their insecticidal activities against deadly mosquitoes.[6] Thirty six components in volatile fraction from the leaves of Negundo grown in DeharaDun were identified using gas chromatography and mass spectrometry.[7] Many plant materials like Neem, Karanja, Negundo, citronella, tobacco five-leaved-chaste tree (*Vitex Incisa*), are reported for their germicidal properties and insect repellency.[3,11,12,14,15] Similarly, Neem wood, Coconut kernel, and turmeric paste are also reported to have insecticidal and antifungal properties.[8,9,10,13,16,17] Herbal pesticides are preferred now a days over synthetic ones and are in great demand because of their eco-friendly, non toxic and degradable nature. Considering good values of herbal products, it is thought of using them in the preservation of cultural property. Since, plant leaves cannot be used in art preservation as they stain the object on contact in moist condition; there is a need to devise appropriate methods. Therefore, the present study is planned to use Neem and Negundo leaves for preserving manuscripts, archival and library materials.

2. Materials

Leaves of Neem tree (*Azadiracta indica*, English-neem tree, margosa tree, Indian lilac, Hindi-Nim, Nimb, Kannada-turakabevu, huccabevu, chikkabevu , Malayalam-veppu,aryaveppu, aruveppu, kaippanveppu Sanskrit-nimbah, prabhadrah, Tamil-vempu,veppuvepa, Telugu-kondavepa,turaka, Marathi-kadunimb) collected from the wild trees grown in the campus of our laboratory.

Leaves of Negundo shrub (*Vitex negundo*, Verbenaceae fam., Eng- five –leaved chaste tree, Hindi-nisinda, sambhalu, nirgandi, Kannada-niragundi, lakkigida, nekka, nekkilu, Malayalam-karonocci, Tamil-nirkundi, nallanocci, Telugu-nallavavili, vavili, tellvavili) were collected by Manjunath, researcher from the hedge on the lake at his village Shivganga, Chitradurga district, Karnataka.

Aroma fixers – (a) Zeolites (Greek, zein, "to boil"; lithos, "a stone") are minerals, naturally occurring in the sedimentary and volcanic rocks and clay deposits that have a micro-porous structure. They are basically hydrated alumino-silicate minerals. Zeolite Nax /fau, supplied bey Ranbaxy fine chemicals limited, New Delhi-110020 was used in this study. (b) Sodium Stearate, sodium salt of stearic acid, chemical formula $C_{17}H_{35}$-COONa, a white powder, gives soapy feel, slight tallow like odour, slowly soluble in cold water, freely soluble in the hot solvents, commonly called as soap. It is used as surfactant emulsifying and stiffening agent. Supplied by S.V. Enterprises, Mumbai-400009. (C) Sodium Lauryl sulphate (SLS), $CH_3(CH_2)_{11}OSO_3Na$, prepared by sulfation of lauryl alcohol, common surfactant which has an amphiphilic properties due to C12 chain (lipophilic) attached to a sulfate group (hydrophilic). This bifunctionality in one molecule provides the basic properties useful in cleaners and detergents. SLS is used as a wetting agent in textiles, foaming and cleaning agent in detergent, cosmetic emulsifier, and sometimes in toothpastes and also used to trap volatile oily fractions because it binds to oily particles (supplied by NICE Chemicals Pvt. Ltd. Cochin-682024).

Handmade paper (Kalamkush, Gandhi ashram, Ahamedabad), Perspex Sheet, a common brand name of polymethylmethaacrylate (PMMA), acrylic polymer supplied by Bangalore.

3. Experimental

Aroma extraction from the leaves

Collected green leaves of Neem and Negundo were allowed to dry in shade at room and then 500g leaves of each plants were taken in 1L round bottom flasks and separately steam- distilled using Clevenger apparatus continuously for 4-5 h at low temperature. The obtained aliquots were extracted with cyclohexane then further extracted in alcohol. The extracts in alcohols were stored in sealed vials in refrigerator prior to use.

Preparation of paper mats

Shredded handmade paper (100g) soaked in distilled water overnight, then transferred into electric blender and after adding 20% w/w of paper weight aroma fixers ; sodium stearate, sodium lauryl sulphate and zeolite , the mixture was blended to form homogenous slurry . The slurry was then poured in the die, designed and fabricated in the laboratory using Perspex sheet and nylon net, and pressed to drain out all the water. The cast paper sheet was dried at room temperature, cut in to small mats of 2x3 cm and activated in oven at about 100 ºC for 5-6 h before use.

Impregnating aromas into the paper mats

Activated paper mats were allowed to soak in alcoholic aroma extracts of Neem and Nirgundi leaves for 1hr and then taken out, dried again dipped in the aroma solution and the process was repeated thrice to ensure proper impregnation of aromas in the paper mats.

Figure 1: above: Clevenger apparatus for extracting aroma from Neem and Negundo leaves, middle: aroma extracted in ethanol, below: preparation of paper mats.

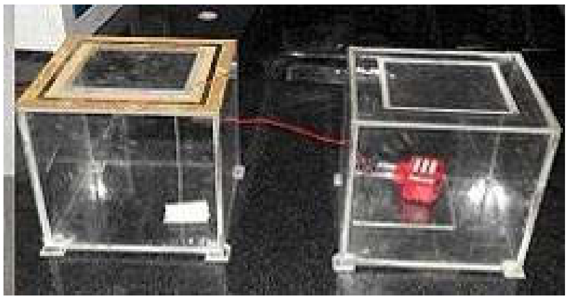

Figure 2: Device made from Perspex (acrylic) sheet used for testing aroma retaining capacity, insect repellent property and insect mortality of paper mats.

4. Aroma Retention Test

To determine aroma retaining capacity, the developed paper mats were placed in two separate chambers customised for the test and made from Perspex sheet (Polymethylmethacrylate) in one at room temperature and in another on the liquid vaporiser Figure 2. Both the chambers were then sealed properly. Aromas of the mats were detected at regular interval of time by smelling using the panel of three observers through the small window provided on top of the chambers.

Table 1: Antifungal activity of paper mats impregnated with essential oils from extracted from plants (*A. indica* & *V. negundo*).

Fungal strain	*Azadirachta indica* (Neem)			*Vitex negundo* (Nirgundi)		
	Sodium lauryl sulfate	Zeolite	Sodium stearate	Sodium lauryl sulfate	Zeolite	Sodium stearate
A.flavus	(+)	(++)	(+)	(++)	(+ +)	(+)
R.oligiospor-ous	(++)	(+++)	(++)	(++)	(+++)	(++)
A.parasiticus	(++)	(++)	(++)	(++)	(+)	(+)
A.nidulans	(+)	(++)	(++)	(++)	(++)	(++)
A.fumigatus	(+)	(+)	(+)	(+)	(+)	(+)
F.solani	(++)	(+++)	(++)	(++)	(+++)	(+)
F.moniliforme	(++)	(+++)	(++)	(+)	(+++)	(+)
A.niger	(+)	(++)	(+)	(++)	(+)	(+)
A.versicolor	(+)	(+)	(+)	(+)	(+)	(+)
P.oxalicum	(+)	(++)	(+)	(++)	(++)	(+)
P.chrysogenu m	(++)	(++)	(+)	(++)	(++)	(++)
P.digitatum	(++)	(++)	(++)	(+)	(++)	(+)
N.crassa	(+)	(+)	(+)	(+)	(+)	(+)
T.viride	(+)	(++)	(++)	(+)	(+)	(+)

+ less inhibition
++ good inhibition
+++ very good inhibition

5. Evaluation of antifungal activity

Strains

Fungal strains were isolated from paper materials, using sterilized cotton swabs and were then inoculated into a potato dextrose agar medium. The pure culture was obtained by subsequent culturing and identified by cultural and microscopic characterization. The identified strains (*A. niger, A. flavus, A. nidulans, A. versicolor, A. fumigatus, R. oligosporus, P. chrysogenum, P. oxalicum, F. solani, T. viride, N. crassa, A. parasiticus, F. moniliforme, P. Digitatum*) were maintained by subculturing on a Czepek-Dox agar medium.

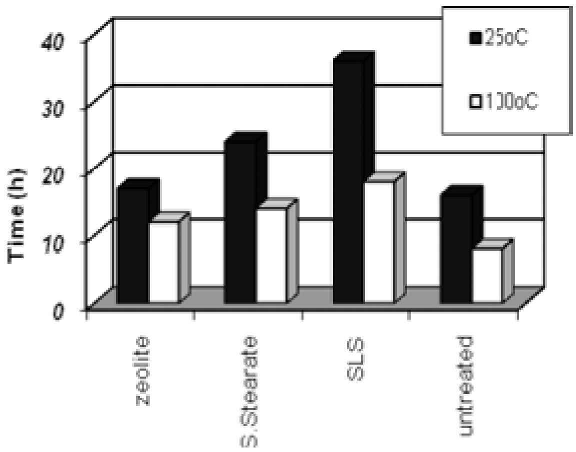

Figure 3: Bar graph showing aroma retaining property of paper mats prepared using different aroma fixers, zeolite, sodium stearate and sodium lauryl sulphate(SLS) .

Antifungal activity

The method developed by Wilson for testing the antifungal property of essential oils was used here with some modification.[18] The prepared spore suspensions (spore count was adjusted to 2×10^5 CFU/mL using haemocytometer) 100 µl was placed in well, row of 96 multi -well microtitration UV sterilized plates. The paper mats (8 mm) prepared with fixers impregnated with 50 µl aroma placed over the well surface of multi-well plates. Wells were then covered with sanitized paper (at 55 ºC for 3 h in oven).The lid of the plate was then attached, and tightly sealed with cellophane tape to hold the lid in place. Simultaneously spore suspension 10 µl was placed on sterilized Sabouraud- dextrose agar surface and distributed over the surface with sterile bent glass rod and placed in incubator at 24 ºC and observed after 24 and 40 h as control. The inoculated multi-well plates provided with same environment and observed after described time periods. After a 40 h incubation period the 10 µl spore suspension from well re-inoculated on the surface of solid agar surface and observed for growth inhibition, Figs. 4 and 5.

Insect repellency and mortality tests

Silverfish (*Lepisma saccharina*), primitive wingless insects and booklice, (*Liposcelis corredens*) heymons, commonly found in libraries and other places where books, documents, and papers are stored used as test organisms for the assay.[19-22] The test chamber similar to described by Sheng-Yang Wang and et al.[19] was fabricated in the laboratory with transparent Perspex sheets were used for testing mortality of selected insects. Neem and Negundo aroma impregnated mats were kept in the two separate chambers, in one at room temperature and in other on the liquid vaporiser along with the reared insects in open Petri dishes. The repellence and mortality of the insects kept inside the test chambers were observed at regular intervals (Figure 2).

Figure 4: Method for testing antifungal activity of aroma impregnated paper mats.

6. Results and Discussion

The yield of the aromas from neem and negundo leaves extracted by the method, standardised in the laboratory, was very good, up to 1% which is in good agreement with the reported data. Zeolites were selected in our study because many researchers have applied them for different purposes. Zeolite because of its excellent adsorption property commonly used as builder in European detergent formulations.[23]

Figure 5: Petri plates showing fungal growth inhibition in plates containing treated spore suspension as compare to control.

Adsorption and diffusive properties of Zeolites with reference to the mixture of linear and branched alkanes have been studied in a PhD project at the University of Amsterdam. Hydrophobic Y-type zeolite has reported very effective for adsorbing vapours of organic solvents like benzene, toluene, dichloromethane and 1,1-dichloro-1-fluoroethane,[24] Zeolites are used as carriers of perfume agents in detergents wherein the perfume is sorbed onto carrier particles which release at least 60% w/w/ of the perfume in the Perfume Release Test and which are inert as defined by the Perfume Stability Test. Indian scientists have synthesised detergent grade Zeolite from Indian clay.[25] In addition to zeolites , sodium lauryl sulphate and sodium stearate, known as very good surface active agents and commonly used in detergent formulations, were also experimented for fixing aromas in paper mats. Aroma retention capacity of paper mats impregnated with Neem and Negundo aromas was presented in the Figure 3, which confirmed that the paper mat without fixer released the aromas quickly as compared to the mats with aroma fixers – zeolite, sodium lauryl sulphate and sodium stearate. Among three fixers, highest aroma retention capacity up to 36 h at room temperature and 17 h when heated in electric liquid vaporiser was observed in the paper mats with sodium lauryl sulphate fixer. Table 1 showing the results of fungal inhibition activity of Neem and Negundo aromas impregnated paper mats tested against 14 fungal strains, commonly occurring in museums indicated that the aromas impregnated paper mats with zeolite exhibited very good antifungal activity against all fungi as compared to other paper mats containing sodium stearate and sodium lauryl sulphate. The probable reason could be that the aroma molecules are just adsorbed in zeolites whereas they are chemically bonded with sodium stearate and sodium lauryl sulphate. Obviously, the chemically bonded aromas compared to adsorbed one take longer time to release from the paper mats and that time lag allows the fungus growth during antifungal activity test. Insect repelling and insecticidal property of the mats was tested against silverfish and booklice using the same device which was used for testing aroma retaining property for aroma retaining property. Apart from very good insect repellence, 100% insect mortality with respect to silverfish and booklice was observed.

7. Conclusion

The paper mats prepared by fixing the aromas of Neem and Negundo leaves with zeolites found very effective in controlling the growth of the 14 fungal strains commonly occurring in paper art materials. These paper mats also showed good insecticidal and insect repellent activity against Silverfishes (*Lapisma saccharina*) and book lice (*Liposcelis corredens*). The developed paper mats are eco-friendly and non-toxic to human beings and found very easy to use in museum showcases and even in small size storage rooms. In order to transfer this development to the beneficiaries, thorough laboratory and field trials are undergoing.

8. Acknowledgments
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HIGH-THROUGHPUT AND *IN SITU* X-RAY ABSORPTION SPECTROSCOPY OF PIGMENT LIBRARIES

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1. Introduction

The ability to investigate effects of environmental conditions on the molecular structure of pigments during storage and display of artworks can provide the scientific insight needed to minimise the deterioration of artworks during long-term display. We have recently begun an explorative programme of measurements that examine the possibilities and limitations of environmental X-ray absorption spectroscopy (XAS) in (i) determining structural and chemical changes in pigments under controlled environmental conditions, and (ii) to obtain such information for libraries of pigment samples non-destructively and efficiently.

XAS is based on the use of tuneable X-rays from a synchrotron radiations source. It provides information on both the chemical state (or, more precisely, the electronic structure of the X-ray absorbing atoms) through the X-ray absorption near-edge structure (XANES) region of the spectra and the local molecular-level structure of samples, without any requirement of long range order (which sets it apart from commonly used structural determinations based on X-ray diffraction) through the extended X-ray absorption fine-structure (EXAFS) region. Detection of the yields of emitted electrons and fluorescent photons permits to carry out these absorption measurements non-destructively and with samples areas below 1 mm^2.

2. Experimental

Experiments were performed at beamlines 9.3 of the Synchrotron Radiation Source (SRS) in Daresbury, UK and at beamline I18 of DIAMOND Light Source (DLS), UK. We commissioned an environmental gas-flow cell with □m-positioning precision, incorporating a large window for combined fluorescence-yield and transmission XAS studies, an internal total electron-yield detector, an exchangeable sample stub system for mounting and exchanging small paper samples (size less than 1 mm^2), and a UV/Vis light source coupled fibre-optically into the cell for fading studies. An overview over the experimental setup is given in Figure 1. The sample stub system is illustrated in Figure 2.

3. Results

For our commissioning experiments we chose to investigate a range of historic Prussian Blue (PB) pigments (chemical formula approximately $Fe_4[Fe(CN)_6]_3{\bullet}xH_2O$, with x = 14-16, but usually with considerable levels of dopants such as K^+ and NH_4^+). They are one of the best-known examples of a pigment that has been observed to fade under anoxic conditions.[1-4] Over a period of several months, some 19th century Prussian Blue pigments have been observed to gradually turn white, and it has been suggested that the underlying cause may be a reduction of Fe(III) to Fe(II), resulting in pigments similar to 'Berlin white', $(NH_4)_2Fe_2[Fe(CN)_6]$ or Everitt's salt, $K_2Fe_2[Fe(CN)_6]$.[5,6] We investigated particularly the fading of original Prussian blue pigment from Turner's studio (dating from the time of his death in 1851) under control of the environmental conditions. The pigment was applied to paper as a dilute watercolour suspension/solution. Specially commissioned paper made using a historic recipe was used. By microfocus XAS at the Fe K-edge we followed the fading process in ambient air, in dry N_2 and in dry He.

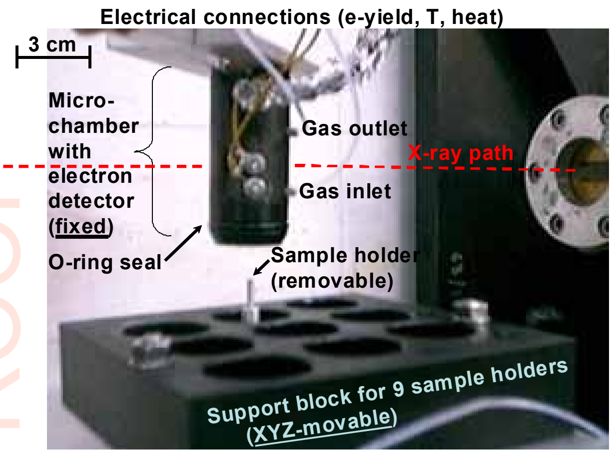

Figure 1: Apparatus for automated environmental XAS of small samples by total electron-yield detection.

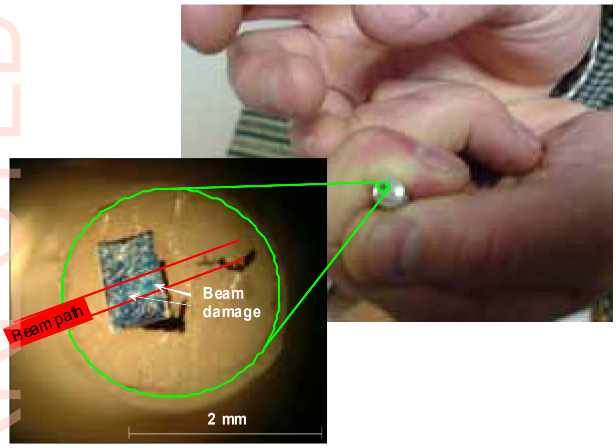

Figure 2: Sample stub system used for mounting small samples in the apparatus described in Figure 1.

Particular attention during these initial studies was paid to investigating beam damage effects, to be able to separate XANES and EXAFS changes due to the fading process with UV/visible light from X-ray induced degradation of the samples. Generally we found that exposure to X-rays had to be minimised and that for every fading step a different region of the sample had to be investigated. Figure 3 summarises representatively (i) the effects of beam damage on the XANES (spectrum with filled circles) and (ii) the effect of UV/Vis fading, with the unfaded sample represented by the spectrum plotted with open dots, and the faded sample spectra represented by thin full lines. Note that the energy scale is uncalibrated.

It can be seen that X-ray-induced degradation has three major effects on the sample: first, it leads to a strong reduction in the intensity of the white line feature at 7132 eV; second, it has a marked effect on the EXAFS region, indicating severe structural degradation; third, it leads to a strong reduction of the near-edge shoulder at 7122 eV, while the intensity of the quadrupole-allowed multiplet of s-d-transitions around 7117 eV remains unaffected (see inset of the Figure).

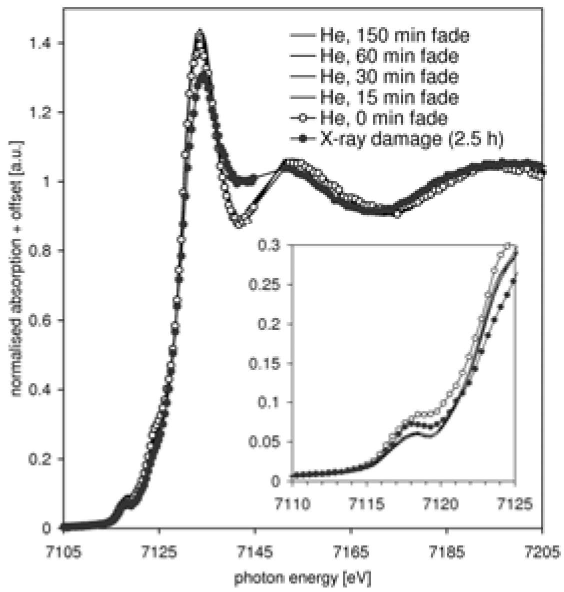

Figure 3: Fe K-edge XANES of a historic Prussian Blue faded by exposure to UV/Vis light in a He atmosphere.

In contrast, the EXAFS and white line regions of the UV/Vis-faded samples are barely affected, while the s-d-transitions are strongly reduced and the near-edge shoulder essentially retains its intensity. Most significant about these observations is the fact that any fading-related spectral changes appear to be confined to rather subtle changes in the electronic structure of the Fe centres, and not to a redox process or structural rearrangement. An explanation for this may be that water can be absorbed reversibly by Prussian Blue structures, resulting in a thermochromic effect wherein the divalent transition metal centres are affected by the nature of the intercalated hydrated counteraction and the amount of structural water in their local environment.[7] We are currently investigating this rather intriguing possibility further through additional laboratory work.

4. Conclusion

We have commissioned an apparatus for *in situ* XAS microanalysis under control of environmental conditions. Use of a newly designed sample stub system and in combination with the use of fluorescence and electron-yield detection modes permits non-destructive microanalysis with rapid sample changeover. Initial results obtained for Prussian Blue pigments indicate that the technique can provides information on subtle crystallographic and electronic structure changes, if the effects of X-ray beam damage on the samples can be minimised.

5. Acknowledgement

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THE MONITORING OF INDOOR MUSEUM ENVIRONMENTS AND THE IMPACT OF THEIR CORROSIVITY ON COMPLEX ORGANIC MATERIALS

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The monitoring of indoor museum environments was performed using dosimeters based on the quartz crystal microbalance principle and developed within 3 EC-funded projects MIMIC (EVKV-CT-2002-00040), SENSORGAN (022695) and PROPAINT (SSP-CT-2007-044254). Initially in the MIMIC project, arrays of varnish coated piezoelectric quartz crystals (PQC) were exposed in holders close to painted works of art in museums, historical houses, and castles in Northern and Southern European locations where the microclimate was monitored for periods of over a year in terms of RH,T, light, and externally generated pollutants.[1] The piezoelectric quartz crystals (PQC) were coated with either artists' varnish (resin mastic) or egg tempera medium. The rationale for selection of these coatings is described elsewhere.[2] These coatings had been previously characterised and chemical markers had been identified which were found to change with accelerated ageing in a systematic manner and there was some correlation with crystal frequency values. The principle of operation of the PQC crystals is that their oscillation frequency depends on the mass of the coating, as related by the Sauerbrey equation.[1] During the MIMIC project crystals were exposed as passive samplers in small holders containing eight crystals, and then continuous monitoring modules were prepared. These were of the order of 20 cmsx 10 cms, incorporated an array of 8 crystals, and required a power supply. Monitoring was selected for given time period and the module could be left recording for extended periods. Examples of continuous exposure were provided by locations in the Petrie Museum, London, National Trust properties (Osterley Manor, London) and Charlottenborg Castle,Denmark. Damage assessment was based on the frequency shift of crystals and related to values obtained from accelerated ageing tests using light and NO_2. Analysis of the surface chemical changes was performed by X-ray Photoelectron Spectroscopy.

Within the SENSORGAN and PROPAINT projects the crystal holder was adapted for use within the restricted environment of organ pipes[1]and microclimate frames containing paintings[2]. The holders also included modified electronic circuitry controlled by dedicated software programme. The aim in both projects was to detect volatile organic acids (VOCs) in these enclosures. The organic acids, predominantly acetic acid, are generated in the windchest, typically made of oak or pine wood, and they corrode the lead pipes. In the COLLAPSE project, heavily corroded pipes of 96% lead content were observed in the St Jakobi church (Lübeck,Germany).[3] Lead was deposited by thermal evaporation on the crystals and these were exposed together with lead coupons in the modified holders. Where dosimetry is applied it is preferable that the material should react faster than the objects in the collection which is monitored, thus being able to give an early warning. Recently it has been shown that by exposing lead coupons it is possible to distinguish between and rank the environments of museum storage rooms and archives with regard to overall corrosivity.[4]

In SENSORGAN accelerated ageing studies of lead coated crystals were performed using the continuous monitoring modules developed in the MIMIC project and then the small holders. Results showed that where values for RH exceeded 60% and acetic acid levels were of the order of 900 ppb the response was fast, and where levels of RH were low (20-30%) and acetic acid levels were << 900 ppb then the response was much slower. Evidence of this was found from exposures at sites with varying conditions.Within the organ pipes at St.Botolph without Aldgate there was a gradual increase in crystal frequency and mass over the 7 month period indicating that the conditions were not posing a threat to the pipes.In situ X-ray analysis of the pipes showed that they contained up to 20-30% Sn which also contributed to their enhanced stability, as reported in the COLLAPSE project.[5] Figures 1 and 2 show the location and Figure 3 shows the results obtained after almost 6 months' continuous testing. For Chalmers the miniaturized holder meant that it was possible for the first time to monitor in situ the effect of controlled levels of acetic and formic acids at selected RH and T and for selected periods. Exposure at the church Orgryte,Göteborg, Sweden showed a fast response of the crystal coating. It reached a maximum value in a few hours in a similar way to that observed in the accelerated ageing cabinets. Climate date in this church revealed high RH and acetic acid values.[5] Surfaces of the coatings were characterised by optical and scanning electron microscopy, Raman and Atomic Force Microscopy. At this stage miniaturisation has been achieved and testing is in progress at selected sites, particularly where damage has already been observed.

Figure 1: Location of holder in St Botolph without Aldgate. The empty holes represent places where pipes had to be removed and which had to be replaced after the installation.

Within the PROPAINT "Improved Protection of Paintings during Exhibition, Storage and Transit" (http://. propaint.nilu.no) project lead coupons and both lead and varnish coated crystals mounted in small holders (initially without continuous monitoring) were exposed in the microclimate frames. To test their response a model painting was prepared and freshly varnished and then placed in microclimate frames where air exchange measurements had been made. The lead coated crystals provided a response which was commensurate with the high levels of acetic acid in these frames. Varnish coated crystals on the other hand gave a low response as their sensitivity is to the presence of light and oxidising agents. To test the protective effect of varnish on a prepared painting, samples from the painting were subjected to variations in RH using a controlled environment DMA analyser and the effect on their mechanical properties was measured.

Samples were tested in tension and measurement was made of the elastic modulus and the sample extension under the influence of programmed RH (1%/min). Measurements showed that there were differences in the behaviour of a varnished and non-varnished layer towards alterations in RH. The study has included wood, archival material, such as parchment and leather, and textiles (wool). Samples that have been subjected to accelerated ageing involving light, heat, and pollutant gases (NO_x).ozone have been studied and in all cases changes in response to RH have been observed.

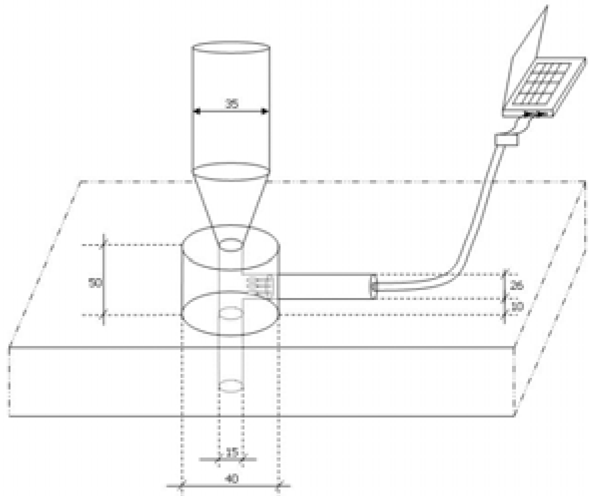

Figure 2: This gives the schematic representation of the location of the crystals within the holder.

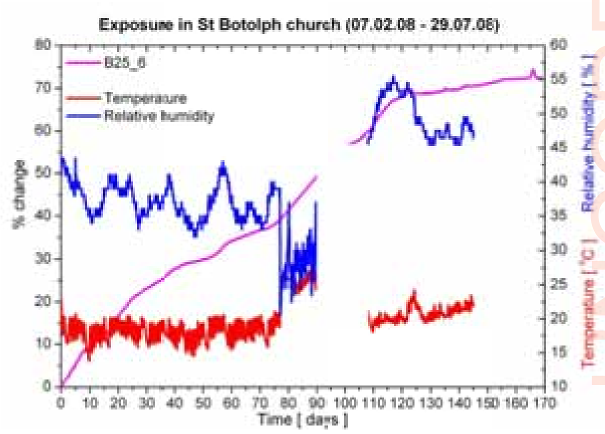

Figure 3: The crystal response together with RH,T data obtained after almost 6 months' continuous monitoring.

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CULTURAL HERITAGE AND SUSTAINABLE TOURISM – HYGROTHERMAL SIMULATION OF THE INDOOR MICROCLIMATE OF HISTORIC BUILDINGS

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1. Introduction

The tourist numbers in Europe are predicted to rise by 2020 up to 700 million visitors per year. In historic buildings high visitor numbers can contribute significantly to the rapid decay of works of art and interior decorations. For the assessment of indoor climate conditions new hygrothermal building simulation tools are available. The possibilities of these models are shown using the example of the King's House on the Schachen that still has very little visitor attendance. This study is part of a bigger project on the climatic stability of historic buildings where also Linderhof castle, which has up to 1 million visitors per year, and the Renatus chapel in Lustheim near Munich, Germany, are investigated. Higher visitor numbers can be very easily introduced in the simulation by raising the interior heat and moisture loads.
The King's House on the Schachen is a royal mountain chalet situated in the Bavarian Alps that has got a very finely preserved interieur. The statistical analysis of the indoor microclimate confirms that the range of temperature and humidity is in a region that is in generally considered save in regard to conservation. Of special interest in respect to the state of preservation is the climatic stability that is examined with the use of whole building simulation with the software tool WUFI Plus. It is shown that the interior furniture and the materials of the building envelope reduce the range of humidity changes inside very effectively by buffering and releasing moisture. Also the infiltration rate plays a significant role in the reduction of fluctuations. A low infiltration rate can aid to conservation of cultural heritage objects.

2. The King's House on the Schachen

The King's House on the Schachen is an impressive example of late 19th century royal interior design from the times of King Ludwig II of Bavaria. The building was finished in 1872 by the architect Georg Dollmann. The wooden post-and-infill structure in the form of a Swiss chalet has five living rooms downstairs with cembra wood panelling and a mixture of stylistic elements. Very much in contrast to the plain and simple exterieur is the luxurious "Moorish Hall" which takes up the entire upper floor of the hunting lodge (Fig. 1). The Turkish Saloon is decorated with painted and gilded wooden walls with carved ornaments, elaborate cushions, curtains and carpets in oriental fashion, carved, wooden lamps and a fountain in the middle of the room that is of course not used anymore today. In the King's times it could be heated by two ornate tiled stoves. The windows of the room are made of colourful stained glass in order to keep out the Bavarian mountain scenery and to aid to the perfect illusion of an oriental court.

Situated in the Bavarian Alps on the Schachen Mountain opposite the Zugspitze (Germany highest mountain) at around 1870 m the King's house faces a very rough mountain climate with cold winters, hot summers and extreme and fast weather changes all over the year. Nevertheless the state of preservation of the interior and the works of arts inside the Chalet is extraordinary good. Since the lodge can only be reached by foot and it is only open to the public from June to October the numbers of visitors is limited. During the winter months the whole building is completely closed.

Figure 1: Photographic view of the King's House on the Schachen from the outside (left, www.schloesser.bayern.de) and its oriental palace room on the first floor (right).

Description of the building construction

A typical problem with historic buildings is how to obtain knowledge about the construction details. Unfortunately the available floor plans from last restoration works in the 1990ies do not show the whole construction for Schachen Chalet. Therefore the following estimations were made in the knowledge of traditional wooden constructions. The wooden outside walls are set on a stone foundation and have a width of approximately 0.5 metres. From the attic it is possible to see that the construction has got an inner and an outer shell made of wooden beams with an air layer in between. The interior surfaces are made of wooden panels that are painted and gilded on the upper floor. The exterior is made of painted wooden shingles and boards. For the inside beams a width of 12-16 cm was assumed, for the outer shell of 8 cm with 2 cm of panelling on both sides. The overall volume of the building is 2035 m^3. The windows have single glazing, only the upper floors have protective double glazing for the coloured stained glass windows. This was taken account for by using a shadowing function with a solar radiation reducing factor (b-value) of 0.2.

Analysing the hygrothermal conditions

During the period from October 2006 to September 2007 the hygrothermal conditions inside and outside the King's house on the Schachen were measured continuously in one hour time steps using stand-alone data-loggers. The outdoor climate data serves as one input for hygrothermal simulations. The weather data for the Schachen are not yet completely available. Instead, weather stations of the German National Weather Service (Deutsche Wetter Dienst) in the vicinity are used for solar radiation (Hohenpeißenberg), wind speed, rain and air pressure (Zugspitze). For relative humidity and temperature the values from the measuring devices at the north façade balcony of the Schachen House were used. In Fig. 2 the measured data for exterior and interior relative humidity as well as temperature are shown. The outdoor data-logger unfortunately had a measuring inaccuracy and does not show values above 96% RH. It must be stated, that the winter 2006/2007 was extraordinary mild. Therefore further measurements are currently going on with new measuring devices.

In order to get additional information like influence of moisture buffering materials, hygrothermal whole building simulations were carried out. For the simulation of the hygrothermal behaviour the software tool WUFI Plus is used.[1] The whole building is simplified as a single zone with a perfect air exchange between the floors. For the model each outside wall and roof is described separately in its construction. The simulation runs one year from October 1st 2006 to September 30th 2007. For the first approximations the visitors during the summer months from June to October are neglected. Since there is no heating equipment in the Schachen House, its indoor environment is only influenced by the ambient weather conditions.

In Fig. 3 the course of measured and simulated indoor relative humidity and temperature from October, 1^{st} 2006 to September, 30^{th} 2007 is plotted. Several variations are used to approximate the behaviour of the King's House indoor environment. The variations with different infiltration rates show the best possible overall fitting for n=0.25 h^{-1}. An assumed infiltration rate of n=0.5 h^{-1} already leads to much larger fluctuations in relative humidity (Fig. 3). Infiltration rate measurements of the St. Renatus Chapel, a 17^{th} century church near Munich, under different weather and wind conditions showed that infiltration rates of historic buildings can easily differ within in this range.[2] At the moment this is not taken account for in the simulation, only a fixed rate was used.

The interior surfaces and their ability to buffer humidity and temperature fluctuations is the second important variable for the climatic stability of the indoor microclimate. Simulations were at first carried out without any moisture buffering (MB) capacity and afterwards with moisture buffering materials (Fig. 3). As reasonable description of the interior surfaces the S_d-values were set to 0.1 for the walls and 0.5 for the floors because a general S_d-value of 0.5 led to much too high fluctuations, which are not shown here. To account for the indoor materials 200 m^2 additional inner wooden walls with a width of 10 cm were added, also with an S_d-value of 0.1.

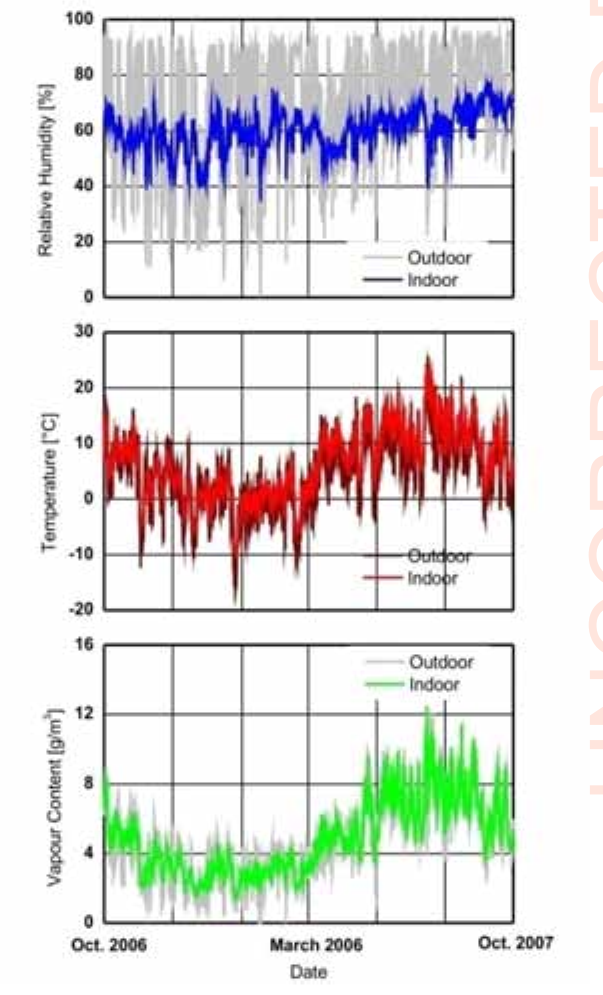

Figure 2: Course of measured relative, humidity temperature and vapour content, indoors and outdoors from October, 1st 2006 to September, 31st 2007. Due to an inaccuracy of the measurement equipment the outdoor relative humidity does not reach 100% RH. The indoor temperature and vapour content clearly follow the outdoor values.

The comparison of the simulations results with the measured data shows quite good fitting for the winter months. For the second part of the simulation the temperature is too high in comparison with the measured data due to necessary simplifications in regard to the building construction and uncertainties in regard to the available weather data in the approximation of the model, especially solar radiation and shading from the mountains during winter months. As the simulation of the vapour content of the air fits sufficiently well, the relative humidity is in consequence too low during summer (Fig. 3).

From June to October the Schachen House is open to visitors. Since the exact number of visitors is not known but the daily number is very strictly limited, it is assumed for the simulations, that no additional heat and moisture sources are present. This is of course another extreme simplification and might be one reason why especially in summer the difference between measured and simulated relative humidity is more than 5% RH.

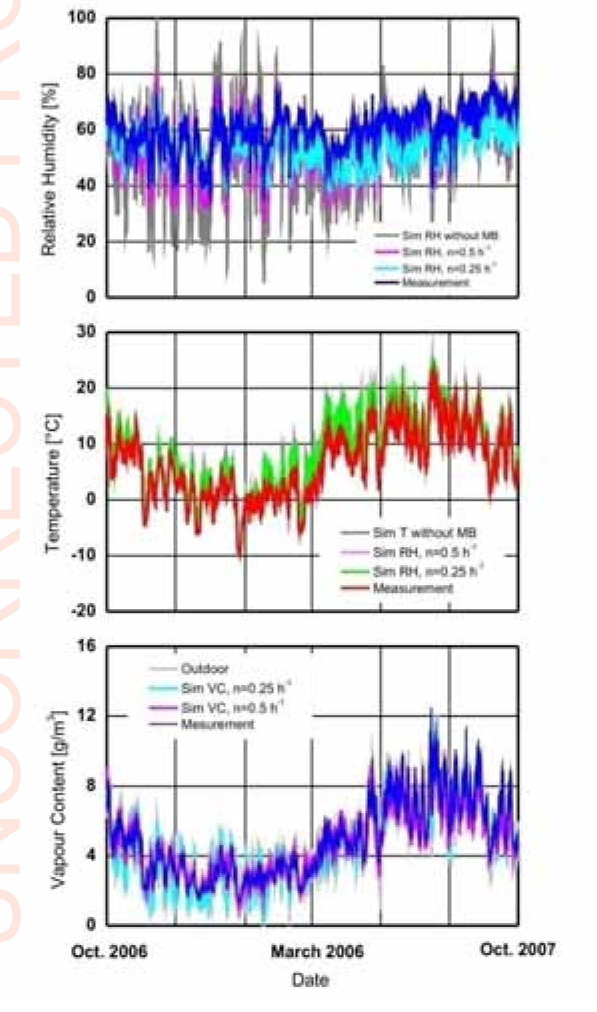

Figure 3: Course of measured and simulated indoor relative humidity, temperature and vapour content from October, 1st 2006 to September, 31st 2007. Simulation results without moisture buffering (MB) and with moisture buffering at different infiltration rates (n = 0.25 and n = 0.5 h^{-1}).

Statistical Analysis of the indoor environment

The existing dataset is used for statistical analysis of the range, the rate of change of the hygrothermal conditions and possible effects on the buildings content (Fig. 4). The measured indoor relative humidity shows a median value of 60.8% RH for the examined one year period (Tab. 1). The relative humidity varies around this value within a range of ± 5% RH in 80% of the time.

In 95% of the time the indoor relative humidity lies in between 40 and 70% RH (Fig. 4, left). Values below 40% RH take place in only 0.2% of the time, values above 70% RH in approximately 5% of the time. But even at higher relative humidity values lie still within a region with very little risk of mould growth due to low temperatures (Fig. 5).

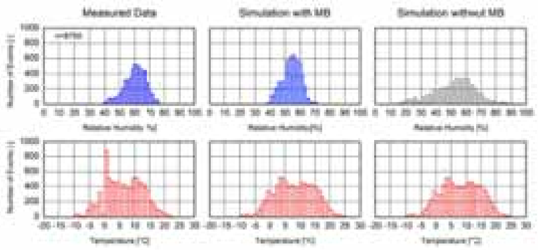

Figure 4: Histograms of the hourly indoor relative humidity and temperature of the Kings House from October, 1st 2006 to September, 31st 2007. Measured data versus simulation, with and without moisture buffering (MB). The spike in the measured temperature at 0 °C can be traced to a measurement inaccuracy.

Table 1: Statistical Analysis (percentiles, mean and standard deviation) of the one year hourly indoor and outdoor relative humidity and temperature measurements of the Kings House from October, 1st 2006 to September, 31st 2007.

	Max	P95	P75	Median	P25	P5	Min	Range	Mean	sd
RH_in	77.5	70.9	65.4	60.8	55.7	46.9	34.5	43	60.2	7.1
T_in	23.3	16.2	11.2	6.4	1.5	-3.6	-10.4	33.7	6.4	6.2
RH_out	96.3 *	93.3	87.4	72.5	54.2	26.9	1.3	94.8	68.5	21.2
T_out	25.7	14.2	8.9	4.6	0.5	-6.4	-15.9	41.6	4.5	6.2

* Due to an inaccuracy of the measurement equipment the relative humidity outdoors does not reach 100% RH.

The hourly variation of the relative humidity is below 1% RH in 84.5% of all cases, in 96.5% of all cases below 2% RH and in 99.7% of the cases below 5% RH. That means that faster variations than 5% per hour happen only in less than 0.3% of the examined cases. The median of the daily variations lies at 4.85% RH. Daily variations larger than 15% RH take place only in about 1.5 % of the cases.

Risk Assessment for Cultural Heritage Items

Although the King's House on the Schachen is situated in a region of rough mountain climate, the indoor environment seems to be well suited for the preservation of cultural heritage from a conservation point of view. Garry Thompson defines an indoor environment between 40 and 70% RH and temperatures that are sufficiently constant to maintain a stable relative humidity as suitable for a so called 'Class 2' museum.[3] The interior climate of the King's House stays within these limits in 95 % of the time during the examined one year period in 2006/2007.

The region somewhere below 40% RH is considered to be dangerous for works of art because of shrinkage and the embrittlement of some materials.[4] The danger of mould growth decreases with lower temperature as the required relative humidity becomes higher.[5] For the measured period there is therefore basically no risk of mould growth for the works of art in the King's House (Fig. 5). A closer examination of the surface microclimate conditions of the building envelope will follow in a later period of the project.

Holmberg[6] stated that the variations of relative humidity for interior decorations smaller than 15% RH during 24 h do not cause damage to wooden objects. Statistical analysis of the daily variations in the King's House shows that during the one year monitoring this threshold was exceeded only on 5 days. A one day variation lager than 20% RH happened only once with a value of 21.2% RH. Low temperatures are in general not dangerous for most materials, at least if the amount of moisture is low enough to prevent frost damages.[6] Low temperatures reduce the chemical decay rate and are sometimes used especially for cold storage solutions for archive materials. At the Schachen House the indoor environment is cold and reasonable dry. According to the measured data (Fig. 5, left) the overall climatic risk for the cultural heritage objects inside the Mountain Chalet can therefore be regarded as low. The climatic stability of the building derives from the ability of the indoor materials to buffer moisture. This can be seen from the direct comparison of the measured data with simulated hygrothermal balance calculated from the inside temperature and the outside absolute humidity (Fig. 5). Without moisture buffering materials the fluctuations would be much higher and the relative humidity would be much more often in regions that are considered unsafe for the cultural heritage materials inside the King's house.

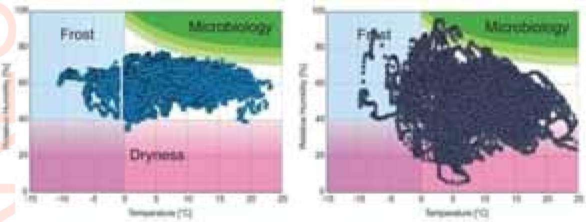

Figure 5: Risk assessment of the measured indoor climate (left) shows that most of the data is in a safe region for the one year monitoring period from October, 1st 2006 to September, 31st 2007 . Frost is considered less dangerous when little humidity is present. The thermal building simulation without moisture buffering (right) shows a far wider range of relative humidity and temperature and the importance of buffering materials for the climatic stability.

3. Conclusions

For the preservation of works of art inside historic buildings from climate induced damages two factors are of importance. The first is the effect of the moisture buffering. From the comparison of the results of the hygrothermal simulation with and without moisture buffering it can clearly be seen how high amplitudes of the relative humidity due to rapid changes in the exterior conditions can be damped by the moisture buffering materials of the building envelope and the furniture. The simulation of the thermal performance without moisture buffering shows that the indoor relative humidity would be in a far wider range and that short term fluctuations would be much harder without the moderating buffer effect. The second important aspect is the infiltration rate. A low infiltration rate will aid significantly to climatic stability.

Future research work on the King's House, Linderhof Castle and other historic buildings will clarify some of the uncertainties and approximations that had to be made for these first simulations in order to improve results. Weather data will be collected on site for this purpose and information on the interior materials and their sorption properties will be collected.

The indoor environment of the measurement period at the Schachen from October 2006 to October 2007 lies within a rather stable and good range for the preservation of works of art especially in regard to relative humidity. The low temperatures during winter do not seem to have much negative effects on the interior decoration. It is also likely that only very stable art techniques were used for the purpose of furbishing the mountain hut. The craftsmen in King Ludwig II time had plenty of experience from centuries of decorating castles and churches in Bavaria to fall back upon. In further research these artistic techniques will be studied as well as their state of preservation from a close range.

4. Acknowledgement

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DESALINATION OF MASONRY STRUCTURES. EXPECTED RESULTS OF THE EU PROJECT *DESALINATION*

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Abstract

Severe salt damage problems caused by sea floods on monuments, as found in the Netherlands, can be still ongoing after more than 50 years. In southern Europe there has been a rise in the sea level near many historic cities on the Adriatic coast, which requires knowledge and remedial measures to mitigate the deterioration problems faced by increasingly salt laden masonry. Increasingly severe storm events have brought higher levels of salts to historic cities, such as Venice and New Orleans.

Salt decay processes are amongst the most recurrent and severe causes of damage to cultural heritage buildings. Application of poultices is performed to preserve these objects while retaining as much as possible of their original materials. However, many aspects of the desalination remain unknown.

Central scientific and technical objectives of EC Project Desalination are: gaining a better understanding of salt transport mechanism between a salt laden substrate and a material applied on top of that and assessing possibilities and limitations of desalination treatments. The research methodology developed is based on Non Destructive Techniques (NDT) analyses, Nuclear Magnetic Resonance (NMR) and laboratory tests to assess the state of conservation and treatments of desalination systems. Moreover, test methods have been developed for the determination of both rheological / mechanical properties and the effectiveness of poultices.

1. Introduction: the Desalination Project

Core of the project is the assessment of desalination systems on wall and finishes in monumental buildings and their impact on these monuments. For this purpose the research has been focused on laboratory tests, devoted to the characterization of poultices and substrates, and Non Destructive Techniques (NDT), applied on site to evaluate the performance of desalination systems in selected case studies in relation to the environmental conditions and weathering processes affecting the building under investigation.

The research focuses on: a) analysis of treatments and technique of desalination systems commonly applied in practice, b) assessment of the state of conservation of monuments in a restricted number of case studies, c) study of the effectiveness of selected desalination treatments in test panels in the case studies and laboratory tests. The knowledge acquired in this way may lead to new compositions of mortars/poultices. The most important aspect is to verify whether laboratory results are comparable with the results in practice.

At first, an international, comprehensive online survey, targeted at a large audience, and in-depth interviews with conservation specialists, was undertaken to gain insight into the current working practice and materials selection of conservators, contractors and architects. The results allow a better understanding about application methods and type and frequency of any pre- and post-treatment assessments currently used in the field and suggest a restricted number of treatments to be used within the project.

As a second step, efforts have been made to increase the scientific knowledge on site, by means of non destructive techniques methodology, on the workability and mechanical properties of fresh poultices and on transport mechanism during desalination. The consortium also developed practical methods to assess the quality of desalination.

2. Analyses and Results

The innovative research methodology based on Non Destructive Techniques (NDT) analyses, consisting of a diagnosis, a treatment and a control phase, has been applied in situ to different building materials (brick and hard stone). Digital image processing, colour measurement, infrared thermographic analysis, ultrasonic investigations and resistivity analysis have been performed before and after treatment application to characterize the substrates in a qualitative and quantitative way and to assess the efficiency of the treatment applied.

Preliminary results collected on brick masonry before and after treatment by NDT measurements show that, after poultice application, a) the digital image analysis, able to detect the variety and the structural properties of building material, reveals the moist spots reduction on a surface; b) the value (L*) of the CIElab colour measurement generally increases; c) a decrease of cold area extension related to salt extraction is registered by IR thermography (Fig. 1); d) the electrical properties of the material under investigation improves; e) the comparison between resistivity values, moisture content (MC%) and hygroscopic moisture content (HMC%) determines the resistivity change in depth beneath the treated surface.[1,2]

In particular, resistivity measurements have been performed together with laboratory tests to assess the relationship between salt transport and moisture content before and after the application of poultices in selected case studies. The electrical properties of a substrate can be monitored in a non invasive way to determine the effectiveness of desalination treatments with time. The results obtained on a masonry wall of the Terese Convent case study (Venice, Italy), an historical building of the XVII century, clearly shows the increase, immediately after treatment, of the apparent resistivity of the bricks, in line with a reduction of salt and moisture contents. The comparison between resistivity values, moisture content (MC%) and hygroscopic moisture content (HMC%) allows to determine the resistivity change in depth beneath the treated surface. The pre treatment condition usually identifies an electroconductive layer followed in depth by a resistive electrolayer. Instead the post treatment condition reveals the presence of a surface resistive layer, substituting the pre-treatment conductive layer: the desalinated layer has in general a thickness of 2.5-3 cm and after this depth the geoelectrical method is not able to discretize the poultice efficiency. Immediately after treatment a migration of moisture and salts occurs inside the brick coming from the treated surface or reclaimed from the inner part of the wall. About one year after treatment, this physical parameter decreases significantly, reaching almost the pre treatment values: the desalination effect is not permanent. The resistivity models appear able to show the effectiveness of the desalination process in situ through the modification of physical parameters.

The performed surveys point at the problem of desalination durability. In fact, the dependence of the resistivity parameters from substrate properties requires a better understanding of the poultices-substrate-environment relationship. The mineralogical composition, structural properties, density and porosity values, moisture and salt contents of the different kind of bricks identified in the masonry affect the pre-post treatments resistivity differences registered. Low resistivity differences are typical of high compact bricks, while high resistivity differences corresponds to bricks characterized by low density and high porosity values. Therefore, the physical petrographical properties are able to influence moisture content and salts transport as well as the salt extraction by poultices.

Laboratory tests developed for the cement industry (penetration and flow) have been adapted to determine poultice consistency and workability, respectively. A new test allowing the determination of the adhesion of fresh poultices was also developed. These tests were performed on seven preparations, based on cellulose (Arbocel BC 200 and mixture BC1000/BW40), minerals (kaolin/sand and bentonite/sand), and mixtures of cellulose and minerals (BW40/kaolin/sand, BW40/bentonite/sand and BW40/bentonite). It was shown that the poultices reveal a real rheologic behaviour.[5] Optimal adhesion of a fresh poultice to the substrate is a mechanical property that depends on the poultice composition (cellulose, type of clay), and is a function of its water content. This parameter is also of primary importance for the consistency and workability (Fig. 2), and could be optimized through the proposed test procedure. Recommendations were established to conservators on how to select a poultice according to their needs and field requirements and also on how to verify if a home-made poultice recipe fulfils optimal rheological and mechanical requirements.

A desalination experiment performed in-situ on a dense microporous limestone (Nt: 5%, Mean pore size : 0.02 µm) suggests the necessity for pore size distribution of both substrate and poultice to be overlapped in order to obtain a good salt extraction.[6] Analyses also suggest that a continuous distribution between the different pore classes may lead to optimised desalination efficiency. Thus, size and arrangement of grains are probably important parameters to take into consideration when formulating poultices, as they influence the connectivity between pore classes. Pore shape may also have a significant influence on suction properties. Sheet-like throats seem less effective than tube-like throats. Grain packing, pore size distribution and pore shape should be considered in addition to adhesion, to optimise desalination systems.

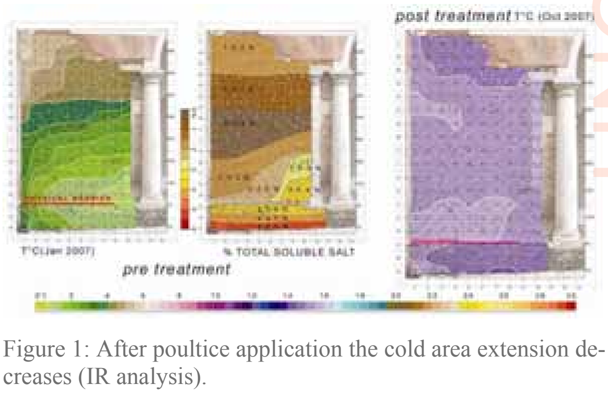

Figure 1: After poultice application the cold area extension decreases (IR analysis).

The amount of salt accumulated in the mortar/poultice, the influence of different salt type on desalination, the depth of desalination, the influence of treatment on salt systems behaviour with respect to relative humidity and temperature, the influence of a filter between substrate and mortar/poultice to protect fragile substrates have been also investigated. Moreover, the effect of selective salt extraction on the thermodynamic behaviour of salt mixtures remaining within the object after treatment has been studied.

Generally, diffusion or advection are the working principle of a poultice. The Nuclear Magnetic Resonance (NMR) research shows that diffusion plays a minor role in the first stage of a drying process, because a quick salt extraction is obtained using poultices based on the advection working principle that is the transport of salt solution due to differences in capillary pressure.

One of the objectives of the Desalination Project is the development of a modular system of poultices, which can be adapted, i.e. fine-tuned to different types of substrates. The advection transport mechanism is faster than diffusion and the application on immovable objects is relatively easy. The principle of the foreseen modular desalination system implies the use of poultices whose pore system is adapted to the pore system of the salt laden substrate. This theory, which has to be validated in the Desalination Project, has been developed on the basis of the model for salt and moisture transport developed in the previous EU project Compass. In order to optimize salt extraction, a poultice working by advection should have smaller pores than the substrate: in this case the salt solution transport will occur from the substrate to the poultice and salt accumulation in the poultice will result. Nevertheless, it is convenient that the pores of the poultice are not too small, otherwise advection would be slowed down. In order to have a water flow from substrate to poultice, the Nuclear Magnetic Resonance (NMR) results show that the pores of the substrate should be larger than the poultice and so the salt are transported from the substrate into the poultices (Fig. 3).

At the time, a first step in the development of the modular system has been taken by designing two component-poultices (kaolin and sand) with different pore sizes. A range in the pore sizes was obtained by varying the kaolin/sand ratio and the grain size distribution of the sand (Table 1). The pore size distribution of the poultices was determined by Mercury Intrusion Porosimetry (MIP) on poultices prepared and dried on a substrate. Besides, thin sections of the poultices were prepared and observed by Polarizing Fluorescence Microscopy (PFM); point counting was performed to further evaluate the porosity.

The results of the MIP show that the total porosity of the poultices varies between 27 and 33 vol %. The presence of the kaolin results in pores in the range of 0.3 µm, while the intergranular pores (due to the sand) vary, depending on the kaolin/sand ratio and the grain size of the sand, between 2 and 200 µm. It has been observed that increasing the kaolin amount leads to a higher amount of small (0.3 µm) pores, while increasing the grain size of the sand shift the porosity towards coarser pores (Fig. 4).

The NMR research on moisture and salt transport has been focused on the salt extraction by advection process in order to obtain quicker desalination in comparison with the diffusion process. In fact, the salt extracting experiments results indicated that diffusion in substrate plays a minor role in the first stage of drying process when the applied poultice has smaller pore size. Experiments consisting in a phase of wetting the substrate with cellulose and a phase of salt extraction with kaolin/sand poultice have been performed to obtain information on the water and salt distribution in the system during drying in order to identify the parameters controlling the ion transport. The results show the distribution of salt which has a large effect for the phase of

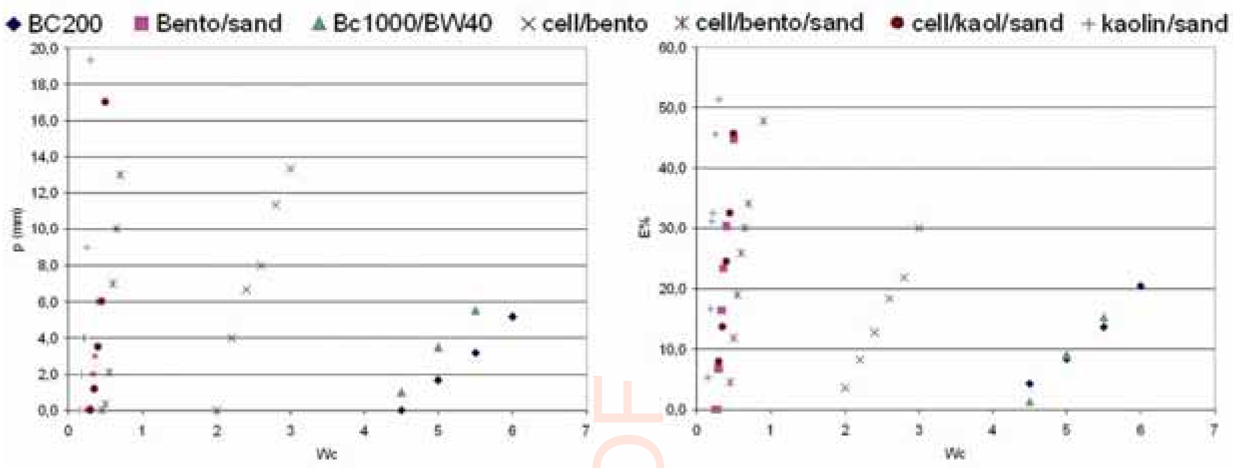

Fig. 2: Penetration (left) and flow test results of different poultice recipes.[5,6]

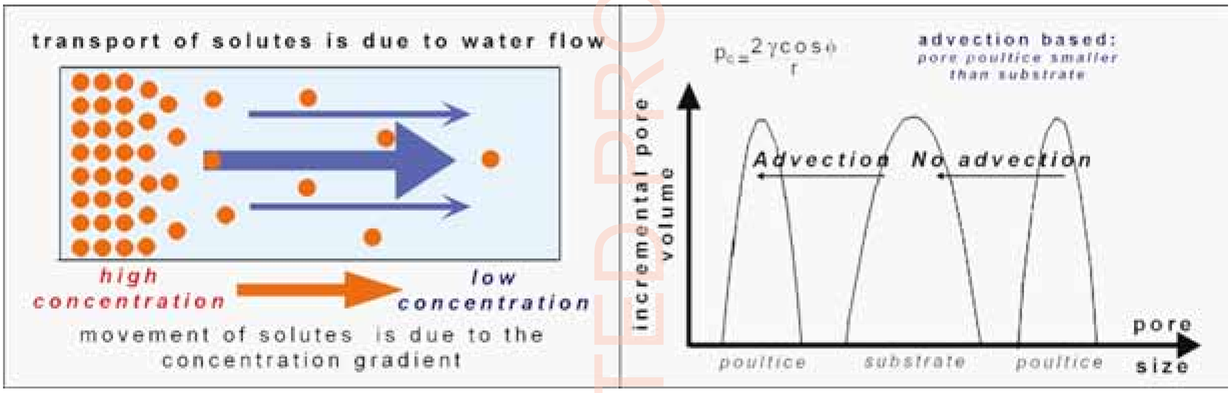

Figure. 3: The NMR results show that the pore sizes of building material have a big influence on the advection process.

ion movement Moreover, the pore sizes of building material have a big influence on the salt transport behaviour, because these properties determine the fluid transport in a single medium.

In addition, the poultice composition, based on kaolin and sand has been studied to improve the knowledge of the influence of clay/sand ratio on the pore size distribution of the poultice. Experiments of desalination treatment performed with poultices of different composition (kaolin/sand/water) and the use of Japanese paper on samples saturated by salts, reveals that the system where poultices had large amount of kaolin become slower due to two reasons. Kaolin penetrates trough the paper and blocks some pores of the substrate surface and paper also retards water flow from the substrate to the poultice. Experiments with wetting and salt extraction of samples fully saturated by immersion show that changes in desalination occur due to salt distribution in the substrate before desalination treatment. Consequently the distribution of the Peclet number during desalination by poultices must be considered: when the majority of the salt accumulate near the wetting front where the water velocity is closer to slow diffusion rate the salt can not be transported by fast water flow. Therefore the treatment will not have an efficient result in extracting salt from the substrate. Another important parameter which can vary significantly salt extraction is the distribution of salt in substrate before treatment.

Moreover, it has been shown that selective extraction does occur, and can cause significant changes in pre- and post- treatment salt behaviour. The current findings indicate that this effect is dependent on the salt mixture composition and support type (Fig. 5). At present the underlying causes for this are not

Table 1: Composition of the kaolin/sand poultices.

Poultice	Kaolin: sand ratio by weight	Grain size sand fraction (mm)	Water content by weight
13S	1 : 3	0.08-0.5	0.22
13L		0.5-1	0.22
15S	1 : 5	0.08-0.5	0.2
15L		0.5-1	0.2
17S	1 : 7	0.08-0.5	0.21
17L		0.5-1	0.16

known, since it is clear that it is not solely due to solubility constraints, but that perhaps to some degree, ion exchange or differences in ion mobility may play a role. Further work will be done to study this effect on a wider range of support types and salt systems. Consequently, it is clear that the potential effects of selective salt extraction should be considered prior to carrying out a salt reduction treatment.

Within the framework of the desalination project, Madame John's Legacy, a historic brick and timber home in the French Quarter of New Orleans was used as a field site to evaluate the effectiveness of four desalination poultices under warm and humid environmental conditions.[8] The poultices were applied to salt-laden brick walls in a sheltered exterior environment and in an air-conditioned ground floor. Effectiveness was defined by the percentage of salts removed as well as the depth of desalination. Preliminary results from the investigation demonstrate the importance of environmental conditions, shrinkage, adhesion and drying rates in poultice effectiveness. Desalinating masonry in a humid environment led to leaving the poultice on to dry for months instead of weeks, resulting in a significant reduction in salt content of well over 90% for two poultices.

3. Conclusions

Until now good results have been obtained both in the field and lab researches. The application of NDT methodology gives interesting outcomes concerning the characterization of a support and the efficiency of a desalination treatment, pointing out the role of moisture transport and its variation during time. The laboratory results allow the calibration of a numerical simulation of ion transport, and lead to a better understanding of the desalination process. The relationship between poultice/substrate pore size distribution and the behaviour of remaining salts is highlighted. It seems that parameters such as grain arrangement and pore shape of the poultice can play a major role in the desalination efficiency. The drying properties of both substrate and poultice also appear to influence the transport of salt solution from the substrate. Moreover, the results achieved up to now show the existence of extremely complicated situations in case studies that require special attention during both with respect to substrate characterization and to treatment evaluation.

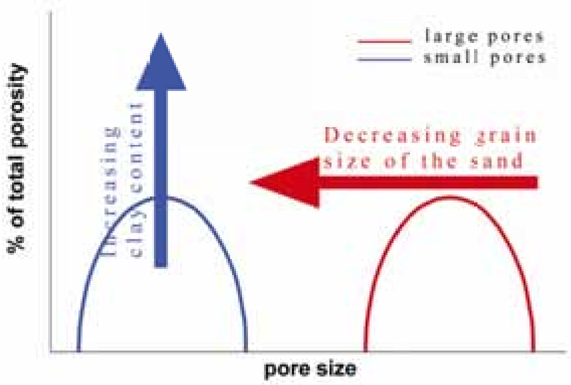

Figure. 4: Effect of kaolin/sand ratio and sand grading on pore size distribution.

4. Acknowledgement

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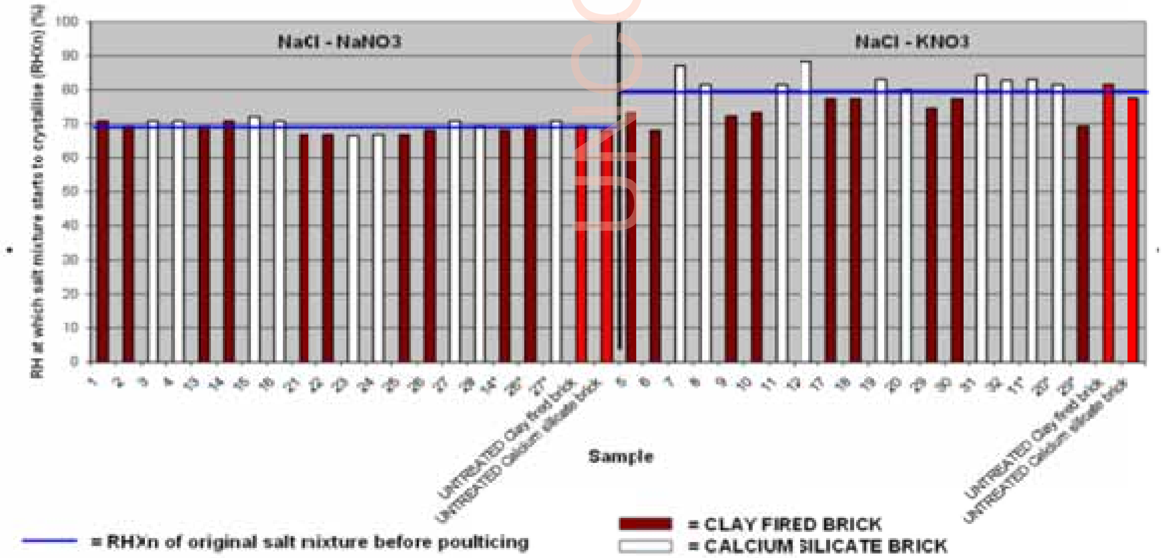

Figure 5: Selective extraction of salts.

HOW DO CONSERVATORS TACKLE DESALINATION? AN INTERNATIONAL SURVEY OF CURRENT POULTICING METHODS

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Abstract

As part of the EU project 'Desalination' an international online survey of conservation specialists has been undertaken, to provide information on the type of poulticing materials and methodologies used in current working practice. This paper reports the survey's findings and also draws upon in-depth interviews carried out with conservation practitioners. The target countries were Germany, France, Italy and the UK; and the conservation specialists consulted included conservators, contractors and architects. Both the online survey and the interviews yielded information on the extent to which pre-treatment investigations and analysis are carried out; the types of poultice materials and methodologies currently used in Europe; and the implementation of post treatment monitoring to assess the efficacy of intervention. The survey was intended to give a general overview of the current practice in the field regarding desalination treatments, and has largely been successful in achieving this purpose. Difficulties with the survey are also discussed. The survey highlights differences between recommendations of best practice in the literature and the reality of current practice, typically as a result of economic considerations.

1. Introduction

The three-year EU project 'Desalination' which began in 2006, aims to develop a straightforward methodology for optimising the selection and assessing the performance of desalination poultice systems. To this end, it is important for scientific research in this area to embrace the long-term practical experience of conservators in field. Therefore, an international survey (target countries: Germany, France, Italy and the UK) was undertaken, as an essential first-step, to gain insight into the current working practice of conservation practitioners including conservators, contractors and architects.

The scope and aims of the online survey were to collect information relating to materials and recipes used, to gain knowledge about application methods, and about the type and frequency of any pre- and post-treatment assessments. An important goal was to try to reach as many practitioners as possible to gain a general overview of the current situation in field. For this reason the survey was kept as short as possible (to enhance the completion rate), and structured in the form of multiple-choice-questions, which also offered respondents the opportunity to record personal comments.

The online survey was carried out in English, Italian, French and German to reach all partner countries. The Cologne University of Applied Science and the Laboratoire de Recherche des Monuments Historiques Champs-sur-Marne announced the online survey directly to about 500 experts in conservation of monuments in different countries.

Salt reduction methods

Of the respondents, 30% reported the use of dry mechanical removal of surface efflorescence, while the most popular method for desalination was aqueous extraction by poulticing (37%), these typically being used in combination. By contrast, electrical methods are used relatively seldom (4%), with 80% of respondents reporting that they had never used electrical extraction techniques (Figure 1).

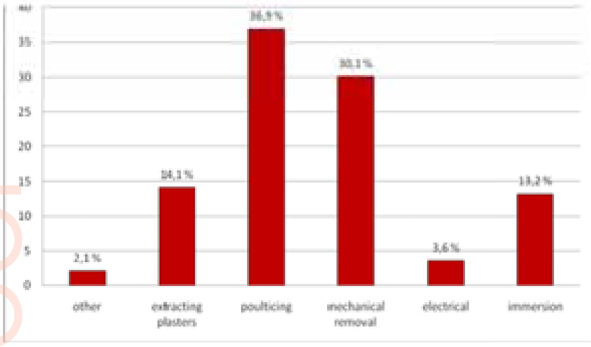

Figure 1: Salt reduction methods used.

In contrast to the one-size fits all approach of the past, where entire objects or complete schemes of wall paintings were treated uniformly using the aqueous poultice method, the interviews revealed a tendency in recent years towards undertaking more specifically localised salt reduction treatments on the basis of thorough condition surveys, investigations and analysis.

Poultice materials

The survey underlined the fact that there are two main groups of poultice materials used in the field (Figure 2). Cellulose pulps are the most frequently selected material type (35%), while other important groups are clay minerals (22%) and mixtures containing clay minerals and sand (10%). Paper (in form of Japanese-tissue) is frequently used, most typically not as a poultice material in itself, but as an intervention layer. The use of textiles is also reported (4%), displaying a minority tendency for the use of modern micro-fibres for desalination treatments. Moreover, 3% reported the use of other materials, mostly in the form of lightweight additives such as perlite and vermiculite, and Poraver. In addition to the main poultice materials, 20% of respondents also stated the use of additives such as carboxymethyl cellulose, and very occasionally biocides.

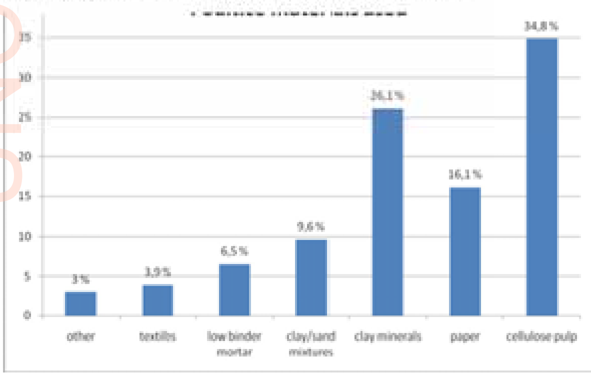

Figure 2: Poultice materials used.

Selection criteria: working properties

The key material properties considered to be most important in governing the selection of a particular poultice material were removal and clearance, viscosity and density (appropriate for adherence to vertical surface), and ease of preparation (Figure

3). This indicates that a main priority for practitioners is the good workability of the material when used on site. Conversely, other aspects relating to effectiveness (e.g. good conformance with the surface, rate of evaporation and moisture capacity) were rated as being of lesser importance.

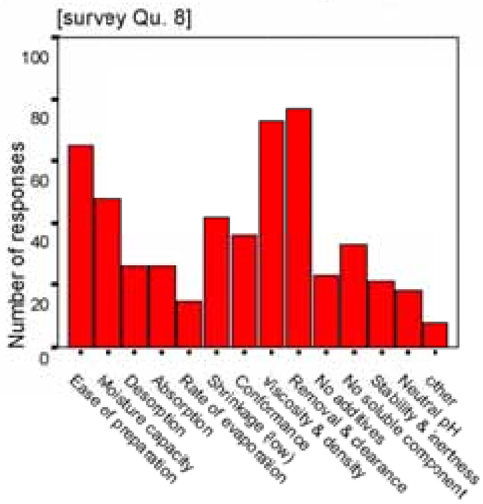

Figure 3: Selection criteria: working properties.

Adaptation of poultice recipes

Half of the respondents were of the opinion that one kind of poultice mixture gives satisfactory results across range of object types, while 30% modify the poultice occasionally on a case by case basis. Only 23% considered that different poultices are regularly needed for different objects. Moreover, the use of 'sandwich' type constructions, in which different poultice materials are layered on top of one another was reported by 15% of respondents.

It is interesting to notice that the respondents who adapt the poultice recipe to the susbstrate do not question if the selected poultice will be capable of removing salinated water from the substrate by capillary suction. It is now becoming increasingly apparent, in particular through work undertaken as part of the desalination project, that the substrate/poultice pore size range is of importance in determining the efficiency of salt extraction in the case of drying poultices.[1,2,3] As a result, work is ongoing to determine the pore size characteristics of a range of commonly used poultice recipes in order to optimise the poultice selection.

Application methodology

The majority of respondents reported the use of drying poultices (55%), while 29% report the removal of the poultice while still wet. Sometimes, poulticing is undertaken with constant water supply during the desalination treatment (16%).

The amount of water introduced during treatment is not mentioned as a key parameter by respondents. Work undertaken during the desalination project has shown that poultices differ dramatically with that respect from one to the other. Preliminary results have shown that the use of copious amounts of water tends to transport salts deeper into the object resulting in accumulation at depth rather than extraction.[3]

Repeated applications and contact time

As shown in Figure 4, a general preference for 2-3 application repetitions was reported (81%).

If an object is poulticed three times, in general the same poultice mix is used for each application, although the contact times may differ. The notion of using different poultice mixes at different stages, each with specific aims, is not part of current practice, although the results obtained within the desalination project to date suggest that such a practice should be developed in the future.

Some interviewees reported greater efficiency using short contact times. This raises the need for further research into what happens within the initial seconds and minutes of poultice application, that is, to investigate whether in certain cases poultices should be removed far sooner than is the case in current practice.

On average a poultice is left in place for the duration of one week, but longer contact times are also used, the longest reported being over 6 months. Many respondents reported that the decision regarding the time a poultice was left in place was also governed by the environmental conditions at the time of treatment.

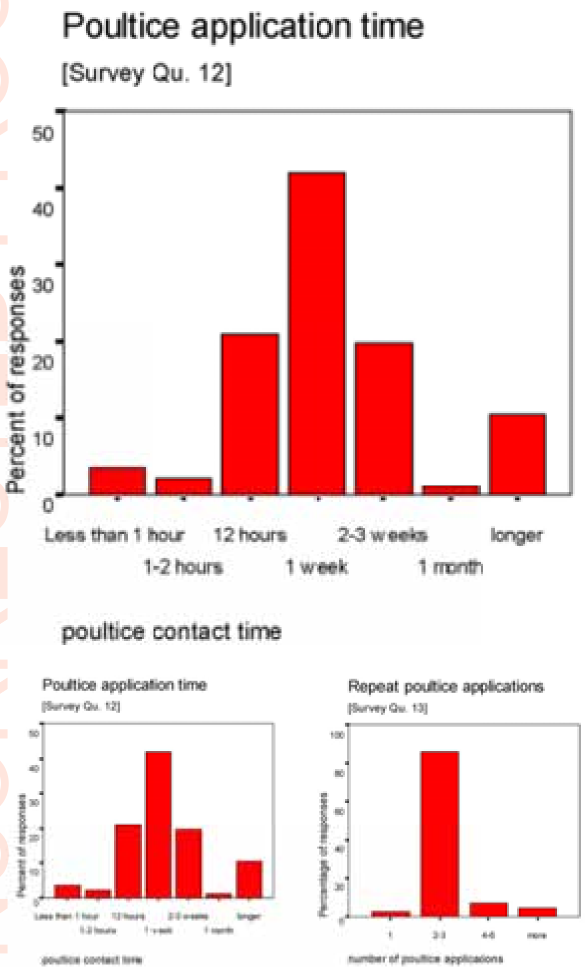

Figure 4: Poultice application time, and number of applications.

The effect of environmental conditions and poultice application time has been investigated as part of the Desalination project, which showed that both of these factors influenced the efficiency of salt extraction.[3] Moreover, it is clear that current guidelines[4] regarding the application time, and number of poultice applications need to be revised.

There was a general reporting in the interviews of poultice-attachment problems with walls and overhead ceiling or vault poultices. Here the water content of the poultice is an important factor for practical reasons: if the water content is too high, the poultice will slip and not adhere (to a wall or ceiling); too little water and the poultice will be too dry to work with and will also not adhere. The adhesion test set up within the frame of the desalination project, has shown that each poultice recipe has, in addition to optimal rhelological properties, an optimum water content with respect to adhesion.[5] Reinforced mesh systems were also reported being used to provide additional structural support for poultices; with these continuously pressed against walls or ceilings to improve contact and conformance.

Use of intervention layers and backing foils

Intervention layers are often used on wall paintings or other delicate surfaces as a form of protection and to facilitate removal of the poultice material. In 60% of cases an intervention layer is reported being used during application. The most commonly reported material is Japanese tissue, while in a few cases synthetic fibres and cellulose pulp are also reported. Intervention layers are used for a wide range of object types.

Over 60% of respondents reported the use of backing layers during desalination, mainly in the form of plastic film. The high incidence of the use of a backing layer being ascribed mainly to improved weather protection.

Auxiliary actions

The most commonly reported auxiliary treatment method was pre-consolidation (65%). In almost 50% of cases pre-wetting is used in advance of poultice application. Dehumidifier and ventilators are seldom used during desalination treatment (11% and 12% respectively). Other instances of auxiliary treatments were also the use of temporary support structures to hold the poultice in place and improve contact with the object.

Pre and Post treatment investigations

Figure 5 reports the results of the inquiry as regards pre and post treatment condition recording. While 50% of respondents reported that they always assess the object's condition immediately before a treatment; less than 10% stated that they undertake a condition assessment 6 month or more in advance of treatment (i.e. to assess the change in condition of the object over time). Moreover, 3% reported that they do not undertake any form of condition assessment.

With regards to post treatment condition monitoring, a similar pattern of behaviour was displayed, with 40% undertaking condition assessment immediately after treatment, but less than 23% re-assessing the objects condition after 1-3 months, and by 6 months after treatment this figure had fallen to 10%.

Environmental monitoring

The collection of environmental monitoring data has become much more commonplace in recent years, but still in 33% of cases no environmental monitoring takes place in advance of treatment (Figure 6). When environmental monitoring is undertaken the monitoring period is typically less than 6 months. Only 12% of respondents reported monitoring periods longer than a year. This pattern of behaviour was fairly uniform regardless of the respondent nationality and profession.

Salt analysis

73% of respondents report that they assess in more than 50% of cases the object's salt content before a desalination treatment, with 62% of respondents also evaluating the salt content after treatment (Figure 7). However, the survey did not report what types of salt analysis are typically undertaken (e.g. whether quantitative or qualitative, or if individual salt ions are analysed), nor did it question if the salt content assessment was repeated after a period of elapsed time. However, given the behaviour trend revealed with respect to pre and post treatment condition and environmental monitoring (see above), it is likely that the reported responses refer predominantly to assessment of the object's salt content immediately before and after treatment, most probably by indirect means (e.g. by semi-quantitative assessment of the salt content of the poultice).

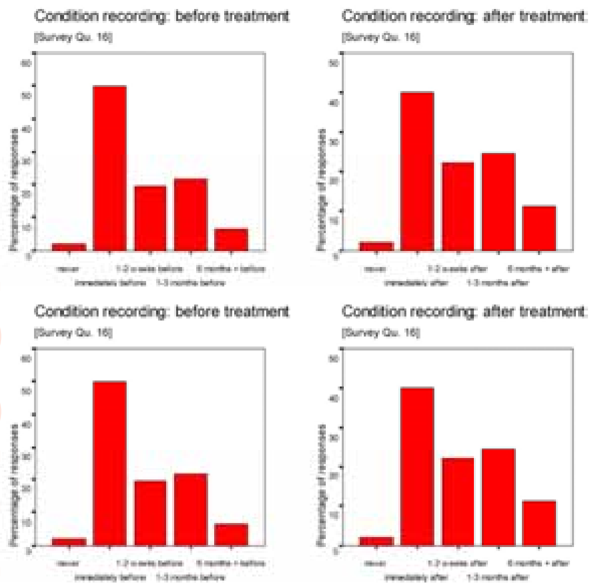

Figure 5: Pre- and post-treatment condition recording.

12. Discussion

In general, the spread of responses to the survey questions was similar for each of the partner countries, thus indicating that in the field there is a good degree of knowledge transfer taking place at an international level.

The survey findings revealed that clear preferences were reported regarding the selection of materials and methods used for desalination - such as the predominant use of cellulose pulps for poulticing, the most common application method being three repeated poultice applications each with a one week contact time. Proprietary poultice products are expensive and many conservators prefer to prepare their own mixes.

Typically, as a first step loose material (dirt and debris) including salt efflorescence is mechanically removed (or reduced) from the surface using a brush. Some conservators report following the mechanical cleaning with an initial poultice of Japanese tissue or even blotting paper. This adds a smaller amount of water and aims to dissolve and remove salt at or near the surface.

While the main materials used are known, it is not possible to make such generalised statements regarding the use of additives. The fact that salt reduction is perceived as an extremely complex topic was underlined in comments made by the survey respondents, indicating that the current state of the art could be improved by more information in this area to aid treatment selection based on the needs of each individual object.

The survey showed that the current practice in the field in relation to pre- and post-treatment investigation and assessment is still very different from recommendations in the literature. It seems clear that funding is not available for intensive analysis prior to treatment, let alone post treatment analysis and long-term environmental and surface monitoring. While experts in the research field have long been aware of the need for long term and detailed monitoring before and after interventions, this aspect is still largely neglected in the field.

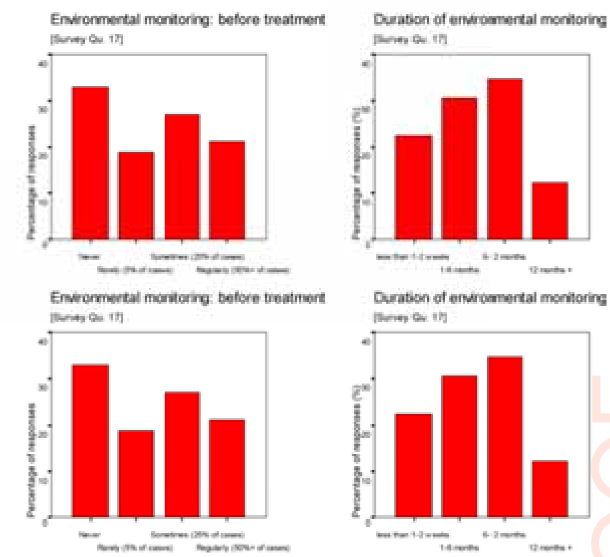

Figure 6: Environmental monitoring.

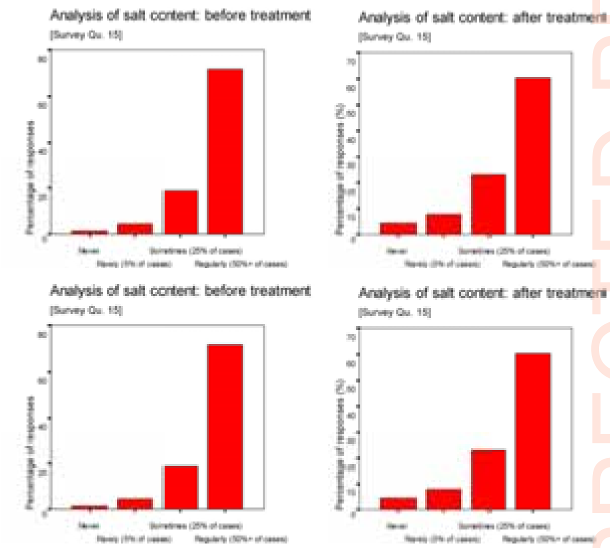

Figure 7: Salt content analysis before and after treatment

The survey revealed that assessment of the condition of the object, its salt content and its environment tends to be made immediately before and after treatment. In the vast majority of cases no further assessment is made of the treatment outcome. This clearly does not allow for adequate evaluation of the salt problem, or indeed the long-term effects of the measures carried out. It seems that analysis of removed-poultice material is typically limited to on-site semi-quantitative strip tests, and on rare occasions, in those cases where greater funding is available, ex situ laboratory analysis of the poultice material.

There were some difficulties with the survey that only became apparent to us at the evaluation stage. For example, the survey did not report what types of salt analysis are typically undertaken or if the salt content assessment was repeated after a period of elapsed time. Such drawbacks are naturally partly due to compromises that are necessarily met between the number and detail of the questions asked and ones intention to keep a survey as short and as manageable as possible, so as not to deter potential respondents. Nonetheless, in hindsight we consider that a larger-scale test run would have revealed important inadequacies, and allowed us to hone (amend) particular questions and add or omit others where necessary.

13. Conclusion

This particular survey was intended to give a general overview of the current practice in the field regarding desalination treatments, and has largely been successful in achieving this purpose. However, by their very nature, short surveys tend to raise further questions and highlight the need for more in-depth information. From the survey findings, more information is needed regarding the methods currently used for undertaking pre- and post-treatment assessments, in particular in relation to the object's salt content.

The survey revealed the preferences amongst conservators regarding materials, workability and application methods, but also importantly it highlighted areas where the work of the conservator could most usefully be facilitated by research. In particular, more could be done to aid practitioners in tailoring the selection of poultice recipes with differing characteristics to suit the specific needs of individual objects. Moreover, the survey highlighted a clear gap between recommendations in the literature and the state of play in the field. For example, while experts have long been aware of the need for long term and detailed monitoring before and after interventions, it was apparent that this aspect is still largely neglected in practice. Respondent comments indicated that the reasons for this are most often economic, but it is clear that greater awareness is needed of the importance of pre- and post- treatment assessment. The "Desalination" project aims to address both of these points, not only through the development of better assessment methods, but also by raising awareness among practitioners and those responsible for the care and maintenance of the built cultural heritage.

14. Acknowledgements

The authors gratefully acknowledge the support of the European community in funding the Desalination project (FP6 022714). Thanks are also due to fellow colleagues of the Desalination project for many stimulating discussions regarding this topic, which have contributed to shaping the ideas and arguments presented here, and also to the practitioners who generously took part in the on line survey and interviews.

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INFLUENCE OF ROTATIONAL STIFFNESS BETWEEN COLUMN ELEMENTS ON GLOBAL STABILITY OF HISTORICAL CONSTRUCTIONS

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1. Introduction

For all countries, historical constructions are of exceptional value and every single case must be treated with great care and respect. During several analyses in Dubrovnik old town we have come across specific difficulties related to column contacts. Different treatments of connections between stone column elements cause different stress distribution and may even affect the global stability of a structure.

2. Problem description

We shall describe the behaviour of connections based on several examples and propose possible ways of reconstruction. We found many specific fractures on columns, their bases and capitals, in traditionally used vault bearing systems (Figure 1). We could also see many traces of restoration and insets of different nuances and styles. Discussions with colleagues from various fields and detailed historical surveys gave us the insight into many types of damage and even types of collapse of the bearing system throughout the history. All preliminary research and experimental data point out that we are dealing with a persistent and serious problem. The logical hypothesis on large relative displacements is not confirmed by observations, measurements and calculations. However, it can only conditionally be discarded because of the short measurement time. At the same time, calculations and experiments show low levels of compression stress. We were therefore forced to seek the problem elsewhere. The examinations of specific fractures around column connections and several cracked columns (Figure 1) revealed some common properties. These traditionally made contacts between column elements were made with great care and outstanding accuracy. Namely, carefully smoothed stone areas of contact are joined with an iron dowel which is centrally placed in a bit larger hole and finally filled with lead. Thus, these contacts are assumed to safely transmit uniform compression and shear stresses. The preliminary analyses showed that insufficient dowel anchoring is the fundamental deficiency. Therefore, dowel can safely transmit only transverse force and small pulling forces. This is a consequence of small anchoring length and week adhesiveness caused by week mechanical properties of lead, especially by its affinity to creep. According to our observations, a dowel is about 20 cm long; the anchoring length is thus only 10 cm long. Obviously, this connection cannot transmit significant bending moments and its rotational stiffness is very small.

Unfortunately, connections that we found were usually eccentrically loaded for numerous reasons (disrupted bearing system, missing tie rods, eccentrically connected elements). Even small horizontal displacements (below 1 mm) cause the rotation of column elements that make problem at contacts because of minimal ability to compensate rotations. The leaning on connection edge results in a significant pressure on a small contact area. The stress exceeds compression limits and a decline of compression trajectories leads to unwanted tension stresses (Figure 2a). The outcomes are fractures near connected areas and a complete loss of bending stiffness, but the connection is still able to transmit compression and transversal force. The described connection can be defined as a hinge.

But, if we treat connections as pure hinges, the bearing system will be unstable because only three hinges, on a single vertical, are enough to make a system unstable (Figure 2b). This is a dangerous state of construction because of the small degree of static indeterminacy. All the presented data stress the significance of rotational stiffness, because the stability of structure or part of it depends on it. Even more, discarded issues must be added: tensile stress in stone due to the pressure of corroded spikes, slender columns, small vertical load, numerous interventions in the construction, current activities on structure, temperature changes and earthquakes.

3. Numerical strategies

We can conclude that the great compressive strength of stone is not essential for the bearing capacity. On the contrary, the bearing system primarily depends on stone tensile strength which ensures small rotational stiffness of joints. Without it the static system would be practically a mechanism. To prove these statements, we made numerous numerical models (Figure 3).

We introduced several original routines into the basic continuous elastic model in order to describe the real connection behaviour. A full 3D model of the complete structure, with tetrahedral finite elements, was made using FEAP 7.4 software combined with GiD 6.1.2a for data input and output. The program codes were supplemented with original routines for exclusion of the overstressed finite elements and for the search of minimal energy in given direction (line search) with the bisection method to improve convergence of incremental Newton – Raphson technique. Fracture criterion of material is determined by the modified theory of normal stresses (originally defined by Galileo and Rankine). Detailed modelling of the column connections was preformed with SAP2000 using brick elements with incompatible modes and links with ability to exclude tension stresses. Many difficulties for accurate analysis and correct treatment of connections were encountered. But numerical results confirmed our assumptions of contact behaviour and matched well with located fractures. Amount of rotational stiffness was decisive for understanding carrying mechanism, finding correct distribution of stresses and assessment of global stability of structure. In our case safety factor dropped from 10 for standard continuous elastic model to 1.4 for models based on our assumptions.

4. Conclusions

The presented data point out the complexities and difficulties of accurate analysis of the described connections. We encountered many situations where unqualified people have intervened on structures. Removed buttresses, decrease of dead load and similar situations violated the essential ideas of bearing structures. Am understanding and proper evaluation of described similar connections are essential in these cases. To ignore or depreciate real connection properties can lead to serious overestimation of the safety factor.

Also, we have tested the possibility to repair columns with thin a layer of lead placed between two connected areas. A material such as lead will enable small rotations and keep the connected areas from large stress concentrations. Lead is already used to fill dowel hole and the additional horizontal thin layer is an appropriate and almost invisible intervention.

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Figure 1: Fractures of column elements.

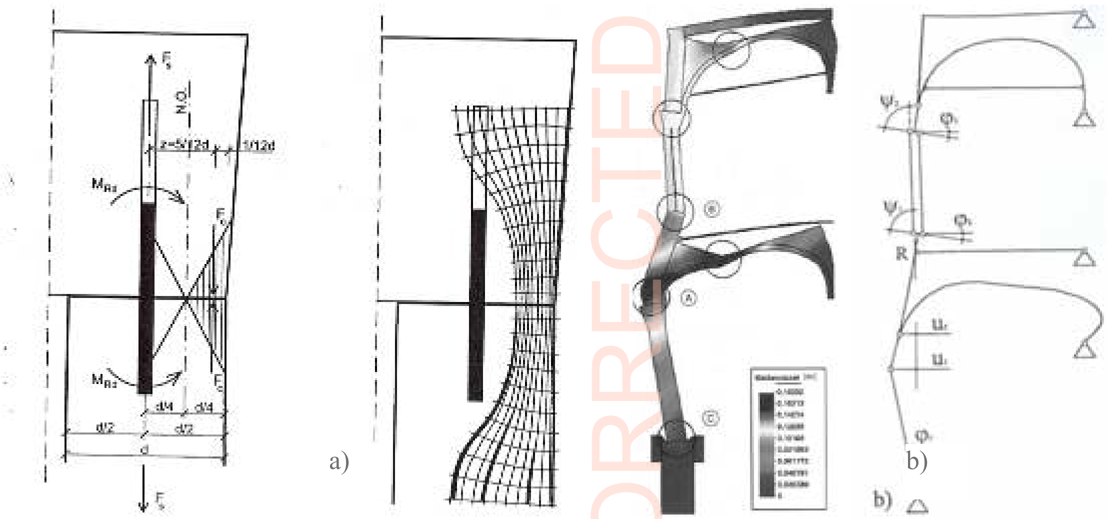

Figure 2: Behaviour of contacts.

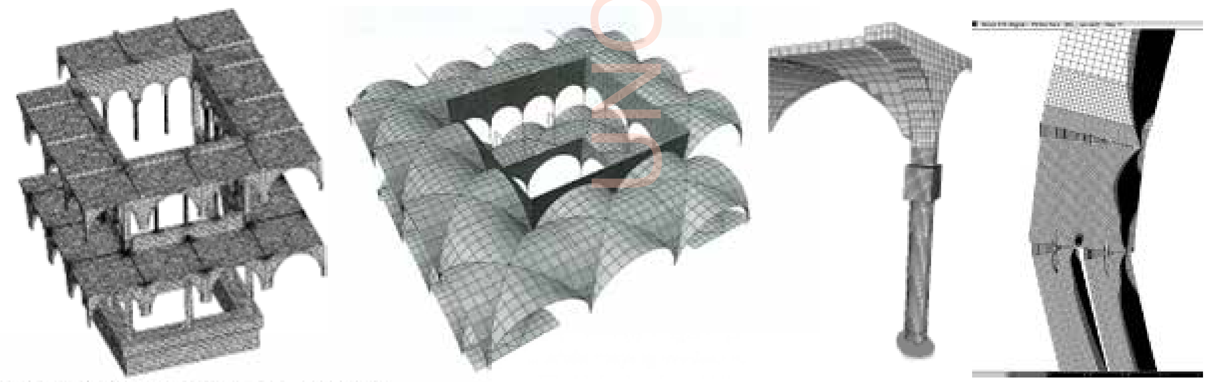

Figure 3: Various numerical models.

CAN ARCHITECTURAL SHAPES HELP DECIPHERING DATA AND STRUCTURING INFORMATION? AN ATTEMPT THROUGH CASE STUDIES

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1. Introduction

Heritage sites match the interests of many in that they materialise historical influences and differences. When analysing their evolution, researchers may take into account various indicators, ranging from specific pieces of data (survey of remains, interpretation of archival material, etc.), to generic pieces of knowledge (historical context, comparable cases, etc.). But gaining a global, context-rich vision of how an artefact or a site developed through time implies integration and a multidisciplinary cross-examination of these indicators. Since indicators cover a variety of disciplines (history, archaeology, but also knowledge representation, computer graphics, surveying technologies…), they often remain in disciplinary barriers (each discipline reading the artefact through its own indicators). In addition, a wide range of new, discipline-oriented, computer tools are today being used, which often raise complex methodological challenges for investigators: in short, the architectural heritage sometimes appears as a playground for other disciplines.

2. Approach

Our experience shows that along with new tools, researchers and professionals need a renewed, multidisciplinary research methodology. Our approach is based on the idea that shapes act as a medium allowing the integration of heterogeneous clues, thereby promoting transversal research (one artefact integrating several tools, methods and disciplines). Provided an architectural analysis of sites and artefacts is carried out under scrutiny, shapes identified as meaningful are seen as the intersection point between, on the one hand, the surveying effort, and, on the other hand, the interpretation and documentation effort.[1] Accordingly, when representing sites or artefacts, indications about their evolution (known or hypothetical) and about their present state can be integrated using a single "informational filter": architectural analysis. In the best cases, shapes may eventually act as information visualisation and retrieval disposals, through 2D/3D dynamic graphics. But applying this simple idea to real cases is far from being straightforward, and it opens several challenges, either technological or methodological. For example, in terms of surveying,[3] this approach implies a clear shift in the way data is collected since raw results of surveys, whatever techniques are used, have to be analysed so as to attach to meaningful shapes elements of the raw survey that may be used to give them geometry. Implications on the survey method itself should not be underestimated, and remain to be critically examined. In terms of information assessment, this approach implies rethinking the way pieces of information are structured, and the way they can be visualised. In short, the objective here is to foster the development of methods for studying and representing the architectural/urban heritage and its evolution where the representation of objects should not necessarily claim veracity, but should support information search and visualisation.[2,4,5]

Our contribution presents a variety of case studies through which the above mentioned implications (and others) can be illustrated, and the common research challenge underlined : how can we link information technologies with multi-scale analysis of architectural artefacts (ranging from urban fabric to architectonic details) in order to foster a better understanding and documenting of the evolutions of heritage sites?

3. Case studies

Our experiments cover a thorough investigation of survey techniques applied to architecture, and the development of web-compliant information systems for heritage sites using 2D/3D representations as navigation tools. It is applied to various real cases that are very briefly introduced in the sections below.

3.1. The medieval site of Carcassonne castle

This study focuses on the analysis of spatio-temporal transformations referring to the building scale. A place rich of historical transformations that proceeded across ten centuries, Comtal Castel in Carcassonne is a site of research revealing the problems of representing change. Events like creation, demolition, rebuilding, annexation, division have deeply modified this castle from the beginning of the 10th century until today

3.2. The triumphal arch in Paris

This project concerns the integration of several surveying and modelling techniques in order to obtain a digital representation of the frieze of the triumphal arch in Paris. Starting from a surveying campaign based on laser scanning and digital photogrammetry, this work focused on the development of a visualisation disposal able to enhance the readability of the figures represented on 145 linear meters of the frieze. A "deep map" rendering has been realised starting form an orthographic projection and its result has been assigned to every co-ordinate of the point cloud. The final colour of each point has been obtained by multiplying this value (expressed onto a 256 levels scale of greys) by the RGB value issued from the photographic texture (Figure 1). The integration of these two layers of chromatic information has allowed the creation of a fluent, real-time photorealistic rendered scene.

3.3. The abbey in Saint-Guilhem-le-Désert

Few monuments have known such a strange destiny as that of the cloister of Saint-Guilhem-le-Désert. Cut up and sold piece by piece in the XIXth century, exported and partially rebuilt at the beginning of the XXth century, in the valley of Gellone, all that remains today is two galleries out of the original eight. Its sculpted decoration is now scattered between three museums: the "Cloisters" of New York, the "Societé Archéologique de Montpellier" and the "Lapidary Museum of Saint-Guilhem-le-Désert". This situation gives to virtual reconstruction the great interest of bringing back in the same space all the original elements, thus allowing researchers to study the cloister in a new way (Figure 2). Founded on several surveying techniques and on a method for 3D model semantic structuring, this project concerns the development of an information system at an architectural scale as a scientific platform for the investigation on the monument.

3.4. The medieval heart of Kraków

The city of Kraków developed significantly during the first six centuries of the second millennium, before entering a period of relative decline. This relative decline constitutes an opportunity for us today, as the city experienced little significant change during the nineteenth and twentieth centuries compared to other cities of similar size. Moreover, years of preservation and investigative actions have resulted in the production of a large quantity of documents (descriptions, analyses, drawings, photographs, plans, etc.) which need to be collected, organised and visualised. The objective was thus to use information technologies for better management and preservation of the documentation, and ultimately for a better understanding of the urban ensemble and its elements. However, we were constrained by the need to allow collection custodians real control over the data that they manage (i.e. favour the use of technologies which do not entail the dependence of collection custodians on a particular platform). Moreover, we identified the need to develop our approach round formalisms for the Internet (thereby providing concrete solutions with regards to the question of the heterogeneity of the contents manipulated). The programme has two central priorities: first to structure and put to use heterogeneous data sets, and secondly to interface these data using dynamically constructed graphics acting as knowledge and information visualisation disposals. A number of issues are raised by this long-term programme, and among them the possibility given by the approach presented in section 2 to provide alternative visual readings of a unique set of data "filtered by architectural shapes".

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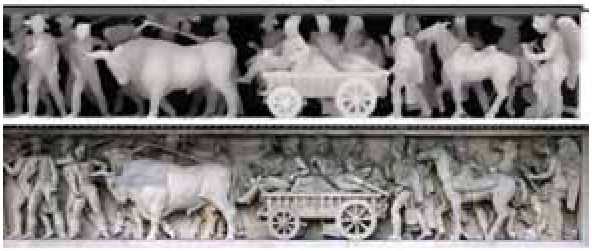

Figure 1: Digital representation of the relief.

Figure 2: Virtual anastylosis of the cloister of the abbaye of Gellone in Saint-Guilhem-le-Désert.

THE BINDING MEDIA OF THE POLYCHROMY OF QIN SHIHUANG'S TERRACOTTA

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1. Introduction

The First Emperor of China was born as prince of Qin in 259 BC. In 247 BC he became king of Qin, one of the most powerful states. In 221 he conquered the other states and united them in one Empire, calling himself Qin Shihuangdi – "First Heavenly Emperor of Qin". His burial complex, constructed between 221 and 207 BC, is situated near Lintong, 30km east of the provincial capital Xi'an. The pyramidal earth mound over the grave chamber is 70m high and is surrounded by a double ring of walls. Inside these walls, there are 79 underground pits containing burial goods, and in an area of ca. 5x6 km^2 around the walls are scattered more than 100 additional pits. Four of these contain the terracotta army. The technological knowledge and skills of the artisans working on the creation of the terracotta sculptures is astonishing. All the sculptures are different from each other. Though larger than life, they were made and fired in one piece. Afterwards, the sculptures were coated with East Asian lacquer (qi in Chinese, urushi in Japanese), which was applied in two thin layers. On the top of this glossy, dark brown surface, the sculptures were painted with bright colours applied in thick layers. The paintbrush strokes remained visible. They were sometimes used for modelling the surfaces, emphasizing facial features or indicating the thread structure of garments. Plastically applied paint even imitates structures such as birds' feathers or ornaments of silk textiles. The reconstruction of the polychromy on replicas of two warriors from the terracotta army, therefore included experiments to find a binding medium or a mixture suitable for producing layers with the structure and thickness comparable to the originals. The mixture of egg and animal glue produced the best results as the appliance properties of glue were preserved, and the layers became water insoluble rather quickly. Figure 1 shows the replicas of a high rank officer and a kneeling archer with reconstructed polychromy.

2. Experimental

Eight paint samples from the original paint layers of terracotta warriors and bronze birds (labelled 1, 1.2, 2, 3, 4, 5, 6 and 7) were analysed. Calcium, copper, lead and mercury-based pigments were present.

The samples were subjected to ammonia extraction to solubilise proteins and separate the proteinaceous matter from insoluble inorganic salts. The extracted ammonia solution was evaporated to dryness and redissolved in trifluoroacetic acid. It was then loaded on a preconditioned C18 Omix® tip. Inorganic salts and other non- or poorly-retained materials were removed by rinsing with trifluoroacetic acid solution, and lastly purified proteins and peptides were eluted with acetonitrile/water solution. The acidic solution of purified peptides and proteins was then evaporated to dryness, subjected to vapour phase acidic hydrolysis assisted by microwaves and the resulting amino acids dissolved in bidistilled water[1]. An aliquot of the amino acid solution was evaporated to dryness, derivatised with a silylating agent and analysed by GC-MS. To identify the binding medium, the amino acid relative percentage content of each sample was compared to those from a dataset of seventy-nine reference samples of egg, casein and animal glue. In particular, principal component analysis (PCA) was performed on the correlation matrix of the relative percentage contents of eleven amino acids (ala, gly, val, leu, ile, ser, pro, phe, asp, glu, hyp) and the first two components accounted for 87% of the variance of the data. The resulting score plot is reported in Figure 1 B.

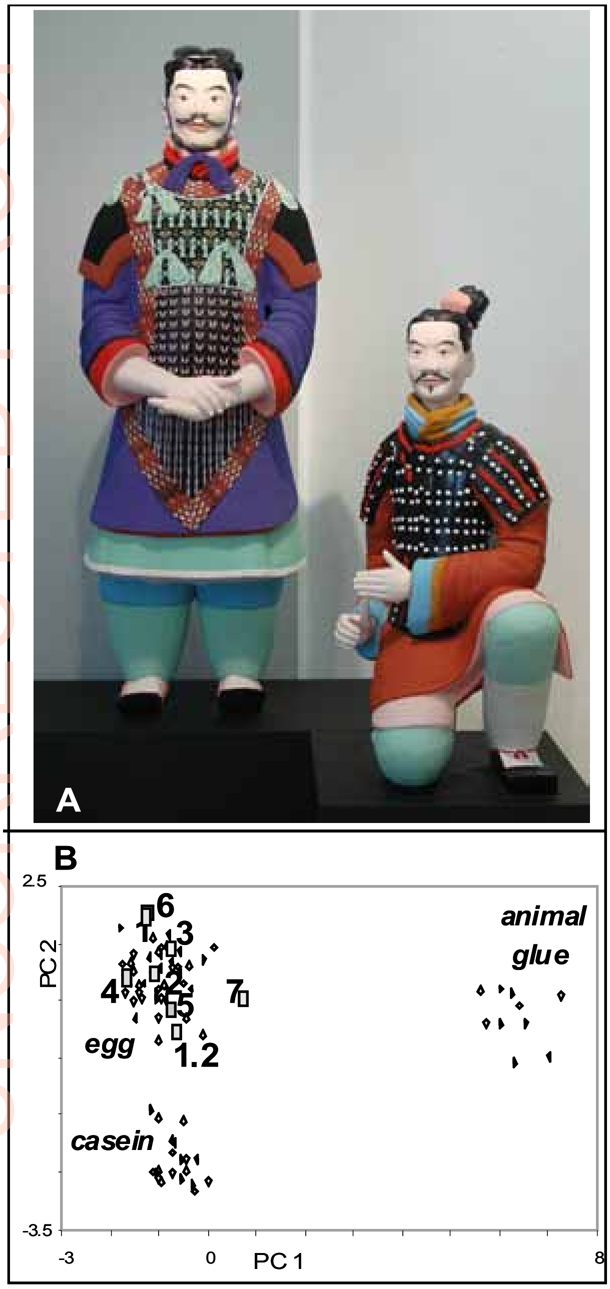

Figure 1: A- Replicas of a high rank officer and a kneeling archer with reconstructed polychromy; B - Principal component analysis score plot.

3. Results and discussion

The paint samples were clearly located in the egg cluster. These results reveal that egg was the binder used, and that it was not mixed with any other proteinaceous media (animal glue was thus absent). As the reconstructed paint tests indicated that egg alone could not produce the thick, structured layers, some kind of additive might be present and needs further investigation.

The identification of egg in the paint binder represents one of the first steps towards an understanding of the painting technique used on ancient sculptures in China of which – despite their fame – nothing is known. The artisans' choice of material on the burial goods of Qin Shihuang, in many cases would seem to prove that they were aiming for long-term stability, and it could also have influenced the choice of the binding medium. The expert use of the paint provides evidence of the skill of the artisans involved. It suggests that egg tempera had probably been traditionally used by the artisans of that period – because of its long-lasting properties.

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5. Acknowledgements

We would like to thank: Mr. Wu Yongqi, Director of the Museum of the Terracotta Army of Qin Shihuang as well as Mr. Zhou Tie, Mr. Xia Yin and Mr. Wang Liang from the Laboratory of the Museum for collecting and providing samples of the polychromy of warriors; the Archaeological Institute of Shaanxi Province, Xi'an, and the Roman Germanic Central Museum, Mainz, for samples of the bronze birds; Dr. Cristina Mossetti, Direttore Storico dell'Arte della Soprintendenza per il Patrimonio Storico, Artistico ed Etnoantropologico del Piemonte (Italy) for kindly providing the East Asian lacquer reference samples; The Central Laboratory of the Bavarian State Department of Historical Monuments, Munich and its head Prof. Dr. Rolf Snethlage, and especially Vojislav Tucic who performed the XRD analyses; Carolin Roth who realised the reconstruction of the polychromy on the replicas and tested different binding media systems.

PROBLEMS AND POTENTIALS OF THE BUILDING STOCK IN BUCHAREST, ROMANIA. FROM INVENTORY TO STRATEGIC PLANNING

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Abstract
In South East Europe the cultural heritage needs to be protected against the effects of earthquakes. Cultural heritage means not just outstanding monuments but also urban tissue of historic buildings. This paper attempts to create an inventory of the building stock in Bucharest, Romania, for the purpose of assessing problems and potentials of an urban housing construction type practiced in Bucharest, Romania, useful for seismic vulnerability diagnosis and the seismic retrofit 'mission'. First a typical mapping of the impact of an intervention in the built stock in Bucharest is presented, since retrofit always affects the built substance. The paper proceeds with defining additional criteria for an area wide survey of the building stock which may permit recognising the structural system. The result is a classification of the building stock in Bucharest in nine building types, mainly dictated by the historic development. The results were technical reports on almost all building types present in the city, even if the categorisation is broad and does not take into account building sub-classes, such as for example pure residential and mixed use for interwar buildings or subclasses based on height. The material collected was included in the World Housing Encyclopaedia.

1. Introduction
The seismic hazard for buildings in Bucharest, Romania, is represented by intermediate depth earthquakes with the epicentre in Vrancea. Bucharest is situated 150 km south of the epicentre, in the main direction of propagation of seismic waves, on the banks of the rivers Dâmbovita and Colentina on non-homogenous alluvial soil deposits. Strong earthquakes with the epicentre in Vrancea occur each 30-40 years. During the earthquake of 4 March 1977 (Richter magnitude 7.2), over 30 buildings collapsed in Bucharest, killing 1,424 people.

Inventories of the building stock for Bucharest were developed in the frame of different projects: the RISK-UE European project,[1] a resilience planning approach, and HAZUS and the German SFB 461,[2] an emergency planning approach. For HAZUS[3] the related Rapid Visual Screening method is available. The experiences of the author were with the early stages of data collection for the SFB 461, however, they leaded for creating a typological review of the housing types, resulting into technical reports included in the World Housing Encyclopaedia (http://www.world-housing.net).

A joint project of the Earthquake Engineering Research Institute and the International Association of Earthquake Engineering: an encyclopaedia of housing construction types around the world using the interactive possibilities of the internet is an example of co-operation, in virtual space. Contributions are compiled using a standard format, and constitute together a database, searchable according to criteria based on the aspects covered by the forms. Relevant aspects from architectural and structural features, to socio-economic aspects, construction process and materials, and insurance are included, either through completing check-lists or as a more detailed description. Text information is completed by photos and drawings. Strengthening technologies are less detailed presented and all relevant aspects are brought under one section.

Aim of the paper is an overview of the vulnerability of the building stock in Bucharest in order to identify the problems and potentials of an urban housing construction types practiced in Bucharest, useful for diagnosis and the retrofit 'mission'. The planning strategy is developed in this case each on building scale. The distribution and of buildings on urban scale was documented.

2. Site survey
The first step was carrying out the site analysis. For this reason several criteria and the classes in which buildings could be categorised according to those criteria were set. An investigation on site followed this. The site analysis was performed considering the exteriors of the buildings. The data obtained was stored in photography and text, collected in form of questionnaires.

Mapping the impact
"Environmental Impact Assessment can be defined as: The process of identifying, predicting, evaluating and mitigating the biophysical, social, and other relevant effects of development proposals prior to major decisions being taken and commitments made."[4] Decision makers shall consider the influence of projects before proceeding with these projects.

Similarly to the environmental impact assessment, a study of impact is performed before promoting an architectural project, an intervention on a building, site or neighbourhood. In order to help assessing the impact, the following characteristics were mapped:

- quality of urban elements and spaces;
- functions;
- hierarchy of the elements and of the façade;
- architectural style;
- height and vegetation;
- building material and maintenance state.

These maps are useful in order to measure the impact of interventions on existing sites. Such interventions can be retrofit with influence on the exterior appearance of buildings or demolishment and rebuilding. In an urban regulation, in Romania, different zones are foreseen and for these specified which: the construction permit, the construction regime, the height category, the terrain occupancy, the coefficient on terrain usage, the minimal parcel width, along with supplementary observations to the above. Conclusions are drawn regarding implications on the investigated element, recommendations (function; conformation: height, façade, parcel), and the impact assessed. The intention is to develop are an alternative (information) instrument to the classical indicators: the 'seismic print'. The print measures the impact of an earthquake on the urban unit of an area. It is derived from the ecological print.[5]

Surveyed characteristics
For the assessment of the vulnerability of buildings, some of the characteristics mapped in the impact study are useful:

- the function of the building can be changed in order to result into a lower importance class and lower vulnerability;
- the architectural style can determine the period when the building was raised and hence its age;
- the building height presents certain interdependencies with the period of vibration;
- the building material is to a certain extent linked to the vulnerability of buildings, although in both reinforced

- the building material is to a certain extent linked to the vulnerability of buildings, although in both reinforced concrete and in masonry load bearing systems the most vulnerable and least vulnerable structures can be found, depending on the structural type.

Therefore the survey further concentrated on determining the structural type. Nevertheless the information on the mapped characteristics can be useful in determining the over-ordered building class and thus restricting the structural system types to look for. Those elements which contain references to the aspects of the building which have to be investigated are called here "relevant building elements".

Some "relevant building elements" also contain references to the architectural style. There was a corresponding construction practice to a building style and thus the structure, not only the age, can be determined this way. In what concerns the age, sometimes the certain construction year is specified at the main entrance, either over the door or on the floor of the hall. Conclusions about the age can lead to further information concerning the structural type which was usual in that time, earthquakes the building passed through and might left traces and in the best cases the code according to which it was built. For example all Romanian buildings erected before 1950 were designed for gravitational loads only but buildings from between 1941 and 1950 have not suffered under the shaking of the earthquake in 1940. Earthquake degradations have cumulative character. The resistance of materials also varies in time under effects of corrosion, permanent loads like traffic or accidental loads like those from war or earthquakes.

If the style of a building is not defined, a critical point is to decide which details belong to the survey. A special attention was given to take photographs of structural details, the later called "key structural elements". Structural details can be identified in two situations:

- in places with removed finishing,
- typical for a certain construction type from studies previous to the survey action.

Construction details useful to recognise a building type can be determined observing partly demolished or unfinished structures at buildings of the same kind, buildings of the same kind undergoing a retrofit process or old photographs. Literature can be a valuable help in what concerns the description of details depending on structural types: for example how were consoled fixed or which characteristics describe a bearing wall as such. In many cases the side facade to the court is richer in relevant elements. Facade walls must be compared to the interior ones when possible. Staircases, fire walls, windows, balconies, loggias and floors belong to places rich in relevant building elements. These are all places where a section through the finished building is seen. Besides these, places with bare structure are relevant in the same way. When buildings are not well maintained, they present many such places. It is especially important to look at the walls, downside of floors and at the corners of the buildings. A good place to get information is the part of the wall corresponding to floor change. It is the in-between place from visible masonry or stone plating to the bare structure parts which helps avoiding evaluation mistakes. Both in case of deciding the floor structure after the balcony/loggia section or from internal observation more floors have to be looked at and compared. It is important to date buildings.

In order to determine the structural type the following characteristics were collected:

- material of the structure;
- frame construction with structure out of which material and infills out of which material;
- load-bearing wall construction out of which material, pre-cast or not, if masonry reinforced or not;
- mixed structure of frame and load-bearing walls;
- floors out of which materials;
- construction time.

After the survey the preponderance of certain types was visible, described in the next chapter.

Typological survey

Once the structural system recognised, the buildings were classified and several detailed reports compiled. The classification followed the architectural style and the relevant building elements are also described. For this purpose the questionnaire of the World Housing Encyclopedia (WHE) was used and the data entered into the database provided by the encyclopedia. The building types surveyed cover the relevant housing construction types in Bucharest, Romania (Table 1). So with this data stored the Romanian building stock can be described.

Table 1: Goal achievement degree.

Building type	EMS						Building	Retrofit
	High seismic vulnerability = very poor seismic performance		*Medium vulnerability*			*Low vulnerability = excellent seismic performance*		
	A	*B*	*C*	*D*	*E*	*F*		
eclectismus	|-	*	-|				65.3%	53.2%
Art Nouveau: one family		|-	*	-|			69.8%	70.7%
Art Nouveau: more families							70.4%	58.1%
interwar	|-		*	-|			65.2%	75.2%
postwar			|-	*	-|		70.8%	69.7%
OD				|-	*	-|	77.3%	74.2%
Y			|-		*	-|	81.7%	94.2%
socialist			|-	*	-|		80.4%	no measures
contemporary			|-		*	-|	77.1%	80.0%

In case of Bucharest, a few maintained buildings from the time before 1850 can be included in one category. Apart from churches, which stylistically fall under the rules of Byzantine, Middle Age or early Classicism, a small number of wooden constructions of the so-called "Fanariots" (ruling Greek dynasty in Romania) can be found. These can be recognised as having wood as their main constituent to the yard, at balconies over more floors. They don't present occidental elements, like their successors almost always do, have elastic structures, which survived many earthquakes, and their maintenance can be concluding to the vulnerability. They weren't investigated in this paper, however, some of them function as gathering estates (restaurants) and are therefore of interest for seismic assessment.

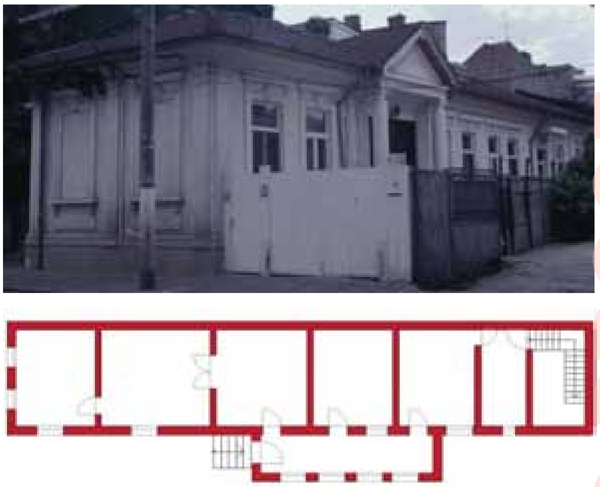

Figure 1: Wagon house (figures from ref. 6).

More buildings, both representative buildings and common dwellings are preserved, from the period of 1850-1880 (Fig. 1). From a stylistic point of view this is the time of new gothic, classicism and eclecticism. Representative palaces, designed under French influence or by French architects, distinguish themselves through a hitherto unknown scale. Meanwhile they respect the Bucharester tradition of single isolated houses. Multiple housing units and built block islands were long unknown to the town. Typical for this time are eclectic one family houses in so-called wagon-type, because their rooms open one into the other without corridors and are arrayed. They can be recognised through their narrow street facade, with usually two decorated windows and the strongly marked entrance door on the side facade. They have mainly functional rehabilitation problems, while the seismic vulnerability varies and is less influenced by design or conformation and more by execution details. A wagon house type from the time of the eclecticism was investigated and the results included in the technical report by Bostenaru and Sandu.[6]

The period 1880-1920 is the one of Romanian Art Nouveau, called "Neoromânesc". Stylistically it is a trial to take over forms of popular architecture into representative buildings. In this period many buildings of extensive dimensions harbouring diverse public functions like town halls, restaurants, universities were erected. Constructions aimed for housing are represented through single family as well as through multiple housing units. In-between spaces, the Neoromânesc loggias, differently treated from the fanariot wooden balconies, are characteristic. They mark representative places (like the facade of the town hall or of university buildings) and have rich ornamented arcades. A further difference is that their arcs and columns, obvious in case of wooden columns, don't reflect the bearing structure. A noticeable structural characteristic of buildings of this time is that the load bearing system, especially floors isn't homogenous in height.

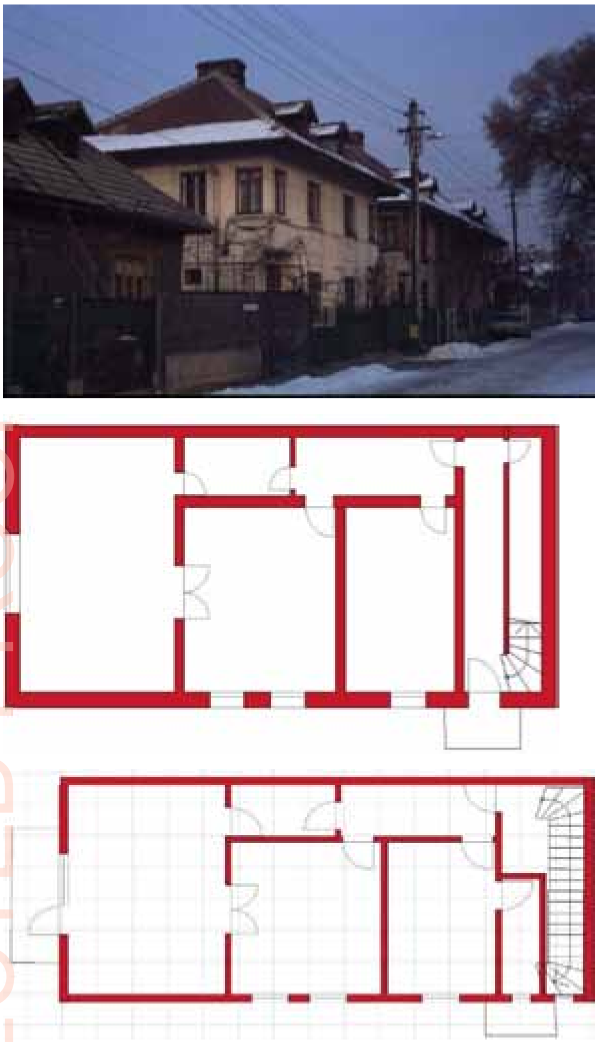

Figure 2: Two storey house (figures from ref. 7).

Among other aggregate structures, floors of ceramic bricks on metal beams are met in the basement and wood floors in the upper storeys. While this periods housing didn't awake a noticeable interest of architecture historians and therefore there are few sub stratums to build further seismic vulnerability research on – there is little known about typical construction techniques and very few available surveys –, for representative buildings expert reports were carried out (like the Bucharester town-hall). Seismic capacity proved unsatisfactory and in some cases retrofit projects are already completed. In other cases visible rush stabilisation measures carried out after past strong earthquakes (like the stair case in the hall of the Faculty of Architecture, old wing, which proves little stability even at normal traffic last, at the time of the survey within SFB461 in April 2000, but which is process of retrofit now). Due to their size a separate evaluation of seismic vulnerability of particular and public buildings is required, as well as study concerning the housing units of different kinds, before drawing general conclusions. However, there is little known of severe earthquake damages of the past on this kind of housing units. Two buildings from this type were investigated: a low rise (Fig. 2) and a middle rise building (Fig. 3) in the report Bostenaru and Sandu.[7]

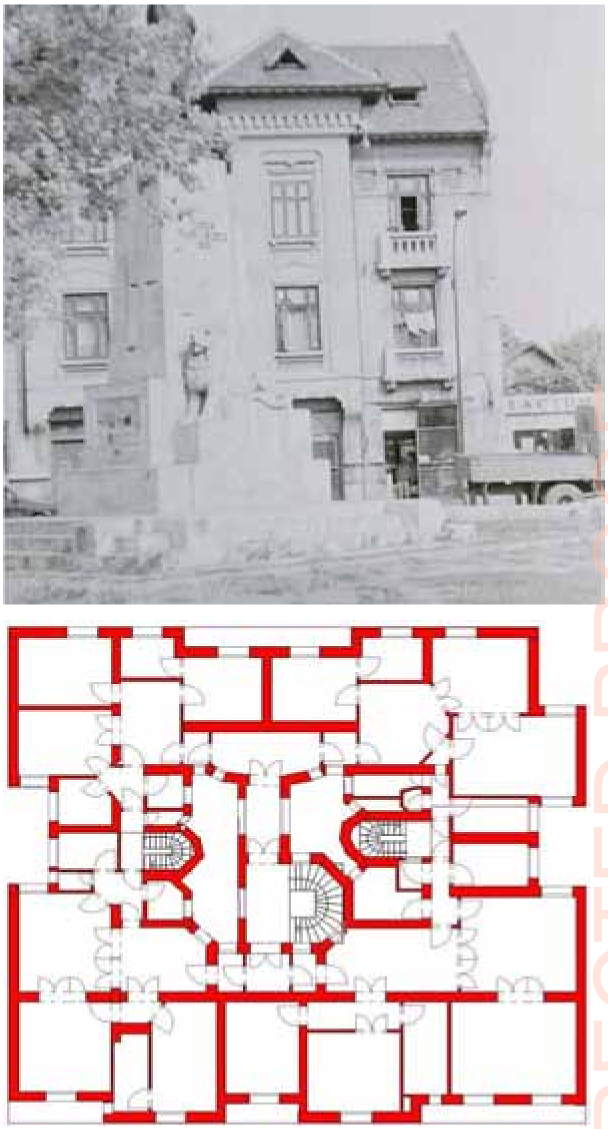

Figure 3: Art Nouveau multi-storey (figures from ref. 9).

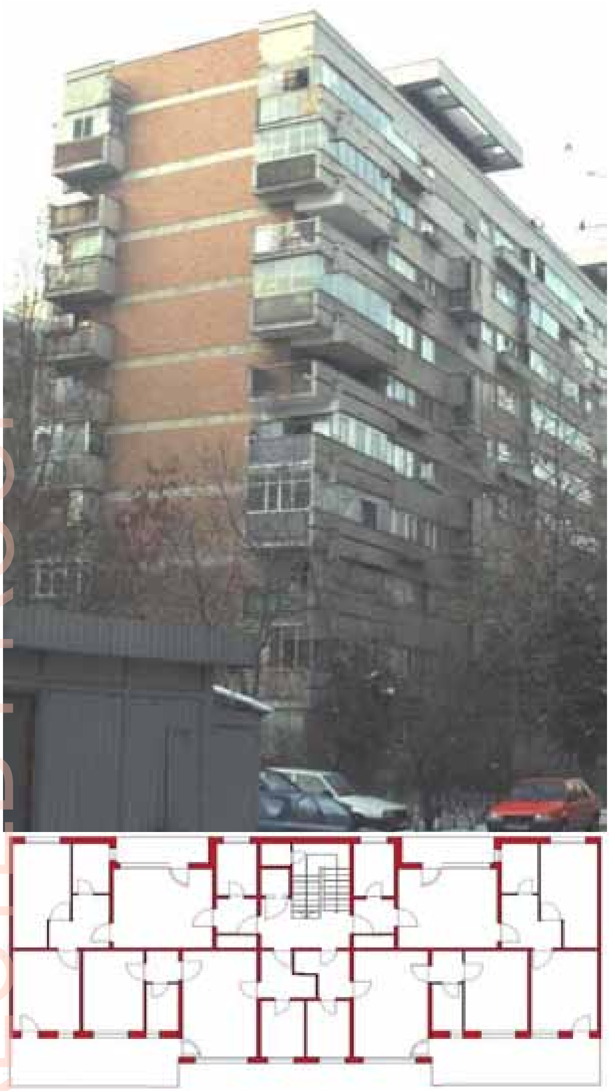

Figure 4: Interwar block of flats (figures from ref. 8).

The constructions giving the Romanian capital's today face were built 1920-1945 in the style of modern Avant-Garde, one characterised by several unmistakable features (Fig. 4). Such one is the emphasis of the horizontal line through window bands and/or balconies, which build a continuous facade surface. Often the transition between them is made through a window corner, divulging the console there. Another seldom missing feature are recesses.

As the Avant-Garde buildings marked the large scale entry of reinforced concrete into the construction industry and that of multiple housing units into the functional repertoire, modern reinforced concrete buildings were much higher, but an urban planning rule constrained the street cornice to remain at the same lower height. Thus the topmost floors were recessed each about 1.2 m behind the other. Single family houses were further built respecting the new stylistic rules. In the 1977 earthquake the majority of collapsed buildings were multiple housing units of this kind. Meanwhile, a vulnerability assessment of this building type has to be differentiated, as different functional layouts leaded to various structures. There are blocks of flats with flexible ground floor harbouring shops which are also highly vulnerable. And finally there are blocks of flats with housing as their single function, accompanied sometimes of garages in the semi-basement which are less vulnerable. The report by Bostenaru[8] discusses exclusive housing use. Sometimes the role of the bearing elements swapped and the well made masonry infill may have a more important role for the structure as the, mostly bad maintained reinforced concrete elements.

The post-World War II variant of the Avant-Garde buildings was practiced in Bucharest rather a short time, from after the War till the nationalisation in 1947 (Fig. 5). This type was investigated in and the data entered in the technical report Bostenaru and Sandu.[10]

The need for fast available dwellings after the Second World War left its traces on the Romanian architecture scene, too. Buildings raised between 1945 and 1977 in satellite "towns", as in the theory Le Corbusier's, of isolated blocks of flats with much green and vegetation around. Economic reasons dictated either height of 5 or of 11 floors and leaded to a rather monotonous image, but nevertheless thus the height became a characteristic of these buildings. Facades are simple, sometimes ornamented with mosaic or brick plates. The windows are emphasised either horizontally or vertically. Most buildings have a cast-in-situ, but some pre-cast shear wall structure. In this case at least the back facade traits the system through visible joint lines. Both are of lowest vulnerability, and it is known that about 60% of new housing in Bucharest was built in this way. Depending on the structural design, quality of the execution and building site, buildings of this type behaved differently well in past earthquakes. A survey in quarters with such buildings is relieved by the typological design, which allows for drawing conclusions for a big number of constructions by knowing one type. Two different construction types, both with cast in-situ concrete shear wall structure, in honeycomb plan, from the time 1965 to 1989 were investigated and reports compiled: buildings of OD-type (Fig. 6[11]) and the Y-type (Fig. 7[12]).

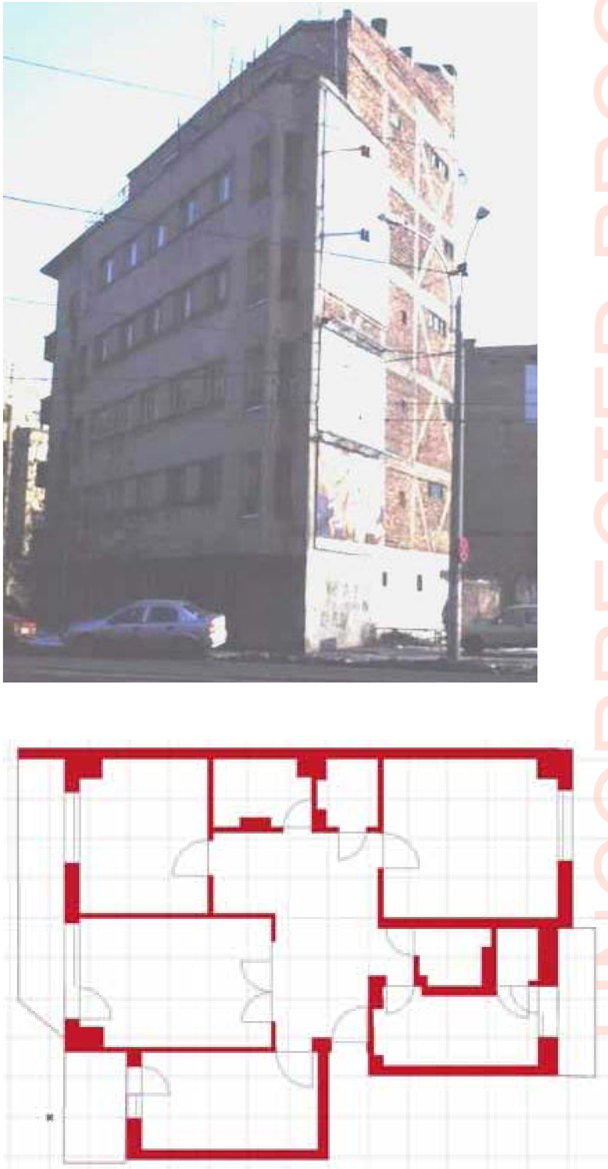

Figure 5: Block of flats with RC frame structure with diagonal bracings (figures from ref. 10).

Figure 6: OD building type (figures from ref. 11).

Figure 7: Y building type (figures from ref. 12).

After the 1977 earthquake, concomitantly with the rebuilding of the town, new construction guidelines were released. The buildings or building units are to be grouped to 'blocks' (closed islands around a court) and the street facade was decorated under the windows and balconies, in a neo-classic manner. This changes today when the facades are redesigned to a play of colours (mostly orange and pink) with the thermal rehabilitation of facades. The height palette is wider and varies even in the same building. Structurally there are mostly reinforced concrete frame constructions as well as pre-cast concrete shear wall buildings. Housing units with commercial functions in the ground floor were designed with a special load bearing system, the so-called dual-system. Some of these buildings replace the ones collapsed in the 1977 earthquake, while some others build the side walls of new streets and thus they are to find both in the city and in the periphery. Frequently they hide broken streets with single family houses. In many places in the town buildings of this kind weren't finished and thus exactly the bearing structure is shown off. This type can be regarded as less vulnerable. A housing type with pre-cast reinforced concrete large-panel construction load-bearing system (Fig. 8) was built in Romania.[13]

After the fall of the socialist regime in 1989 the design practice changed. Two main styles persist concomitantly: High-Tech, with its glass curtain walls, and Post Modern, buildings with more or less historic ornamental quotes. The last type has in the majority of cases the same structural system previous mixed use buildings. Some more vulnerable variants have beamless flat slabs. This type is still practised and a visit to building sites can help evaluating the structural system. Buildings with moment resisting frame structure (Fig. 9) were investigated and the data entered in the technical report.[14]

3. Results and discussion

In the multicriteria decision system the decision tree, the decision matrix and the cooperation between the actors in urban planning were modelled.[15] In a further development,[16] this was adapted to the categories included in the WHE, and thus two decision trees, one for the new building and one for retrofit resulted.

Since the 1980s the image of planning changed in two regards. The image of planning is characterised by co-operative action17 and the strategical planning was developed as a solution to the change in the understanding of planning. Today, instead of participation of citizens, communication is aimed for, which is, according to Selle17 a collective term for information, participation, co-ordination and cooperation activities. With cooperation the decision process is relocated to the exterior, through the acceptance of simultaneous decision processes in own action fields outside politics and administration. The 'ingredients' of a strategic plan for the reduction of seismic risk are action plans, goals, operative means, human resources, time and costs, oriented on the analysis, the evaluation, the setting of priorities and the communication.[18]

In ref. 18, the interdependencies and the phasing of urban management operations have been shown. The management module 'identifying problems and opportunities' covers the operation of transforming data to information, with the function of problem analysis. In a next operation, with the management function of generating alternatives, relationships between the problems and opportunities are set. A following operation concerns the pathology, with the function of predicting. 'Evaluation' is operation and management function in one. All three described operations compose the management module of the 'diagnosis'. The subsequent module, of the so-called 'mission', is a first one with decision function. It comprises the operations 'priority setting' and 'goal stipulation'. In a next module objectives and sub-objectives are defined, as main and partial tasks in field of operations. The third management module with decision function comprises setting up measures packages. These constitute at the same time an operation, which is then followed by setting up the strategy, in form of an action plan. Decision is followed by implementation, in form of a model project. In this later case, classic project management can be employed. Finally, the last management function, control, is operatively reflected in the feedback for a 2nd implementation phase. All these are graphically exemplified.[18]

Figure 8: Pre-cast building (individual figures from ref. 13).

4. Conclusions

A survey of the building stock in Bucharest, Romania, was performed. The starting point was the mapping of the impact, then the surveyed characteristics were described. After the survey, some common housing types for Bucharest were identified, all of them from the late 19^{th} century respectively 20^{th} century. These were documented in photographs, drawings and text information. This information is useful for the ongoing project of the author on the evolution of the zonification of plans in the 19^{th} century. The layout of structural elements, the construction materials and the previous damage in earthquakes determine the vulnerability of housing buildings in Bucharest, Romania. Based on this vulnerability seismic retrofit measures can be recommended, in form of strategic planning.

Figure 9: Moment resisting frame building (individual figures from ref. 14).

5. Acknowledgements

The work within the World Housing Encyclopedia project is useful for the further research on the "The innovation in the plan of the current floor: Zoning in blocks of flats for the middle class in the first half of the 20th century" (PIANO project) since it displays the evolution of the current floor plan. The financial support of the European Commission to present this work at the CHRESP conference, grant agreement MERG-CT-2007-200636, for the project with the acronym PIANO is gratefully acknowledged. The CHRESP travel grant to Ljubljana from the conference organisers is also gratefully acknowledged.

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CRITERIA FOR THE SELECTION OF REINFORCED CONCRETE STRUCTURES TO BE PRESERVED

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Lewis Mumford once wrote that the stones of Athens would not tell us the story of urban life in the city, hadn't the written heritage remained. But the stones in Ostia tell another story: the story of construction technique. They display the material concrete, an artificial material that could be employed to create a different type of architecture. Compared to the Greeks, the Romans introduced the vault and the dome with the help of concrete; one only has to think of the Pantheon. Existing buildings tell such stories, on construction materials and techniques.

This paper is about the preservation of reinforced concrete buildings, buildings built with the new material of the 19th century: reinforced concrete. To the artificial stone concrete iron, and then steel reinforcement was added, thus changing its structural behaviour. Not only the technology but also the acceptance of reinforced concrete influenced the generated shapes and the surface treatment. Avant-Garde architects started to employ reinforced concrete in housing construction in the years 1920-1940. During this short span of time several different architectural styles co-existed with newest developments in music, arts, physics, philosophy, economic and social theory and industrialisation. Housing was a priority programme of the Avant-Garde of the Modern Movement. Advanced construction technology was employed before the possibilities of the materials and the construction systems were researched.

In the CA'REDIVIVUS project, financed by the European Commission with a Marie Curie Individual Fellowship 2005-2007 within its mobility scheme the preservation of early reinforced concrete buildings in earthquake prone zones of Europe was investigated. The objects of the investigation were early reinforced concrete buildings in Romania, Italy, Greece and Portugal. This research is now continued in the frame of a Marie Curie Reintegration Grant, project called PIANO, running 2007-2010. The objects of the investigation are the blocks of luxurious flats from the interwar time in Romania, Italy, Greece and Hungary.

The Modern Movement introduced the concept of the free plan and that of the Raumplan. Before that, in solid structure buildings, a structural plan was employed. The latter meant that structural elements were delimiting the space. In the free plan the elements determining the space are independent of the structural elements, while in the Raumplan there is interdependence. But the employment of new technologies, such as steel and structural concrete made it possible that such shapes of plans were created. User exigencies with regard to housing are different today to those from the time when these buildings were raised. The lifestyle changed during almost hundred years. The preservation strategies of early reinforced concrete buildings address the challenge of the change. Often preservation interventions do not respect the character of the building given by the reinforced concrete structural skeleton: the free plan or the Raumplan. This happens either due to structural retrofitting or to new zoning desired by the present inhabitants.

The term 'mission' derives from a strategic approach to urban management and operations in urban planning. In this parlance carrying out a 'strategic mission' means the process of carrying the measures in order to gain the objectives of the plan. The mission is formulated based on the diagnosis. The mission includes goals without priorities. Each point is a sub-objective for an actor implied in the retrofit measure, meant to be reached through packages of measures. Within a strategic planning framework the means for reaching the envisaged goals are also assigned. A package of measures includes communication means, implementation means, and implementation plans at different levels and time horizons, forming action plans. Implementation means result in model and pilot projects for operations, which are also concretisation forms for action plans.[1]

In this work a decision model is developed to determine the most suitable preservation strategy. The first step in developing the decision model is the determination of the criteria employed by various actors involved in the preservation. Four groups of interests were identified: organisational, social, technical and economic. The criteria of the architect address aspects of spatial organisation. Subgroups of criteria with regard to the way historical aspects are affected, the intervention to the whole building, the building elements and the materials. The criteria of the inhabitant address the social impact of the preservation measure. They regard the execution conditions, the acceptability of the measures, the use of the building during and after the measure and its residential value. The criteria of the engineer are with regard to the technical aspects of the implementation of the preservation strategy. They accomplish the vulnerability, the structural performance, the retrofit system and the implementation strategy of the retrofit system. Finally, the investor is concerned about the economic aspects of the preservation: the management strategy, the availability of technologies, materials and funds and various indicators showing the relationship between reparation and rebuild.

In the first phase[2] the utility value method was applied. For each criterion a from-to span was attributed and a measurement unit. For non-measurable criteria the units and points were set and the data table contains also observations on the units. Each criterion is assigned also a weight it has in the decision tree. This utility-value method is supported by an electronic data editing environment as an MS Excell file developed by Ulrich Bogenstäter at the University of Karlsruhe. A second step is the transition from this utility value based approach to a pair-wise comparison method, a multi-attributive decision system. For this purpose it was begun[2] with the development of a multimedia system. In the paper the balancing of the criteria itself will be shown.

The above mentioned criteria were determined with the method of regression[3] and in his work techniques were analysed useful in building planning with an emphasis on decision related aspects. The usage of some of these techniques gives adequate instruments for a systemic decision. Such one is an approach where characteristics and criteria are deducted based on analysis of existing projects, while know-how is derived by means of scientific disciplines. In this work, decision trees were modelled by regressive means using a related approach. Regression was used for determining the goals of the architect and the criteria concerning the retrofit elements. For both data sets are obtained from case studies and the hypothesis for the decision tree induced. From these individual hypotheses a single hypothesis is obtained, to be integrated into the mission/recommendation. Then hypotheses for the individual elements are derived and finally statements about them deducted. These statements are feedback compared with the induced hypothesis in order to regressively reformulate the later. The paper presents which were the data sets and the hypotheses in induction and the hypothesis, hypotheses and statements in deduction for all four categories of the actors.

An example is considered. It is a building with reinforced concrete skeleton structure, seismically retrofitted with steel braces. Steel braces are a retrofit method easier to compute in software which can compute line elements. In the case study various amounts of retrofit were proposed. The ranking of the retrofit alternatives determined through the pair-wise comparison method differ from the point of view of various actors. The balancing example given was for different locations. One can be considered also for different actions (different retrofit measures). Examples known by the author of the two discussed criteria comparison methods (utility value and pair-wise comparison) are at different geographic scales but they proved suitable at building level, as this study demonstrates.

In this paper a multidisciplinary approach has been considered. However, there are also disciplinary criteria employed as survey criteria by different professionally associations with an interest in preservation. Such, the survey form developed in the World Housing Encyclopaedia considers the same categories as in this paper but not in an equal amount. The structural engineering aspects are given most space. In the survey form of the DOCOMOMO (Documentation and Conservation of the Modern Movement) the architectural preservation is predominant. No such disciplinary databases of this kind are known for the point of view of the user or of the investor. In disciplinary sociological circles statistical surveys are spread. The author of this paper proposes a case-study based approach.[4]

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NEW OLD BRIDGE (STARI MOST) IN MOSTAR – A "REINFORCED" PERFECTLY SQUARED STONE BRIDGE

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Abstract
The Old Bridge ("Stari most") on the Neretva river in Mostar, Bosnia and Herzegovina, built from 1557 to 1566, destroyed in the 1990 conflict, was rebuilt in 2004. According to UNESCO "The Old Bridge area, with its pre-Ottoman, eastern Ottoman, Mediterranean and western European architectural features, is an outstanding example of a multicultural urban settlement. The reconstructed Old Bridge and Old City of Mostar is a symbol of reconciliation, international co-operation and of the coexistence of diverse cultural, ethnic and religious communities". A rehabilitation project was initiated in 1999, began in 2001 and completed on July 23rd 2004. In April 2000 Italian company General Engineering, specialized in design, survey and diagnostic, together with the Department of Civil Engineering of the University of Florence, was in charge of the design for the reconstruction of the Old Bridge. During the year 2000 and in part of the year 2001 General Engineering has proceeded to the execution of the necessary surveys and of the architectural design, while the Department of Civil Engineer has completed the structural design. They have been working in collaboration with other companies involved in other bids pertaining to the same project (German company LGA in charge of laboratory tests on construction materials, Croatian company Omega Engineering and others). International Commission of Experts (ICE), together with UNESCO was supposed to guarantee correct execution of designs and works. It was one of the most prestigeous and ambitious UNESCO-Projects: "to copy a historic masterpiece by using adequate materials and forgotten technologies, to build a replica of a lost heritage". From 2005 Mostar is among 17 cultural cities inscribed on UNESCO's World Heritage List.

1. Introduction
The bridge span is 28.7 m and the arch raise is ca. 12 m. The shape of the arch was something completely new for the area. Concerned with the huge span and the characteristics of the material being used the builder manages to make a rather thin but elegant structure.

The Old Bridge was built by Hajrudin, student of the famous Kodza Mimar Sinan. The bridge was completed in 1566 in the last year of Sulejman Magnificent's reign. Hajrudin made the front walls on both sides 80 cm thick and refused to fill the cavities or core of the bridge with heavy stones and soil which was the usual procedure on other bridges (Žepa bridge for example). Instead of this he introduces one middle rib and where possible he incorporated cavities to reduce the weight of the bridge. This method of construction was used on the "Kriva ćuprija" bridge which straddles the Radobolja creek, a tributary of the Neretva river.

The main structural element of the bridge is the load bearing arch with a depth of 3.95 m and an height of 0.8 m. The arch is composed of 111 rows with 2 to 5 (more frequently 3 to 4) voussoirs (arch stones). Shapes and sizes of stone blocks are variant (average 0.4×0.8×1 m).

Design of bridge was far ahead of its time. In contrast to other structures of this era, the Old bridge is hollow inside (weight was reduced by more than 40%), what is nowadays the most common approach for reinforced concrete construction.

The arch, because its shape, was subjected to compressive strengths. The connection of the stones among each other were performed with the use of mortar and of metal reinforcing connectors: dowels among row joints, cramps for side joints and extrados cramps mounting in a continuous layout to guarantee a tying action. The use of forged iron devices to strengthen the structure was one of the peculiarities of the monument and was applied almost to every element of the bridge following different assembling methodologies. All the other stone elements of the bridge were linked by metal connectors, including the parapets which were doweled to the upper cornices and linked one to each other trough cramps placed on top edge. Metal cramps, dowels, stirrups, melted lead poured through carved channels. This was the wise assembling techniques that was used by the Ottomans almost five centuries ago! The Old Bridge stone elements were reinforced trough the use of metal reinforcing connectors made in hand forged iron. So, the Old bridge is an "reinforced" perfectly squared stone bridge.

The bridge arch, cornices, spandrels and parapets were made of "tenelija" stone (local oolithic limestone of Neogene age clasified as oosparit) from Mukoša Quarry, 6 km south of Mostar. Tenelija is stone of yellowish colour at the moment of extraction from the quarry and it has light brown colour in moist state. In accordance to categorisation of architectural-structural stones, tenelija belong to the group of stones with very low strengths (25 to 45 MPa), week resistance to wear (resistance by Böhme – app. 48 $cm^3/50\ cm^2$), middle class heaviness, extreme porosity and great water permeability (app. 10^{-6} to 10^{-5} m/s).

Being the bridge arch, at the top, considerably higher than the adjacent street levels (about 2.7 m), the footpath over the bridge was steep and tilt in a way that all the architectural elements, like spandrels, parapets and upper cornices were following these directions until the top. Spandrel walls of the bridge were divided from the arch by a stone cornice (lower cornice), that followed the arch curvature, and were limited on top by another cornice (upper cornice), of straight but tilt profile.

Lower cornice stones were jutting out from the load bearing arch and determined the base from which started the spandrel walls; at the same time upper cornice was jutting out from the spandrel walls and finally parapets were almost aligned with

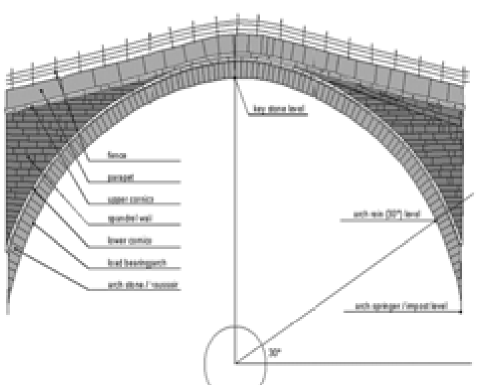
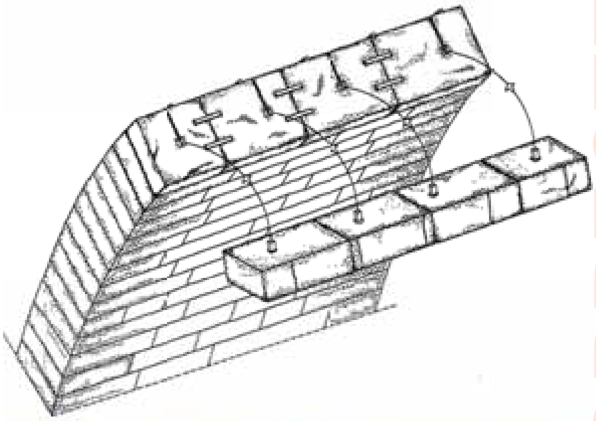


Figure 1: Bridge elevation with identification of the terms used (General Engineering WorkGroup).

Figures 2&3: The Old Bridge (above); "Kriva ćuprija"; a prototype of the Old Bridge (below).

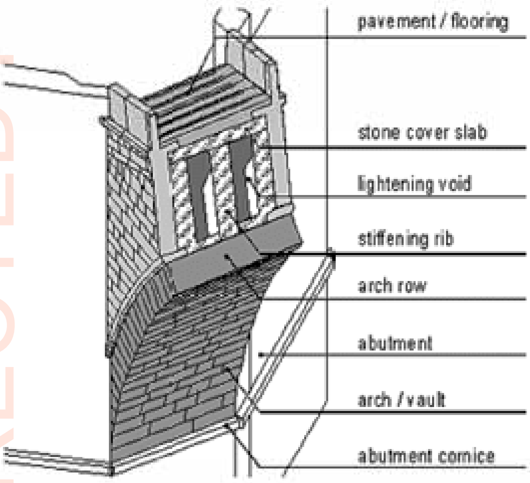


Figures 4&5: Axonometric view of the load bearing arch during the assembling stage, General Engineering WorkGroup (above), with a detail of construction (below).

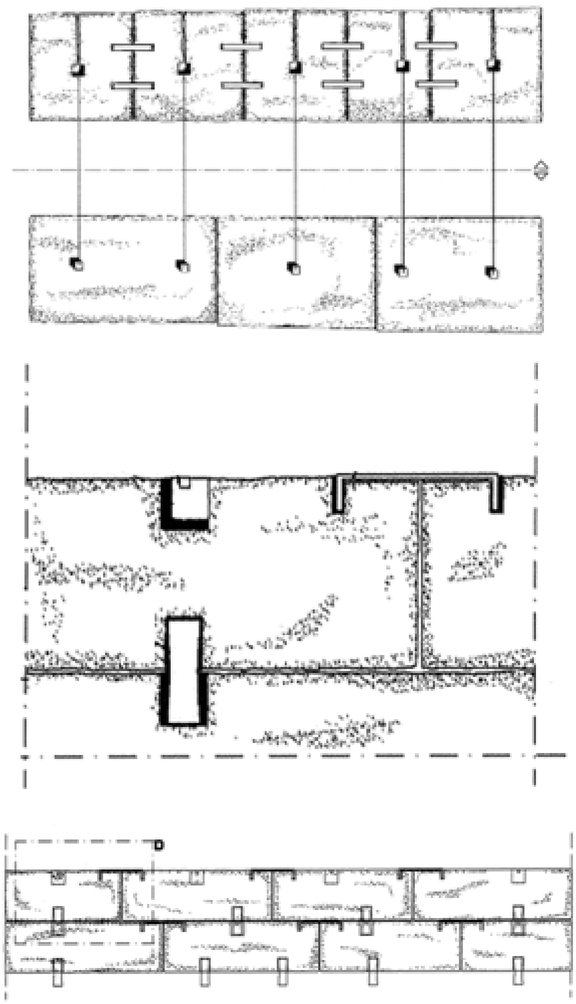
the below spandrel walls, but slightly leaning outwards while getting to the bridge top, as to give an optical effect of a wider footpath.

The pavement and the stone slabs over the lightening voids were in limestone from locality *Opine*, 2 km south of Mostar (limestone of Eocene age hard and resistive marble-like) and was characterised by transversal rib-steps to avoid slipping. Limestones of Eocene age distinguish themselves with fossils of alveolina and nummulites. These fossils, like white brindles, decorate polished stone surfaces and give them unique appearance. This particular appearance has symbolised, for instance, the pavement of the Old Bridge, where these fossils had strike out thanks to the glaze of surfaces made by passenger's footsteps.

The bridge's pavement was melted in *Pink mortar*, which fills up completely the joints between the stone elements. Its purpose is to stiffen the pavement and to prevent the water penetration. Originaly, mortar was prepared with the filling of *terra rossa* or bauxite and bond – quick lime slaked inside the fill. In trial mixtures of new suitable mortars same materials were used with addition of stone powder to achieve desired shade, and tryouts with powdered brick were also made.



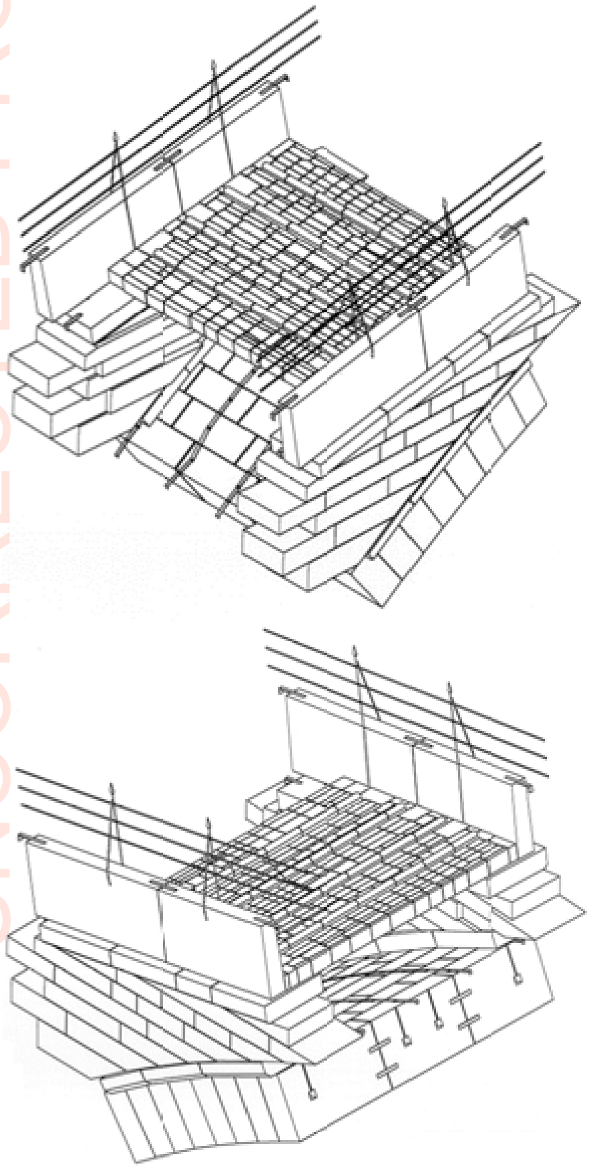
Figures 6&7: Bridge axonometric cut view, General Engineering WorkGroup (above); Lightening voids inside bridge (below).



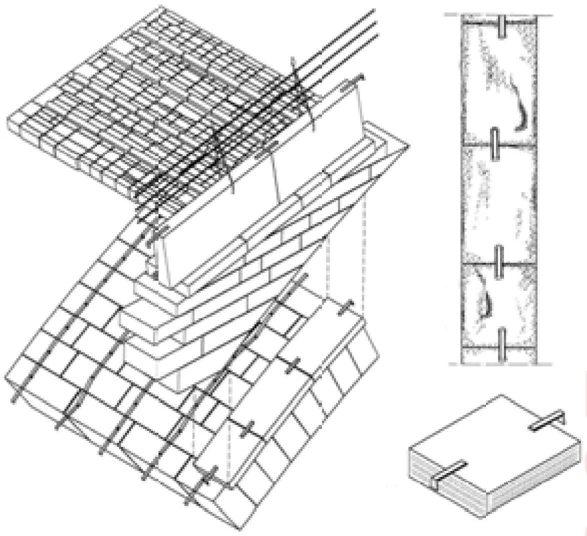
Figures 8-10: Two adjacent rows (side open view) - built-in row and row to be assembled (above); plan view (section) - a detail of a dowel (middle); plan view of a portion of the load bearing arch - side cramps are visible crossing the inner joints (below) - General Engineering WorkGroup.

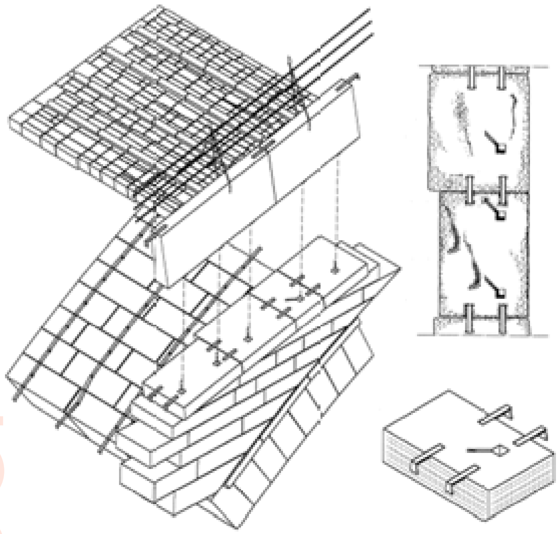
Instead of quick lime, the lime paste was used. *Dark red mortar* (or Turkish insulation) is located immediately below the stone elements of pavement and above the release cavities stone slabs and above the stone elements of the arch. The task of this layer was to transfer the load of the pavement and the pedestrian traffic upon it and to prevent the breakthrough of water inside the bridge's elements. Such kind of "mortar" is a compressed structure in multiple layers of red soil and crushed rock with lime as bond. To avoid greater deformations of mortar (shrinking, swelling, creep) crushed rock aggregate of grain size 0-8 mm was used, and at the lower layers on the bridge the larger grains could have been used. At the time of construction it was prepared by adding the quick (not slaked) lime in the red soil and slaking (adding the water) at the building point. Appropriate kind of "mortar" used for the bridge's reconstruction was produced as chemical (with lime) and mechanical (by compressing) stabilised layer of different thickness (by the bridge's ends up to 120 cm and at the crown approximately 25 cm). Characteristics of such layer (strength, water permeability, stability) are directly related to compression, so this parameter was especially pointed out.

The origin of *tenelija* and its variety "*miljevina*" (fine-grained limestone), is located at the area of "Mukoša" (Mukoša quarry), approximately 5 km south from Mostar. *Tenelija* and *miljevina* were intensively exploited and used as architectural-structural stone for the last five centuries, through the time of Ottoman empire and Austro-Hungarian regency until nowadays. Structures of Ottoman architecture in Mostar are characterised by use of hand-cut *tenelija* blocks, with sharp edges precisely folded into bearing structure of the building, leaving very narrow joints with little mortar, and smooth surface dressing of the stone on the elevations. Examples of such building are among others the Old Bridge and many mosques. *Tenelija* have proved itself to be the stone easy to cut and dress; freshly extracted from the quarry while still has the quarry moist it can be cut with the common hand saw and dress with the simplest tools. Due to this it is favourable material in use for decorative elements on the structures, frames and arches, columns with decorated capitals and memorial grave monuments.



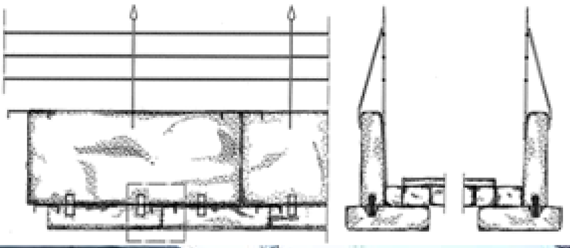
Figures 11-12: Axonometric cut view showing the parapet stones assembled (on the left); axonometric cut view of the stone elements of the bridge (on the right) - General Engineering WorkGroup.





Figures 16-17: Axonometric cut views showing: upper cornice stones with plan view and axonometric scheme - General Engineering WorkGroup (above), with a detail of construction (below).

Figures 13-15: Axonometric cut views showing: the lower cornice with plan view and axonometric scheme, General Engineering WorkGroup (above), with a details of construction (middle and below)



Figures 18-19: Front view and transversal section of the parapet - General Engineering WorkGroup (above), with a detail of construction (below).

Figures 20-21: Construction of the pavement (above), with a detail (below).

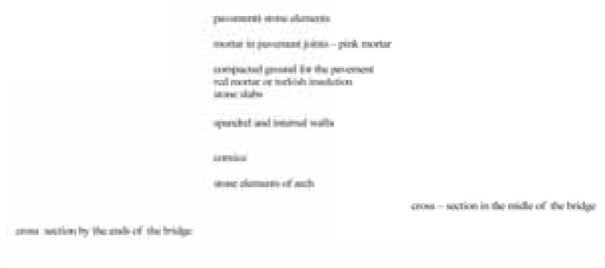


Figure 22: Bridge transversal sections with technological details.

Figures 23-24: Hand-cut *tenelija* blocks for the Old Bridge.

Most of the scientific analyses on Mukoša quarry stones, since 1950 until today, were related to the stone built inside the Old Bridge. Detail data on physical-mechanical characteristics and mineral characteristics of this stone were obtained during repair and conservation of the Old Bridge’s arch in 1963. The stone built in the Old Bridge was studied on that occasion, samples were tested at area of quarry and replacement of damaged blocks was initiated. Results of tests are indicating very interesting results of the stone structure, internal cristalization, strengths and water apsorbation, what are explaining its durability in longer time interval. It was noticed that *tenelija* gained strength increase during time. Due to high porosity *tenelija* contain large amount of quarry moist, which can contain dissolved salts, when first extracted from the quarry. In stone drying process, salts migrate together with the moist towards the stone surface where they become crystallized creating the patina. Also, with highly porous limestones with connected porous space, the water penetrates easily on the inside and together with the carbon dioxide it turns calcite into soluble calcium-hydrocarbon, which migrates towards the surface by drying making in such way the firmer crust. That is how by aging with forming the patina on the surface mechanical characteristics are improved.

Within reconstruction of the Old Bridge in 2003-2004 detail physical-mechanical characteristics of *tenelija* from the Old Bridge's remnants were made, as well as for *tenelija* extracted from quarry. In accordance to categorisation of architectural-structural stones, *tenelija* belong to the group of stones with very low strengths (25 to 45 MPa), week resistance to wear (resistance by Böhme – app. 48 cm^3/50 cm^2), middle class heaviness, extremely porous and of great water permeability (app. 10^{-6}-10^{-5} m/s).

Great suction of water has direct influence to reduction of compressive strength in conditions of watering and resistance to frost. Reduction of compressive strength with the presence of humidity inside the stone is described with coefficient of softening (over 0,80 for *tenelija*). Due to *tenelija*'s large-grained structure water is more rapidly removed from stone, i.e. shorter remaining period of water inside the stone structure.

On characteristics and durability of *tenelija* speak best built in stones in structures of closer and further past. Unfavourable results on durability of *tenelija* were gained on freshly extracted samples of rock mass, but *tenelija* blocks at the Old Bridge have resisted to atmospheric influences and earthquakes for almost five centuries, which speaks enough about its durability.

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DISCRIMINATION OF CONSOLIDANTS BASED ON UV LASER EXCITATION AND THE INDUCED PHOTODAMAGE

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1. Introduction

Recently, we have witnessed impressive advancement of laser-based techniques in the field of cultural heritage. Rapid and reliable tools have been developed for diagnosis and assessment of conservation and preservation of precious artworks.[1] An innovative compact scanning hyperspectral lidar fluorosensor apparatus has been designed in the ENEA laboratory and it has been used to perform field measurements on wall paintings decorated with *affresco* technique. The LIF system is able to measure fluorescence radiation induced on a sample surface at a series of narrow and contiguous spectral bands, so that the light emitted by each spot illuminated by laser light is broken up in components, thus providing the most complete spectral information presently conceivable in the UV to VIS wavelength range. The analysis of spectrally resolved images was aimed to reveal the occurrence of organic materials used as protective varnishes and/or consolidants, being a topic of particular interest, since the presence and alteration of protective layers could influence the deterioration processes.

In the present work, ultraviolet (UV) laser excitation at 266 nm was used as diagnostic tool on plaster samples specifically prepared in the laboratory with different pigments and consolidants. While UV excitation is preferred because of its unique ability to excite the protein-like components found in most organic protective varnishes, selection of the energy density per pulse and total irradiation dose still remains a critical issue, because of possible photo-damage induced by the laser.

2. Experimental

The hyperspectral scanning Laser Induced Fluorescence (LIF) system developed at the ENEA laboratory in Frascati is able to measure fluorescence radiation induced by ultraviolet (UV) light incident on a sample surface.[2, 3] The emitted radiation is collected and spectrally dispersed in a large number of narrow (>90) and contiguous spectral bands, so that fluorescence induced on each illuminated spot is broken up in components, and optically analysed in order to provide a complete spectral information extending from the UV (ultraviolet) to VIS (visible) wavelengths.

The system here used relies on a pulsed diode Nd:YAG laser (Thomsom DIVA) to generate radiation at 266 nm, having light pulses of 10 ns duration. The laser fluence at the target is adjusted by regulating the current discharge into the diode pumping unit, to obtain a useful range between 1 and 50 mJ/cm^2.

All the reflected and emitted light is collected by an optical receiver and sent to the spectral analyzer. To cut off the very intense elastic backscattering from the target surface, a low pass filter is placed just in front of the entrance slit of the spectrally dispersing unit (spectrometer). The spectrometer is an Ocean Optics device (model S2000) with a useful range between 250 and 900 nm and a resolution depending on the entrance slit width. The spectrometer is fed with the light carried by a 60-□m diameter fibre optic (type BFH22-910); for the present case the spectral resolution is estimated to be approximately 5 nm at a wavelength of 500 nm.

The digitized spectrum is transferred to a portable computer where a custom made control program allows the user to set experimental parameters, to perform data acquisition, and to execute some preliminary data analysis.

At the sample surface several physical mechanisms take place simultaneously, which might be grouped in two broad classes as elastic and inelastic scattering: each of them has an angular dependence on the surface orientation, type and on the protective and or glossy layers deposited on the sample as well. Usually the elastic component is characterized by very large cross-section, so the reflected light dominates on the inelastic emitted light. The latter one then produces a weaker light emission with an approximately isotropic diffusion angle; to prevent for detector saturation and distortion the elastic contribution is almost completely aliminated by use of appropriate band-pass filters in front of the receiver.

The hyperspectral LIF scanner here described is able to accurately measure the fluorescence radiation induced on a target surface at a series of narrow and contiguous spectral bands; it has been used in field campaign and in laboratory tests as well, and examples will be given, to demonstrate its potentialities (1) as a tool to discriminate among different kinds of protective layers and (2) to promptly reveal the photo-damage processes occurring on surfaces illuminated with ultraviolet light. It is worth to note that these tasks will be done by using spectrofluorimetric and chemometric analysis alone, and this is a very important point because it makes the fluorescence analysis self consistent making possible to perform diagnosis on artwork without recurring to complex instrumentation with long time for analysis. Among the most relevant properties of the LIF system, we want to mention the ability to operate remotely, in large environment at dark or with low light level, to scan large surfaces in a limited amount of time and last but not least to perform quantitative measurement which serve as basis to compare images and analysis results acquired during periodical checks executed from time to time.

In order to efficiently perform spectrofluorimetric analysis, a possibly complete reference spectral library for the largest number of substances and pigments present in the samples under study must be built; then a semiautomatic processing of hyperspectral images allows for distinguishing among different spectrally similar materials. Several software tools have been devised and reported in literature to perform image analysis: like for example the false colours reconstruction, the Principal Components Analysis (PCA), the methods for multivariate analysis as the Clustering Analysis (CA), and the like.

As already pointed out, the first step consists in collecting a laboratory database for the spectroscopic characterization of pigments and protective layers used on fresco. To this end a set of laboratory samples has been prepared for the measurements: each one was composed of a plaster substrate, a pigment on its surface and a layer of acrylic resin over the pigment. The fluorescence spectra acquired for each sample type upon excitation at 266 nm are shown Figure 1.

Observation of Figure 1 reveals that, at least for the samples taken into the account, the consolidant spectral signatures are quite different one from the other, confirming former results obtained on similar samples excited at several wavelengths, including the UV excitation at 266 nm. All the shown spectra are broadly characterized by either a relatively narrow peak centred at 320 nm (50 nm FWHM) or by a large band centred around 420 nm (250 nm FWHM); it is possible to observe how the prominent distinctive spectral features are responsible for the significant differences observed in their shapes. The large and intense band present around 320 nm can still be found also in those cases characterized by the broad band, where it appears slightly displaced toward the red region of the spectrum so that a peak can be found at approximately 350 nm: this peak is undoubtedly due to the resins. A comparison among the spectra obtained from treated and untreated samples has also been done: by comparing the spectral features of a substrate with and without any resins (shown in Figure 1C), we may easily grasp that it is possible to discriminate between treated and untreated surfaces.[3] Moreover we have the additional possibility to discriminate the acrylic resins by means of their fluorescence emission at the excitation wavelength of 266 nm as it was also demonstrated by Miliani et al.[4]

The PCA analysis performed on the respective spectra has shown good discriminating capability, while spectral mapping algorithm resulted in further differentiation between different resins and pigments, and in precise location of pigments in the scanned surface. The analyses conducted so far provide evidence of a reliable and fast discrimination between non treated samples and samples treated with different consolidants: it is worth noting that although several wavelengths are suitable for discrimination because we can induce fluorescence emission with peculiar spectral features, the best results are obtained when the 266 nm excitation source is used. However some working parameters such as selection of the energy density per pulse and total irradiation dose still remains a critical issue, because of possible photo-damage induced by the laser.[5] Further studies are now in progress with the purpose of assessing the maximum level of irradiation causing no visible damage.

3. Conclusion

In conclusion, the experimental findings demonstrate good identification potential and ability to analyze acrylic resins used in conservation and restoration provided that the fluorescence is induced by 266 nm excitation wavelength. This makes the LIF technique very promising for discrimination between consolidants on treated and non treated artworks surfaces. This can help restorers to better document past restorations and to assess the present conservation state of art objects. Nevertheless, selection of the experimental parameters proved to be critical: while UV excitation is preferred because we can easily excite protein-like components found in most organic protective varnishes, not all the effects related to UV irradiation are known, and are currently the subject of a further study.

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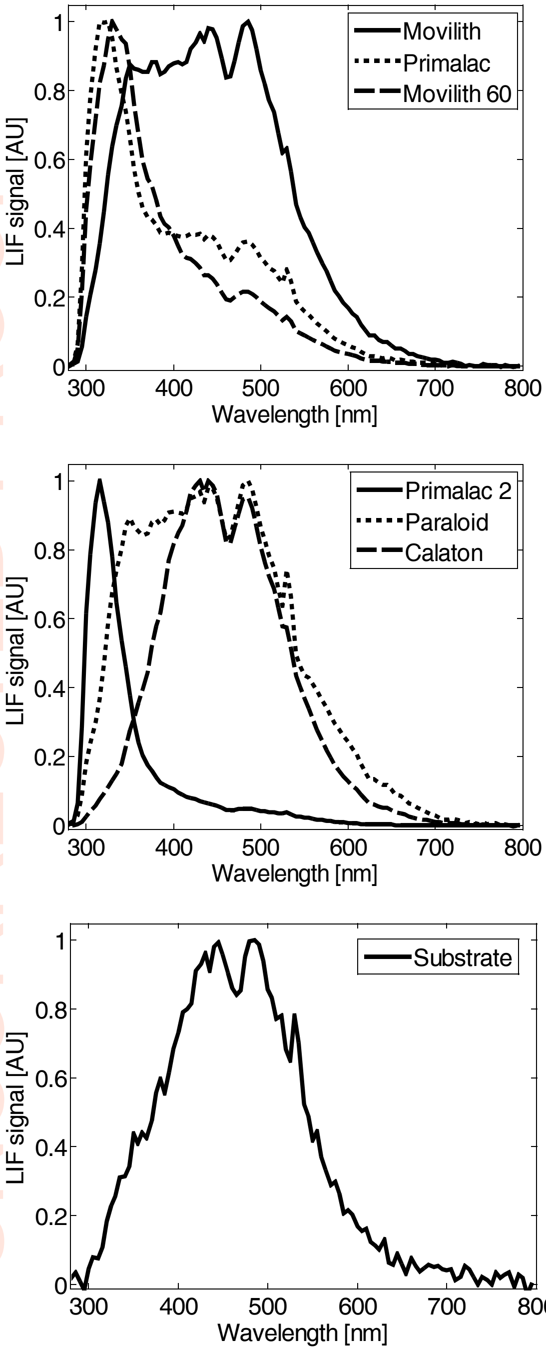

Figure 1: Fluorescence spectra at λ_{exc} = 266 nm: (A) acrylic resins types Movilith, PrimalAC, Movilith 60; (B) PrimalAC, ParaloidB72, Calaton; and (C) plaster substrate.

THE EFFECT OF PROTECTIVE COATINGS ON THE MECHANICAL AND PHYSICAL PROPERTIES OF NATURAL STONE

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Abstract

Lithothamnium limestone and calcareous sandstone were treated with a commercially available silicon-based strengthening product. Water absorption, porosity (open and total), water vapour permeability and changes in gloss and colour were evaluated after the treatment. In the case of both of the studied samples, water absorption at atmospheric pressure decreased after treatment, and the water absorption coefficient by capillarity decreased significantly. Porosity also decreased after treatment on both lithotypes. The consolidant reduced the water vapour permeability coefficient to acceptable limits, and induced the least variation in specular gloss. The deviation of colour (ΔE^*) is significant in the case of both studied samples, which means that the limestone and sandstone are categorized into class B, according to the SMT4-CT98-2263 empiric classification, and according to the Sasse and Snethlage[1] range the applied product in not within acceptable limits. Although the total pore volume of the selected stones is similar, different pore characteristics (e.g. pore size and the presence of micropores) can be seen due to the different water vapour transmission rate. It appears that the performance of the product Wacker® Stone Strenghtener OH 100 depends greatly on the pores in the stone. According to the results of the tests that have been performed, the consolidant behaved positively for the treatment and strengthening of lithothamnium limestones and calcareous sandstones. Only the deviation in colour causes some concern.

1. Introduction

The deterioration of stone is all too familiar to anyone who has looked closely at a historic stone building or monument. While there are a few stones that seem to be little affected by centuries of exposure to the weather, the majority of stones are subject to gradual deterioration. A high portion of the Slovenia's cultural heritage is built in stone, and it is slowly but inexorably disappearing. Before we can take any action to prevent or to remedy the deterioration of stone, we must understand what causing it. Sometimes, the cause is obvious, sometimes there may be several different causes acting at once.

In the cases of highly degradable stone materials or when replacement of stone elements inbuilt in the monument is not possible, durability and aesthetic functionality can be improved with consolidation. Stone consolidation is performed when serious decay patterns and loose cohesion is encountered down to a certain depth[2] and where stone is weakened by process of deterioration. Stone strengthener has to have such characteristics that it slows down the rate of surface loss, penetrates well into the decayed stone, binds together loosened grains and protects it from further decay. Consolidation should improve internal cohesion and restore some strength without altering other physical properties of the stone. The treatment will need to be reasonably cheap, easy to apply, safe to handle and remain effective for decades of time. Since moisture is one of the main climatic parameter which causes deterioration of stone, it is desirable that consolidant decrease water absorption but in the same time allows trapped water to evaporate from the stone matrix. The treated stone will need to have much the same moisture expansion, thermal expansion and elastic modulus as the untreated stone, as to avoid internal stress. Further, it is recommended that the stone surfaces are protected against graffiti and other anthropogenic influences and that efficient removal is enabled. For this purpose it is crucial to study protective agents as well as stone material and their compatibility. Compatibility with any particular stone and the characteristics of the deterioration process it suffers must be also known. It is clear that consolidant products should be selected on the basis of a correct understanding of their behaviour.[3] Ideally, the treatment should work equally well on any type of stone, regardless of the cause of decay and it must be completely invisible. It sounds like trying to find one pill that will cure all the diseases known to humankind.[4]

Alkoxysilanes have been used for stone consolidation worldwide for decades.[5] Alkoxysilanes, such as tetraethoxysilane, are regarded as the most promising of the commercial products available since 1990.[6,7] After hydrolysis and condensation alkoxysilanes deposit colloidal silica inside the porous structure. Alkoxysilanes penetrate deeply into porous stone, show a weathering-resistance and slightly reduce the water vapour permeability.[5,8] In addition, they polymerize upon contact with moisture in the stone, producing a strong, resistant consolidant. After a drying and ageing process, a stable xerogel with silicon-oxygen (Si-O-Si) backbone similar to the stone binder is achieved.[3] Although silica molecules show a great chemical affinity to the siliceous sandstones, alkoxysilanes have been frequently used as consolidants for carbonate materials.[9,10] Important drawbacks of alkoxysilanes are the poor chemical bonding to calcite, and the tendency to crack during shrinkage and drying due to their brittleness.[5]

2. Experimental

The aim of the present study was to evaluate the effects of strengthener on mechanical and physical properties of two different stones. Interest of authors was to learn and to recognize positive and negative effects of strengthener on the particular stone. Standardized methods were used in order to evaluate the efficiency of the stone strengthener on two samples – lithothamnium limestone and calcareous sandstone.

Stones

Studied limestone frequently occurs in the historic masonry, for example, in Carthusian monastery at Zice (Slovenia).[11] It is a biogene stone of Badenian age. Lithothamnium algae are the main constituent of the biogenic component. Beside algae other fossils are present, such as bryozoas, chorales, molluscs and foraminifera. The main lithiogenic component are quartz grains, also present are grains of sandstone, as well as magmatic and metamorphic rock. Ratios between biogenic and lithiogenic components determines these samples as biosparite, biomicrite, biosparrudite and biocalcirudite limestones. The binder is calcitic, with some traces of clay and limonite.[12] The sample was taken from the abandoned quarry at Sv. Jernej/Loce (Slovenia).

The second sample is fine to medium coarse calcareous sandstone of middle Miocene age (Sarmatian). It originates from abandoned quarry Sedovec, near village Strtenica, south from Smarje/Jelse (Slovenia). It is known as Strtenica sandstone and it is also used in historic constructions, particularly in central-east Slovenia. The most famous masonry built-up with Strtenica sandstone is recently restored church Sv. Rok with 14 chapels of Way of Cross.[13, 15] Lithiogenic components are relics of dolomite, glauconite, chlorite and green biotite.[14]

Sandstone compounds 70% grains and 30% cement, not including pores. Grains contain 40% non carbonate grains, mostly terrigenous grains, and 30% calcitic fragments of fossils. Size of grains is 0.07 – 0.9 mm, average size is 0.3 mm, bad or medium sorted. The most frequent mineral of terrigenous component is quartz. Feldspar, lithic grains (fragments of metamorphic and magmatic rocks, chert) and filosilicates (muscovite, partly chloritic biotite) are inferior. Fossils (fragments and spicules of echinoderms, foraminifera, fragments of mollusc, bryozoas, red algae) are the main alochemical component. The binder is calcitic.[15]

Product

Samples were impregnated with a commercial product for stone consolidation which is composed of silicic acid and ethylesters of producer Wacker Chemie. Wacker® Stone Strengthener OH 100 is a solvent-free ready to use product for the consolidation of building materials and it is based on ethyl silicate. When applied, it penetrates through the capillaries deep into the construction material. The neutral catalyst (dibutyl dilaurate) promotes the reaction between ethyl silicate and water from atmospheric humidity or the moisture in the capillary pores. A glass like silica gel binder (SiO_2 aq.) is formed. The ethanol by-product evaporates. Under standard conditions (20 °C / 50% r. h.), final hardness is reached after two weeks, i.e., when the most of the ethyl silicate has been converted to silica gel. Product does not contain any hydrophobic additives such as silanes or siloxanes. Tested consolidant was applied three times with a brush.

Methods for evaluation of the applied product

In order to characterize the impact of the consolidant on the initial properties of the fresh samples of studied limestone and sandstone, the following methods were used: open and total porosity (SIST EN 1936), water absorption at atmospheric pressure (SIST EN 13755), water absorption coefficient by capillarity (SIST EN 1925) and water-vapour transmission rate (SIST EN ISO 7783-1). In order to characterize the influence of the impregnation on the aesthetic and visual effect of the stone element, further two methods for specular gloss determination (SIST EN ISO 2813) and colour measurement (ISO 7724/2) were used. Namely, the aesthetic effect of the inbuilt stone after chemical treatment is an important factor, which influences functionality of the stone monument. The visual appearance of the stone element shall not change significantly after treatment. The effect of consolidation treatment on mechanical strength of studied stones was studied with comparison of compressive strengths before and after impregnation according to SIST EN 1926.

Tests for open and total porosity were taken on six cubes 50 x 50 x 50 mm of each sample, treated and untreated, which gives total number of 24 specimens. In the same standard two methods for the determination of real density are described: Method A (pycnometer) and Method B (Le Chatelier volumenometer). The first method is more accurate but requires longer time. In present study Method A was used.

Measurements of water absorption at atmospheric pressure and water absorption coefficient by capillarity were taken on 6 cubes 50 x 50 x 50 mm for each treated and untreated sample. This gives total number of 24 specimens.

For the water vapour permeability tests the studied samples (8 untreated specimens for each sample and 8 treated specimens for each sample) were put in a light metal dishes, that are resistant to corrosion under the test conditions. The same specimens were used for measurements before and after treatment. The diameter of stone samples was about 120 mm and thickness was 13-14 mm. Wax mixture that adheres strongly to both the dish and the specimen, and is not brittle at the test temperature, not hygroscopic and not susceptible to oxidation, was used as a sealing material. Test surface of specimens was surrounded by ring templates (SIST EN ISO 7783-1 / Annex D.2.2) of 103 mm diameter. Prior to testing, test specimens were exposed to three cycles of artificial ageing with the following programme: 24-hour immersion in water (23 ºC) and 24-hour drying at 50 ºC, whereafter they were still conditioned for 24 hours at (23 ± 2) ºC and (50 ± 5)% relative air humidity as defined in ISO 3270. Water vapour permeability of specimens was measured gravimetrically as the quantity of water permeating a specimen at 23 °C in a unit of time from a measuring dish filled with the saturated solution of ammonium dihydrogen phosphate - $(NH_4)H_2PO_4$ (93% r. h.) into a conditioned room with 50% relative air humidity. The test was run for at least 10 days when the required stability in the sample weight was obtained.

Specular gloss is the ratio of the luminous flux reflected from an object in the specular direction for a specified source and receptor angle to the luminous flux reflected from glass with a refractive index of 1.567 in specular direction. Dimension of specimens were 100 x 50 x 20 (10) mm. Three specimens were used for each sample, untreated and treated (in total 6 specimens). The same specimens were used for measurements before and after treatment. Measurements were taken on six points on each specimen (in total 72 measurements).

To evaluate colour changes of the treated samples the chromatic parameters were obtained by reflectance using a colourimeter Minolta, CR-300, calibrated to a white tile standard surface ($L^* = 97.55$, $a^* = -0.02$, $b^* = 1.56$) at channel 00. Random readings were taken from the treated and untreated area, at five locations. For the calculation of the chromatic variations the untreated stone was selected as reference. L^* refers to the brightness (lightness), while a^* and b^* to the red-green (redness) and yellow-blue (yellowness) colour, respectively [15]. Total colour difference ΔE^* is calculated from the CIELAB colour difference formula. The chroma difference ΔC^* and the hue difference ΔH^* are the differences between untreated and treated specimen.

Compressive strength has been determined according to European standard SIST EN 1926 on three specimens of each material.

3. Results

Pore space, flow properties

Both studied samples have different porosities. While the limestone has relatively high porosity (21.0% of open porosity and 21.3% of total porosity), the sandstone porosity is approximately 1.4 and 1.2 times lower, respectively (15.4% of open porosity and 17.0% of total porosity). After consolidation the open porosity of the sandstone decreased by 4% and the total porosity of the sandstone decreased by 2%, while the open porosity and the total porosity of limestone in both cases decreased by 1%. The apparent density of the untreated limestone is 2131 kg/m^3, while the sandstone has the apparent density of 2249 kg/m^3. The apparent density of the treated limestone is 2159 kg/m^3 and the treated sandstone has apparent density of 2294 kg/m^3.

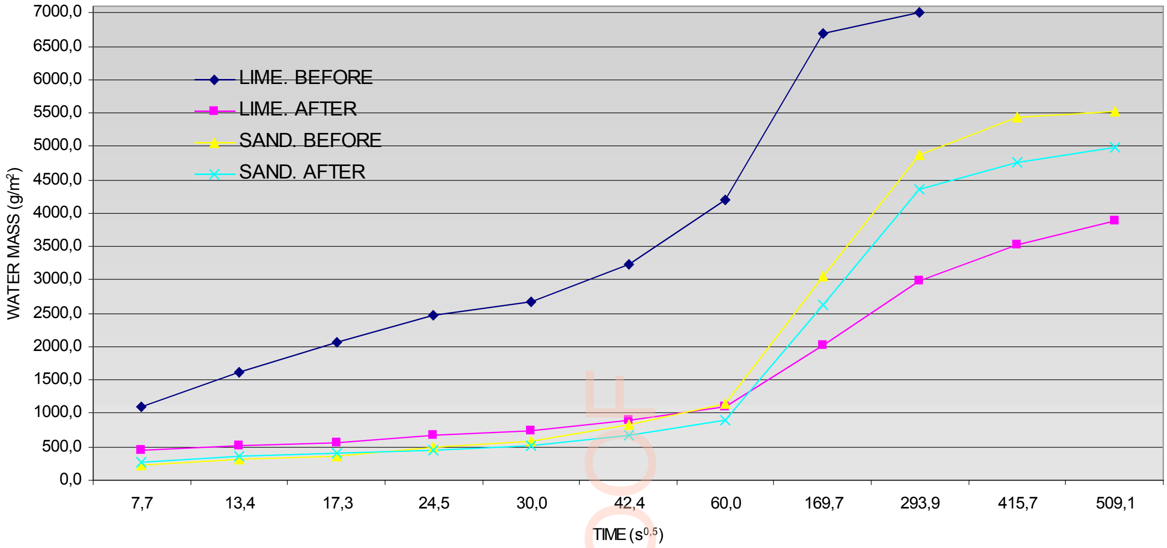

Figure 1: Water absorption coefficient by capillarity of the limestone and sandstone before and after treatment.

It can be observed that lithothamnium limestone has higher water absorption at atmospheric pressure and the water absorption coefficient by capillarity which is a result of higher porosity. After treatment average water absorption coefficient by capillarity and water absorption at atmospheric pressure decrease in the case of both samples. Since it is desirable for a consolidant to be capable of reducing the water absorption, the efficiency of consolidation was good. Never the less, decrease of water absorption is not the main requirement for efficient consolidation. A different character of studied limestone and sandstone before and after impregnation, determined with water absorption coefficient by capillarity is clearly visible in Figure 1. All results in connection to porosity and flow properties are given in Table 1.

Table 1: Flow properties and visual-aesthetic properties of studied samples before and after treatment with Wacker OH 100.

	Water absorption at atm. pressure	Water absorption c. by capillarity	Open porosity	Total Porosity	Water vapour transmission rate – diffusion resistance factor (µ)
Lithothamnium limestone					
Untreated	7.4%	23.88 g/ms$^{0.5}$	21.0 %	21.3 %	13.4
Treated	6.3%	6.64 g/ms$^{0.5}$	19.8 %	20.0 %	24.8
Calcareous sandstone					
Untreated	5.3%	17.37 g/ms$^{0.5}$	15.4 %	17.0 %	14.0
Treated	3.5%	6.79 g/ms$^{0.5}$	11.2 %	15.3 %	51.7

Water vapour transmission rate is characterized with diffusion resistance factor (µ). Diffusion resistance factor is almost identical in the case of fresh samples. After treatment the limestone has almost 2 times higher diffusion resistance factor than fresh sample, while treated sandstone has 3.7 times higher diffusion resistance factor then fresh sandstone. Similarly, increased trend of diffusion-equivalent air layer thickness (s_d) can be observed in the case of both samples. After treatment, the water vapour permeability coefficients decreased by approximately 29% for limestone and approximately 62% for sandstone. This is mainly due to the prevalence of large pore in the limestone microstructure. The large pores facilitate the water vapour transmission rate.

Aesthetic properties

The average value of specular gloss after application has slightly changed, for less than 3 units.

The change of brightness after consolidation was applied, was determined according to the following equation:

$$\Delta L^* = \Delta L_t^* - \Delta L_{un}^* \qquad \text{Eq.1}$$

This value describes a change in brightness, where negative values of ΔL^* correspond to the treated samples (index t) which reflect less light than untreated samples (index un). Colorimetry was characterized by total colour difference ΔE^*. Total colour difference ΔE^* between two colours is the geometrical distance between their positions in the colour space. The (CIELAB colour difference formula) value represents the colour change between the treated and the untreated surface. The CIELAB formula is following equation:

$$\Delta E^* = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2} \qquad \text{Eq. 2}$$

The chroma of the untreated (or treated) specimen is defined by the following equation:

$$C_{un}^* = \sqrt{(\Delta a_{un}^*)^2 + (\Delta b_{un}^*)^2} \qquad \text{Eq. 3}$$

The hue difference is defined by the following equation:

$$\Delta H^* = k_H \sqrt{(\Delta E^*)^2 - (\Delta L^*)^2 - (\Delta C^*)^2} \qquad \text{Eq. 4}$$

where $k_H = +1$ for $(a_{un}{*}b_t{*} - a_t{*}b_{un}{*}) \geq 0$ and $k_H = -1$ for $(a_{un}{*}b_t{*} - a_t{*}b_{un}{*}) < 0$.

Coloumetric characteristics of analyzed limestone and sandstone are given in Table 2 and Table 3.

Table 2: Aesthetic properties of treated stones.

	Gloss (60°)	Gloss (85°)	Colorimetry – total colour difference (ΔE^*)
Lithothamnium limestone			
Un-treated	1.22	0.45	-
Treated	1.13	0.85	16.51
Calcareous sandstone			
Un-treated	1.12	0.39	-
Treated	1.05	0.54	6.32

Mechanical properties
The samples have different compressive strength; the compressive strength of the sandstone is approximately 1.2 times higher than the compressive strength of the limestone (42 MPa and 34 MPa, respectively). After consolidation treatment, compressive strength has slightly increased in both cases (44 MPa and 39 MPa, respectively). Never the less both stones are highly heterogeneous and standard deviation of individual results is significant. Results of compressive strength testing are listed in Table 4.

Table 3: Variation of the chromatic parameters of treated limestone and sandstone.

	ΔL^*	Δa^*	Δb^*	ΔE^*	ΔC^*	ΔH^*
Lithothamnium limestone	-14.92	1.44	6.93	16.51	7.06	-0.36
Calcareous sandstone	-6.26	0.37	0.77	6.32	0.78	-0.38

Table 4: Compressive strength of studied stones.

	Compressive strength (MPa)
Lithothamnium limestone	
Untreated	34.37
Treated	38.99
Calcareous sandstone	
Untreated	42.21
Treated	44.39

4. Discussion

Pore space properties, such as open porosity and total porosity of inbuilt stone and flow properties (water absorption and water vapour transmission), have significant effect on building physics as well as on durability of stone element. There is a general assumption that materials with lower porosity have better durability characteristic, which is not always the case [17]. In this study, lower porosity was determined in the case of calcareous sandstone, which could indicate better durability characteristics; never the less the final answer regarding efficiency of treatment could be given only after additional test of durability of untreated and treated stones will be carried out.

Stone materials with lower porosity have better absorption properties (lower absorption). According to Maravelaki-Kalaitzaki and his co-workers[18] who have studied effect of treatment with silicone-based consolidant on different limestone, one of the important characteristics of consolidant is capability to reduce water absorption. In the case of water absorption at atmospheric pressure calcareous sandstone shows slightly greater decrease of water intake after consolidation, while lithothamnium limestone shows greater decrease in case of water absorption coefficient by capillarity. This indicates presence of different type of pores (capilar pores in the case of lithothamnium limestone).

Positive effect of consolidants on stone has been identified in the case when less than 35 % of water vapour transmission decrease was detected.[17] According to this criterion Wacker OH has more positive effect on lithothamnium limestone, where water vapour transmission decrease after consolidation is smaller (28.9%).

The chromatic variations induced by the applied product range in acceptable limits when parameter ΔE^* is < 5.[16] In this study both materials show relatively high chromatic change, which is concerning. Another classification was used in the European project GRAFITTAGE (contract no. FP6-2003-SSP3-513718). According to this empiric classification both samples fall into class B, where deviation of colour (ΔE^*) before and after treatment is > 4 units. Positive values Δa^* and Δb^* indicate that the treated samples are more red and yellow, respectively, than the untreated.

According to the criteria of gloss developed in the European project GRAFITTAGE (contract no. FP6-2003-SSP3-513718) results of gloss measurement classify both samples as semi-glossy (measured at 60° angle) or as matt (measured at 85° angle). Obtained difference between untreated and treated samples, classifies consolidation agent as class A.

The difference in the compressive strength is due to a difference in the porosity. On the basis of mechanical properties of fresh samples higher durability can be expected in the case of studied sandstone.

5. Conclusion

This study assessed and compared the performance of certain consolidant in two types of stone: a lithothamnium limestone and a calcareous sandstone. Determining factors of weathering, such as porosity, water absorption and water vapour permeability indicated a modern state of decay for the studied lithotypes. The assessment of efficiency of the used strengthener took into consideration the least chromatic variation, the least gloss variation, the lowest decrease in water vapour permeability, greater change in water absorption and porosity. If all this characteristics are considered together neither of two types of stones can be marked as more or less appropriate for usage of chosen consolidant. Never the less considering individual properties, studied materials respond differently to the treatment. Greatest differences between limestone and sandstone can be found in change of colour and water vapour transmission rate.

Further test of durability are needed to determine long-term performance and suitability of strengthener for studied stones. It is very important to consider chosen characteristics together with durability as well as the concentration of consolidant, before starting the consolidation treatment. Obtained results from such programme of testing give needed information regarding compatibility of studied materials and consolidating and protective agents from the point of efficiency, aesthetic effect and economical point of view. This enables further planning and implementation of cultural heritage protection policy, when stone material is involved.

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THE USE OF NIR WITH CHEMOMETRICS FOR NON-DESTRUCTIVE CONDITION ASSESSMENT OF CELLULOSE ACETATE NEGATIVE FILMS

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Cellulose acetate has been the preferred material for photographic negatives, movie films and microfilms since about 1940. Most of the 20th century colour film is based on cellulose acetate, also called "safety film" that has been popular due to its resistance to combustion, as opposed to the earlier cellulose nitrate. Though developed to be a permanent film base, these films were unfortunately not as stable as expected and the widespread degradation is threatening many museum house collections. If deteriorated, acetate may be discoloured, shrunk, vinegar-smelling, depending upon the stage of deterioration. It also becomes increasingly brittle as the film ages, and its performance decreases. So do the strength properties of the cellulose acetate film, such as tensile strength, elongation and stress crack resistance that depend on the molar mass of cellulose acetate macromolecules. In order to identify items potentially at risk, it is vital to have a good understanding of the physical state of the cellulose acetate film base, and a technique that would provide this information in a non-invasive, fast and reliable manner would be of a significant value.

Characterisation of historical materials is a complex analytical problem because the materials are extremely inhomogeneous due to production processes, and because the sampling requirements are usually very restrictive. Degraded historical materials represent an even more challenging area of research, as they are less well defined and more inhomogeneous as new objects. Due to the non-destructive or micro-destructive nature, spectroscopic methods are very appropriate for the purpose. There are traditional techniques available such as FT-IR, FT-IR/microscopy, FT-Raman and Differential Scanning Calorimetry. However, most of them are inherently destructive, since a sample is required and destroyed during testing.

The non-destructive technique of near-infrared spectroscopy (NIR) has revolutionised the measurement of quality parameters in many industries, and has recently been introduced to the heritage field.[1] Because of the nature of NIR analytical data, a lot of effort is needed for developing methods to derive useful information from the generally weak and overlapping absorption typical of NIR data. Quantitative NIR spectroscopic methods require the application of multivariate calibration algorithms to model NIR spectral response to the properties of a sample set.

Our current work has focused on the application of NIR spectroscopy, in combination with chemometric data analysis, to the assessment of the molar masses of cellulose acetates. Restrictions in the motion of the cellulose acetate main chain increase with increasing molar mass and along with the cumulative intermolecular forces will affect the local vibrational frequencies of cellulose acetate groups which in turn results in small variations in NIR band shape and position. Therefore, molar mass of cellulose acetates should be possible to determine using NIR spectroscopy.

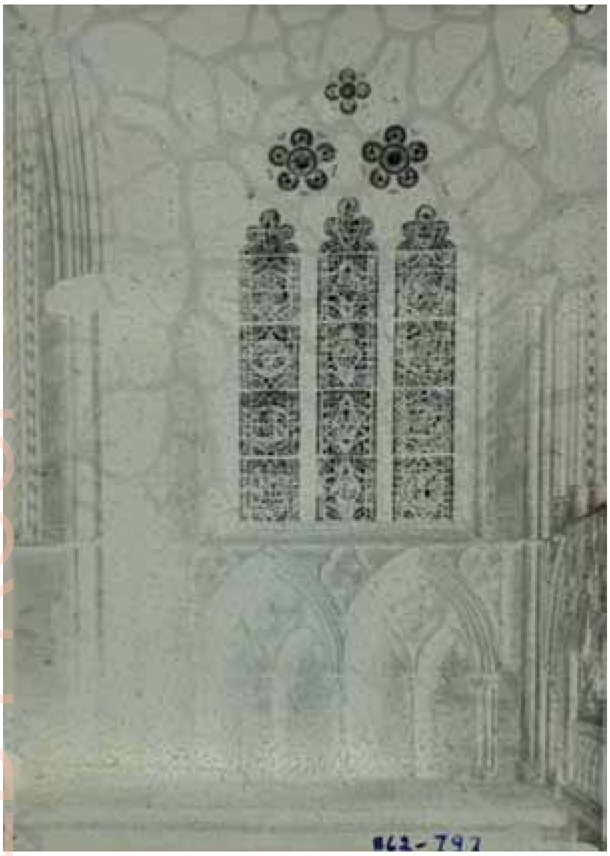

Figure 1: A typical degraded cellulose acetate negative showing buckling and graining as a consequence of dimensional changes due to material degradation.

In this work, we demonstrate the principle of extracting meaningful molar mass information from near-infrared spectra using multivariate analysis performed on model cellulose acetate films. A fibre-optic NIR instrument was used to allow for maximum versatility. The reference data of mass average molar mass (M_w) were determined using size exclusion chromatography.[2] Once the mathematical model between the reference property of M_w and NIR spectroscopic data of the same samples is established, the analyses of the unknown samples can be performed on the basis of their NIR spectra with reference to the properties of interest, which involves virtually no sample manipulation and certainly no sampling.

A promising NIR calibration derived in our laboratory was obtained for the analytically determined M_w values and predicted (modelled) M_w values from the NIR spectra. The successful NIR calibration will be developed further for historical acetate negative films. The NIR technique provides a valuable tool to obtain information about the condition of cellulose acetate collections and opens new perspectives in the analysis of other historical materials, including chemical and physical aspects. Regardless of the specific developments that take place, there is no fundamental limit to the other types of historical materials that can be analyzed using similar methods, as attested by the numerous and successful recent developments in heritage laboratories.

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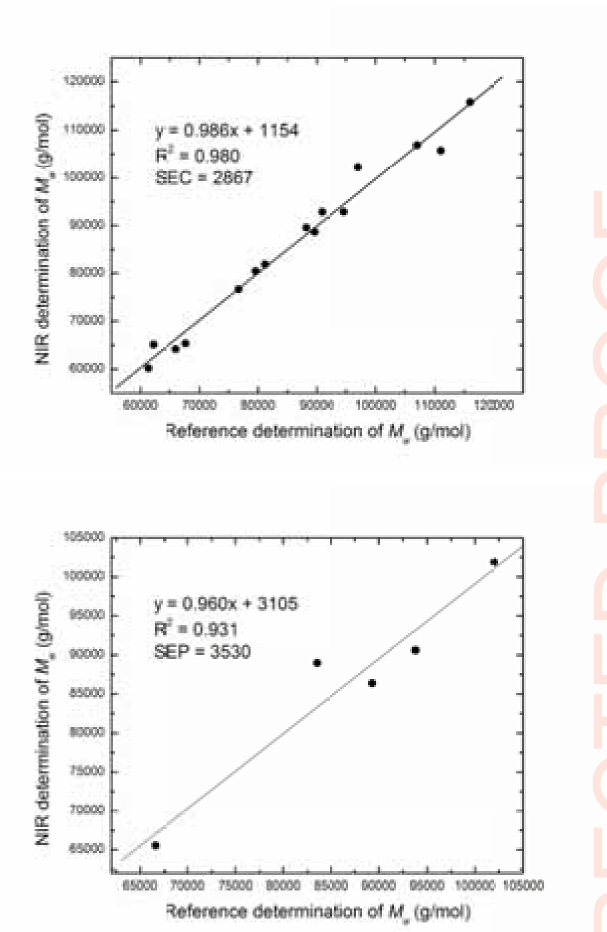

Figure 2: Partial least square analysis was performed on a calibration set of 15 NIR spectra acetate films following the second derivative treatment and Standard Normal Variate correction. The PLS model (up) was then used to predict average molar masses of separate set of 5 sample spectra (down) with a standard error of prediction 3530 g/mol.

METHODOLOGY OF MATERIAL SELECTION FOR MASS CONSERVATION TREATMENT

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1. Introduction

A large scale and long term research programme on preservation of library and archival materials produced extensive knowledge on paper degradation, mechanisms and also on different techniques and processes in order to improve permanence, durability and life-span of the materials. Because of the large quantities of acidic paper materials many deacidification processes have been introduced and several treatments are commercially used on a large scale.

In the Slovak Republic there are approximately 50 million book items in libraries and about 180 km of archival documents in the network of the state archives. Documents from 1850 to the present represent about two thirds of the stocks in libraries and archives. In order to be able to preserve such a large quantity of materials mass preservation treatments should be involved.

2. Project aims and results

The first aim of our work was to describe the state of the 20th-century stocks in archives and libraries on the basis of a survey of 2,500 model books and statistical evaluation of these results (document classification from the point of view of preservation priority and technological criteria). One of the examples is the classification of books into several groups based on acidity, mechanical properties and lignin content. Another example is a collection survey at the Slovak National Library and creation of a database for the purpose of creation of technological criteria for potential mass treatment of books. The tested parameters are as follows: acidity (pH – indicator, surface electrode), mechanical strength (puncture depth – centre and edge of page), thickness of the sheet, sizing, lignin content, yellowing and alum content - $Al_2(SO_4)_3$.

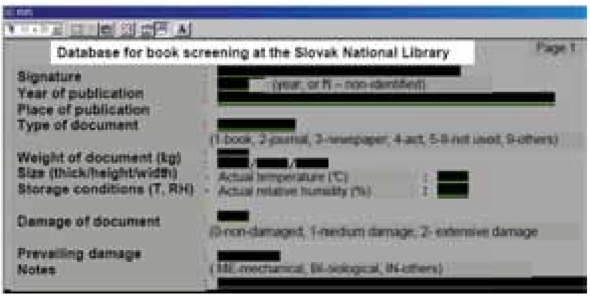

Figure 1: Recording the obtained information about the state of a document is done in the CDS-ISIS program.

A user manual was elaborated presenting simple work procedures and brief descriptions of procedures for determination of individual parameters, and detailed procedure for each tested parameter.

Another part of the work was done in order to prove the effectiveness of fast screening methods using analytical methods, and to define the relations between them. The methods were defined and material properties observed in real documents part of the so called illustration set. The goal was to use an explanatory example for presenting the result and classification of the document into the proper category.

Figure 2: Assessment of pH.

Figure 3: Paper toughness testing by ZT3P.

Figure 4: Assessment of yellowing.

The spot test with phluoroglucinol or sulphanilic acid is a fast and non- or micro-destructive test for lignin presence. The methodology of classification of model documents into individual groups according to groundwood content was done by determination using analytical methods: Kappa number and using the method according to Konig-Rump.

3. Conclusions

The importance of the tested parameters must be recognized for proper evaluation of the actual state of library and archive collections. It is necessary to involve a test document in the suitable process of mass conservation based on the obtained information and find a way and method of quick and reliable evaluation of the paper as a whole.

Some methods of evaluation are destructive even if there is no big intervention. However, the user must consider the suitability of the intervention and the extent of damage inflicted. We decided for methods of the least intervention and destructive character.

The tested parameters were chosen for evaluation of books but they can be used even for evaluation of other paper materials (archival documents, magazines, writings, newspaper, etc.). It must be considered which analysis is suitable for the selected document. The program CDS-ISIS should help the library curator handle and protect book items and propose the way how to rescue damaged book items. The program allows searches in the created database according to selected criteria. The curator can consider the development of a library through time in relation to book binding, lifetime of paper, type of damage, etc.

The results and methodology of the work can serve as a manual also for librarians and archivists and it should help them to describe and evaluate the current state of stocks.

The overview of testing parameters, selection of criteria and methods is described in detail in the quoted monograph Qualitative classification of book and archival documents on a paper carrier.

4. Acknowledgement

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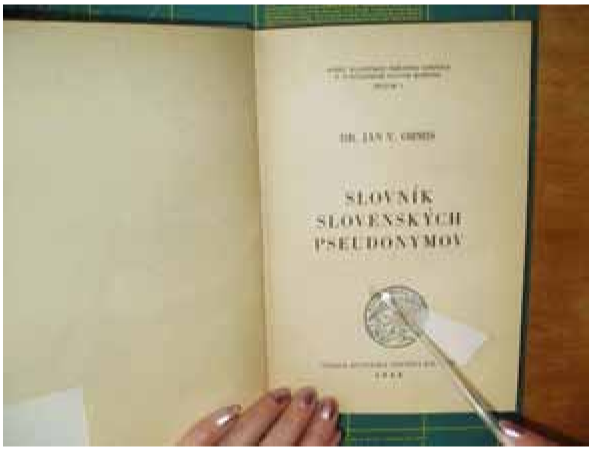

Figure 5: Testing colour stability in chosen solvents.

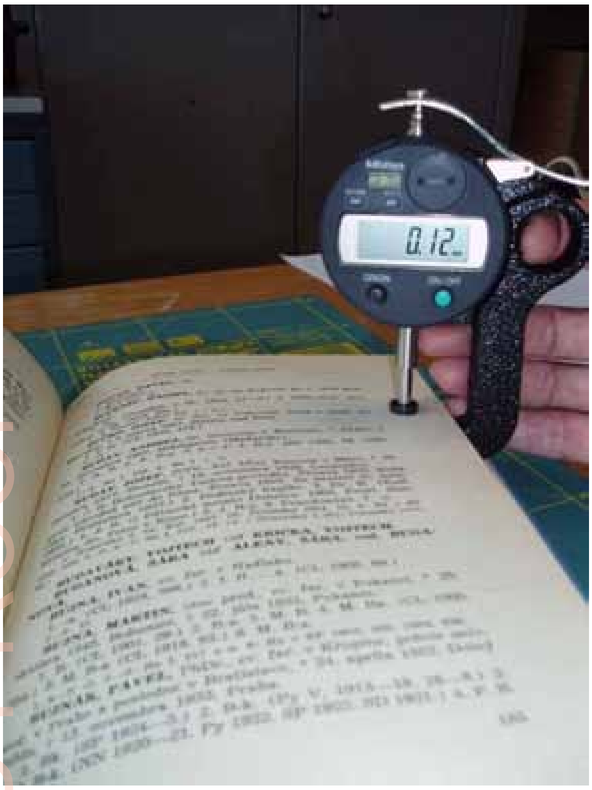

Figure 6: Assessment of paper thickness.

Table 1: Screening and analytical methods.

Risk group	No risk	Moderate risk	High risk
Screening method	0	I	II
Kappa number	0-10	10.1-25	25.1-59.3
Lignin content (%)	0-3	3.1-20	20≤

THE MONASTERY AND THE CITY: REVISITING FRANCISCAN HERITAGE, SEARCHING FOR NEW CULTURAL EXCHANGES

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Urban history in Brazil, especially in the colonial period, is written basically by two hands: the Crown and the Church. In the beginning of this period, an agreement between the Portuguese king and the Order of Christ, an exceptional heir of the Order of the Templar that remains in Portugal, turned the expansion into an enterprise moved not only by the desire to strengthen the Portuguese empire but also to enlarge the basis of Christianity around the world.

As a consequence, the foundation of villages and towns appeared as a method of establishing the presence of the colonizer in the new land in a definitive way. The vastness of the territory was a challenge but soon it was started to be faced, through the exploration of large amounts of land and the foundation of the first urban settlements, as small spots over the large surface of tropical greenery.

From the very beginning, Franciscans had been included in voyages following that of the Portuguese Pedro Álvares Cabral, the "discoverer" of Brazil in 1500. They were, together with the Jesuits who arrived later in 1549, the most important religious agents in the conquest of lands. The Franciscans were fundamental in making Brazil what it is today, especially in the way they positively interacted with the native population, the new landscape and its resources.

The relationship between Franciscan architecture and the city is confirmed by various examples, first in Europe and latterly in Latin America. Medieval monasteries traditionally had the role of improving urban settlements, but usually this process demanded time as they were placed far from the cities. The Franciscan order, as is well known, breaks with this procedure by not avoiding the crowd. The seraphic rule says that the place of the mendicant is where people are, since they have to be responsible for conversion, maintenance of faith and begging for money. For this reason, their houses are located within a reasonable distance of the urban centres, allowing them to be in touch with the population, at the same time as securing conditions conducive to meditation.

Another important point concerning the Franciscan order, is the motto "in via" or, in other words, the tradition of being always moving. Itinerancy and peregrination are important procedures for the order and were one of the reasons for the constant presence of the friars in maritime expansion events and in missions everywhere.

In Brazil, acting as the main agents in the construction of the religious and the civic landscape of the new country, the Franciscans had to deal with the spatial organization of the new communities that developed thorough conversion. Also, they had to provide religious support for the Portuguese population who moved to Brazil in order to colonize the country.

For these reasons, the mendicant order travelled through the sertões, or the inner lands of the country, searching for native tribes, and along the seashore, where the villages and towns were established, acting as constructors of urban places. Their missions spread all over the lands, from the Amazon forest to the deep south of the continent around the river Plate.

This paper will focus on the "Franciscan School of Northeast Brazil" and the effects the order had on the Portuguese colony of America. The term was coined by Germain Bazin, a curator of the Louvre who came to Brazil in the 1950s. It covers a group of 13 convents built from 1585 to 1660 which are still preserved today. Emulating the behaviour of the Franciscan Friars, he travelled to remote parts of Brazil and this allowed him to reach important monuments. He went on to publish his findings in a book that was to become a classic in its field.[1]

From Bazin's point of view the "Franciscan School of Northeast of Brazil", is "one of the most original creations of religious architecture in Brazil".[2] He identifies a continuation of experience as if one building confirmed the aesthetical traces of another. His hypothesis is that the Franciscan motto "in via" was responsible for this fact, following the medieval mode where "each creator continues the line of imagination of his predecessor", forming a school of masters of the baroque style.[3]

Seventeenth and eighteenth century chronicles reveal a Franciscan world quite different from the one that we currently have in mind, with appeal and atmosphere being provided by characters such as the Brother Sun and Mother Moon. In these chronicles, Franciscan history is described as a long battle against temptation within the baroque extremes of pleasure and suffering. In the narrative of the life of the friars, we find plenty of examples where the negation of beauty and ostentation is in apparent conflict with their houses, especially their splendidly architectural churches with rich interiors encrusted with gold.

Nowadays these thirteen convents are listed as part of the national patrimony of Brazil. Olinda and Salvador were of such great importance to the cities where they are located that UNESCO has placed them on the World Heritage List indicating that they have "outstanding universal value".

The purpose of this work, in addition to improving links among the exemplars in Brazil and abroad, was to present each convent as a piece of religious, scientific, social, and artistic knowledge. It is very important to understand the setting of each convent in its city, to be able fully to consider all of these aspects. This is one of the ways of enhancing the richness of the seraphic experience.

There are very important Dutch and Portuguese cartographical and other visual materials dating from the 16th and 17th centuries and these have been studied as part of the project.

Nowadays, an important issue that we should consider is the impact of the thirteen convents on their communities and the possible benefits they could bring. The historical importance of a convent is beyond the feeling of visual pleasure brought on by looking at its architectural, pictorial and sculpted aspects. The original function of an area can also inform our understanding or appreciation of a place. For Example: the entrance hall was also used for distributing food to needy people; the hydraulic system was important in providing water to the convent itself but also, sometimes, to the village; the adro -a large area in front of the main entrance of the convent – in the past used for burying people, today used as a public square; not to mention the sacred space as a whole, where a suspected Christian criminal could claim sanctuary, that is the right to remain within the sacred place and not be taken immediately to prison.

In spite of their value as national heritage, the Franciscan convents have nowadays lost most of their religious importance. Since the friars are rarely seen, it is necessary to think about new alternatives for the upkeep of their old houses within the dynamics of contemporary life. Tourism can be part of a solution, offering an opportunity to blend patrimony and cultural activities. However, proposals concerning these convents should always contemplate the full range of aspects linked with their tangible and intangible heritage.

Only by being re-integrated into the life of people can heritage act as a cultural tool. How could this happen in the case of these houses? In some respects, it is possible to conclude that Franciscanism still has relevance for our contemporary world. Given its so-called "ecological behaviour", it can provide an interesting source of inspiration when dealing with the question of how to preserve Mother Nature.

Furthermore, spirituality, and contemporary desire for equilibrium in private & social life, can often find a resonance in the atmosphere of these convent houses. The human scale of the buildings, and the arrangement between the constructed & open spaces, are aspects that can support this desire.

Yet another aspect is their indisputable beauty, and their value as a works of art. Added to these artistic attributes is their location within pleasant natural surroundings, usually including favourable views of the city.

However, the seraphic houses also can be seen to be in conflict with modern aspirations. The world of secrecy, sacrifice and punishment represented by the convents collides with the expectation of a positive view of the world. Viewed in this way, the houses can contribute to debate by helping us look at the present from a different perspective. It is important to retain evidence that shows how mankind conceived of itself differently and also to recognise that the philosophical aspects of life that the Franciscan baroque sought to deal with are among those that preoccupy mankind today.

1. References

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3. Idem, ibidem, 156.

PICO-SECOND TIME-RESOLVED OPTICAL SPECTROSCOPY FOR THE ANALYSIS OF WOOD

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1. Introduction

Climate-induced fluctuations may be particularly important for the conservation of works of art executed on wooded supports, which include panel paintings or other wooden polychromy (ranging from Egyptian Sarcophagi to Fayuum portraits, Byzantine Icons and Renaissance Crucifixes to Altarpieces and painted sculptures).1 Changes in humidity may cause expansion and contraction of the wood and can also affect paint layers; movement of wood can be reversible but may also result in irreversible buckling or cracking of the support. One important aspect of preventive conservation is the determination of suitable threshold values of RH within museums and buildings or during transport of objects. However, non-destructive determination of moisture content of wooden works of art, which varies with external conditions, is not an easy task.

We propose and experimentally demonstrate that picosecond time-resolved optical spectroscopy in the visible/near-infrared (NIR) region (700-1040 nm) is a useful technique for non-invasive characterisation of wood,2-4 with specific focus on the determination of water content by separately measuring absorption and scattering spectra,4 which can be related to chemical composition and structure of the sample, respectively. Time-resolved spectroscopy in the visible/near-infrared region is a non-invasive technique for bulk analysis and the typical penetration depth of the technique is from several mm to a few cm. The penetration depth of the detected photons depends on the optical properties of the sample and the distance between the injection and detection points. This technique has been used for the analysis of water content and induced changes which occur with humidity fluctuations.

2. Materials and Methods

In order to evaluate time-resolved reflectance spectroscopy for the determination of water content in wood, samples of wood cut from the same beam were prepared and these samples were conditioned in different environments, with relative humidity varying between 12% to 95%, at an ambient temperature of approximately 25 °C.

A schematic of the experimental design is shown in Figure 1. A broadband pulsed laser source emits light pulses shorter than 20 ps (repetition rate of 20 MHz over the spectral range 465-1750 nm) with total emitted power of 2.6 W and a spectral density higher than 1 mWfor all the wavelengths. The laser source (SC450, Fianium, UK) consists of an amplified Yb-doped fiber laser emitting at 1060 nm, coupled to a photonic crystal fibre to generate a supercontinuum (SC). The broadband output is spectrally dispersed by a F2- Pellin-Broca prism and focused by an achromatic doublet (f=150 mm) into a 50 µm core graded index fiber, which is used to direct the light pulse into the wood sample. Prism rotation is controlled to select the desired wavelength. The bandwidth depends on the core dimension of the fibre and it is lower than 18 nm over the whole spectral range. A 1 mm plastic-glass optical fiber is placed adjacent to the delivery fibre on the same face of the sample (reflectance geometry) to collect the diffuse light as it exits the sample. The interfibre distance between the injection and collection fiber is depending on signal intensity; hence in wood, the interfibre distance is dependent on the orientation of the optical fibers with respect to the wood fiber.4 The collected light is finally detected by a water-cooled double microchannel plate photomultiplier. The electronic signal is sent to a time-correlated single photon counting (TCSPC) PC board to record time-resolved curves.

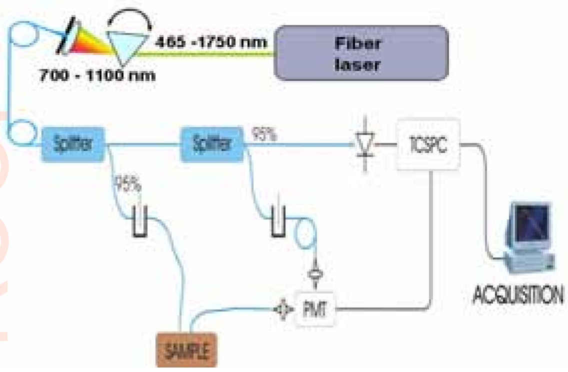

Figure 1: Experimental setup for time resolved spectroscopy of wood.

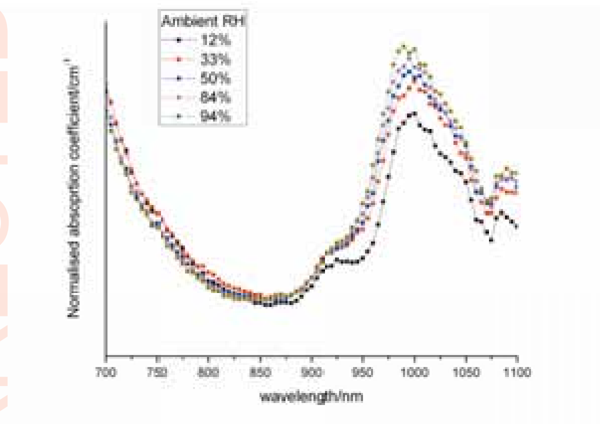

Figure 2: Time resolved spectra of absorption coefficient vs. wavelength as a function of relative humidity,

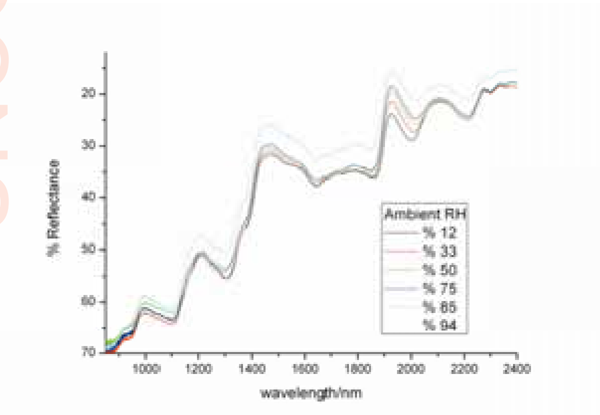

Figure 3: Near Infrared spectra of the same samples as a function of relative humidity.

In order to evaluate the absorption and reduced scattering coefficient, time-resolved curves are fitted, with a standard Levenberg–Marquardt algorithm, to an analytical solution of the diffusion approximation of the transport equation with the extrapolated boundary conditions of an infinite slab. The fitting procedure is repeated for each wavelength.

For reference Near Infrared (NIR) spectra were recorded using a Thermo FTIR spectrometer accessory based on a room temperature InGaAs detector. Spectra were recorded from the centre of the wooden blocks in the same position analysed using time resolved absorption spectroscopy with 32 acquisitions at a resolution of 4 cm-1 and in a range between 10000-4000 cm-1.

3. Results

The absorption of wood depends on the chemical composition (principally lignin and cellulose); water also has a direct influence on the spectra of wood, both in time resolved spectra (Figure 2) and NIR spectra (Figure 3). Wood samples stored in dry conditions (12%, for example) can be differentiated from the samples cut from the same wood exposed to higher relative humidity (84%, for example) due to the grater extinction coefficient of water (present in wood due to the absorption of humidity), which is responsible for the broad band centred at approximately 980 nm (2v1 + v3).5 Other water overtones are observed as a function of relative humidity in Figure 3. Although differences between NIR spectra of the samples stored at RH 12-75% are not immediately apparent at all wavelengths, a linear trend is observed in reflectance at 1470 (v1 + v3) and 1900 nm (v1 + v2 + v3) which decrease with increasing humidity. This is due to the difference in the equilibrium moisture content of wood at different relative humidity. Statistical analysis of the spectra has been carried out, and time resolved absorption spectroscopy has also been used to monitor the real time changes following alterations in relative humidity.

4. References

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TECSIS PROJECT: SUBMARINE CAMPAIGN IN NAPOLI ARCHAEOLOGICAL AREA

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Abstract
The project TECSIS (Diagnostic technologies and intelligent systems for the south Italy archaeological sites) was dealing with the concept of remote museum that is an extension of the virtual museum concept. The remote museum allows the use of the cultural goods also in hostile environmental (marine sites, caves) or in site where the human presence can damage the goods (site sensible to climate change or similar). The aim is the application of advanced new technologies in archaeological research, maintenance, supervision and valorisation of the historical and artistic patrimony to help archaeologists in surveys of important sites and inspection of submarine finds; moreover the remote visual touring , possibly integrated with multimedia interactive instruments, can develop a new kind of tourism. This poster is concerning with some measurements performed during the marine campaign leaded by ROV (Remotely Operated Vehicle) in the archaeological sites in the Napoli's area, as suggested from the local authorities proposed to the protection of the sites. In particular we performed bathimetric and morphological measurements by Side Scan Sonar, Multi Beam EchoSounder integrated with camera vision. The visited sites were the city of Baia (Napoli), the Agrippa Postumo's villa (Sorrento), some columns close to Procida and a modern ship sink close to Ischia. All the measurements were georeferenced by GPS and local pinger to mark the position of the ROV.

1. Introduction

TECSIS is a project financed by the Italian Ministry of Research (MIUR) to develop "Technologies and Intelligent Systems for the development of Archaeological Parks in Southern Italy" (http://robotica.casaccia.enea.it/tecsis/index.php). The project was dealing with the concept of remote museum that is an extension of the virtual museum concept. The remote museum allows the use of the cultural goods also in hostile environments (marine sites, caves) or in site where the human presence can damage the goods (site sensible to climate change or similar). The basic idea is to open to the cultural tourism the archaeological and artistic areas currently unavailable owing to the position of the historical sites and samples and often to the physical impossibility to move them to Museums. Moreover it opens the possibility for the expert people to work in situ from their laboratories.

Tecsis is one of the biggest national projects on robotics funded by the Ministry of Research in the last years and collects the contributions of three industries, two Universities and four public Institutes with ENEA (Italian National Agency for New Technologies, Energy and the Environment) as the main operator.

ENEA has a long tradition in the exploitation of high-tech diagnoses in the preservation of artistic masterpieces. Recently, cultural heritage thematic has been chosen as one of its reference projects. The relevant element of this choice is in the possibility to support the preservation of the goods and the opportunity to appreciate the cultural heritage itself through the exploitation of the technological know-how of the Agency.

ENEA has developed and is still working on many facilities, among these acoustical, optical and X-ray analysis instrumentation, Remote Operated Vehicles (ROV), Underwater Autonomous Vehicles (AUV), underwater communication systems and others. These facilities have been used in the projects focused on the archaeological research, maintenance, survey, protection of the historical heritage, both marine and terrestrial. It includes a number of research activities including the exploration and data acquisition of archaeological masterpieces and historical rests lying on the Mediterranean basement. The aim is to support archaeologists in surveys, inspection and digital reconstruction of submarine sites as well as in the valorisation of the historical and artistic goods by means of remote visual tours.

A multi disciplinary technological approach to cultural heritage currently represents the preferred solution to preserve the masterpieces from environmental and "aging" damages. A cautious exploitation of the tools that the modern technology is able to supply opens new possibilities to enjoy the masterpieces and also allows increasing the number of the visitors of artistic heritage sites and Museums. More specifically, the use of Robotics in cultural heritage could allow the introduction of an entirely new concept of "artistical journey", potentially able to cope with many of the before mentioned concepts.

A very advanced digitalised museum can offer to many more visitors the opportunity to access to masterpieces, to preserve the goods from the attacks bound to the presence of hundreds and thousands of human beings, to deepen certain analyses and studies in such a way that couldn't be allowed in a "real" visit. Advanced technology can lead to feelings similar to those that the most of people can enjoy during a "real" visit and the effort of the research in this field is to make the difference between walking among the masterpieces and perceiving their magnificence through electronics devices minimal.

Robotics approach, moreover, can allow the visitor (as well as the archaeologist) to recover some feelings of the "true" visit, avoiding at the same time the difficulties coming from hostile environments as deep waters, caves, and other "hard" places where archaeological goods are often hosted and cannot be removed. A significant part of cultural heritage is in fact located in similar places. Therefore robotics can develop a new kind of virtual museum where the visitors are active actors of the scene for a cognitive experience. We called all of that a "Remote Museum".

Sophisticated rendering technologies, joined with the opportunities inside the concept of Remote Museum could allow the augmentation of perceptive and cognitive feelings in a large number of visiting persons and the quality itself of interactive perceptions.

The project explicitly does not preview the realization of a pilot park, but the realization of demonstrative experiences. Some not commercial demonstrations are realised with campaigns in collaboration with the local authorities. This cooperation leaded to recognise some central keys of the project:

- Diagnostic function,
- Recovering and maintenance of the goods,
- Mobility function,
- Remote ability to use the good function.

Points of force of the project are the integration of possessed innovative technologies from various partners into an "homogenous corpus"; the introduction of the concept of "remote museum"; the development of totally new technologies, such as the submarine LIBS (Laser induced breakdown spectroscopy) and the model of the plume (plasma spandrel) the underwater laser cleaning, and some techniques of control adopted for the first time on submarine's robot.

The results obtained by the project were many: 4 patents, 3 copy writes of software, more than 100 publications, 6 measurements campaign, to name a few..

Some of the principal improvements are:

- The quantitative analyses of underwater technique LIBS;

- The application of sophisticated control techniques for the laser treatment of surfaces exposed to the action of polluting agents;

- The development of low cost technologies for surveying the coastal submarine;

- The development of "in situ" measurements technologies where the only applicable option was (and not always usable), with very high costs was laboratory analysis;

- The improvement of the 3D reconstruction systems, using special technologies increasing the precision by active stabilization.

Four terrestrial and two marine campaigns were performed. The marine were on the historical site of the Egadi battle (among Romans and Carthago ships) and within the Naples bay.

The poster presents some of the measurements performed during the marine campaign lead by ROV in the archaeological sites in the Naples area, as suggested by local authorities delegated to the protection of the sites. In particular we performed bathymetric and morphological measurements by Side Scan Sonar, Multi Beam Echo Sounder integrated with camera vision. The visited sites were the city of Baia (Naples), the Agrippa Postumo's villa (Sorrento), some columns close to Procida and a modern ship sink close to Ischia. All the measurements were georeferenced by GPS and local pinger to mark the position of the ROV.

2. Experimental

Archaeological sites

The choose of the archaeological sites has been leaded together with the local government of Napoli. The chosen sites are the following:

- Marbles wreck,
- Misero wreck,
- Pila di Bacoli,
- Villa di Agrippa Postumo's villa (suppose),
- Baia sunken city.

The wreck is composed of the a sank ship into Procida's channel with its load. Four marbles columns (about 1.6 m x 0.8 m and 2.5 m x 1 m) and three block squared. The ship belong to the 19^{th} century but the load is oldest. depth is about 12 m.

Miseno wreck

The wreck is a modern ship (1943). Depth is about 70 m.

Pila di Bacoli site

It is a column (square section), part of a roman port in the city of Baia. The depth is between 6-20 m.

Agrippa Postumo's villa

Agrippa Postumo was a nephew of Augusto; he was relegated to Pianosa for political reasons. Later he was killed to prevent him from participating in the struggle for succession, probably on the orders of Tiberio. Previously, by the will of Livia Drusilla Claudia (his stepmother), was confined at the present town of Sorrento. The villa in question was probably his residence. It is partially submerged but visible and accessible.

Baia submerged city

The ancient city of Baia (Baianus Lacus) was a holiday resort for the aristocracy and for the Roman emperors, favoured by the presence of thermal waters; it was subject to bradisism phenomena as the entire area of Campi Flegrei. Part of luxury buildings is today, therefore, below sea level in the Bay's Pozzuoli. These are the remains of buildings of old imperial remains of some of the richest villas that still have whole floor mosaics. Also visible are a piece of a street, taverns and remains of a thermal building.

3. Technical resources

The ROV "Falcon"

The ROV "Falcon " (SeaEye) is one one of the most versatile and light currently on the market.

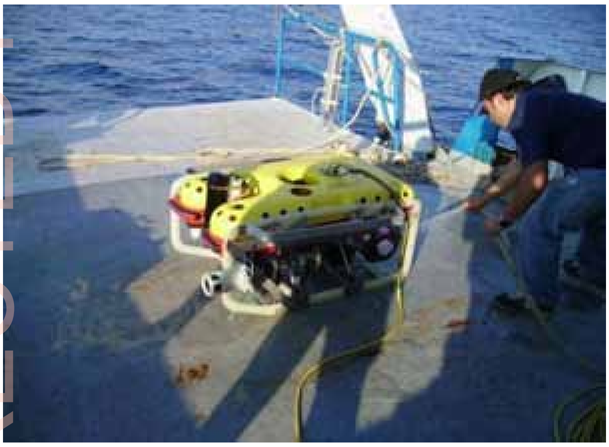

Figure 1: ROV Falcon at the beginning of a work day.

Its main features are:

- 300 meters depth.
- 300 meters of umbilical cord.
- 4 engines horizontal and a vertical coupled magnetically and without brush current control loop with 50 KG strength.
- Distributed intelligence control system.
- Full diagnostic system.
- High resolution color camera.
- Front lighting system 150 Watt.
- Auto adjust the depth and direction

Side scan sonar

The ROV "Falcon " (SeaEye) is one one of the most versatile and light currently on the market.

Figure 2: Side scan sonar.

The Side Scan Sonar (SSS) Tritec seaking is designed to be installed on ROV and AUV. In picture you can see the two transducers and the head. It must be connected to the surface unit proocess, usually Seanet SCU or a PC card with dedicated (ARCnet protocol). In addition to external data can be superimposed as those from a differential GPS. The operational depth is 4,000 meters.

Sonar

The ROV is equipped with a panoramic sonar large radius (about 100 meters), shown in Figure together with its control unit. The sonar was installed on the ROV with its white protective hat, but was also used horizontally (to brush the bottom of the sea) to help the operator to search for artefacts.

Figure 3: Sonar mounted on the ROV and its control unit.

Processing unit

The surface control unit Seanet SCU is a multi purpose unit operating system with Microsoft Windows XP preinstalled on a solid state disk. It allows you to control various instruments of Tritec and store the data collected. The communication system at high speed (156kBits/sec) protocol on RS232.

Figure 4: Side scan sonar: control unit.

Other instruments

Table 1: Other instruments used.

Instruments	Description
DGPS Fugro SkyFix	Differential GPS
HPR400	Acoustic ROV position system
Girocompass SGB Meridian	Gyroscopic compass
Multibeam EM3000	Sonar multibeam
TSS DM S2-05	Motion sensor to compensate multibeam
PC Nav	Navigation Software
SW nav Qinsy	Hydro graphic Software
Probe Valeport	Salt Measurement Probe and sound speed

4. Results

Starting the job

Here we shall present a few of the pictures and graphics that we have generated in a week of measurements.

Figure 5: Ship laboratory.

The work on the measured data is still in progress concerning mosaic three dimensional reconstructions, augmented reality by fusion of the information extracted by Side scan sonar and optical image. All the instruments were calibrated in situ.

Figure 6: ROV Falcon during immersion into the sea.

Archaeological sites

Here we show some photos and pictures of the archaeological sites visited. The material is still object of investigation to extract the information contained in the data. No photos or picture of the Baia submerged city is showed here because a cleaning job on the rough data must be performed. The intention is only to show the technical used.

Marbles wreck

Figure 7: Marbles wreck: columns.

Figure 8: Marbles wreck: columns.

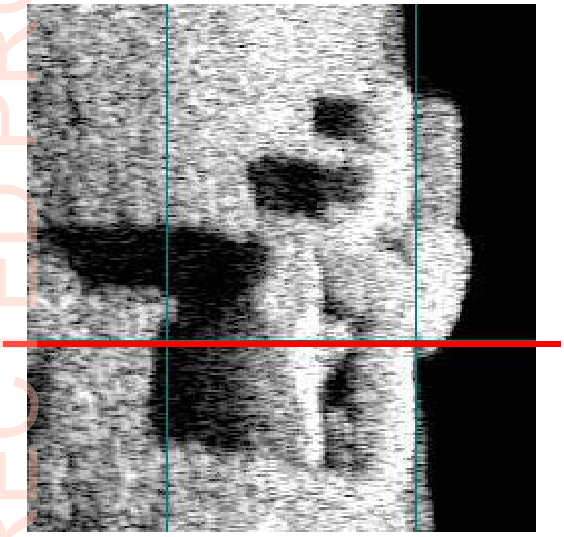

Figure 9: Marbles wreck: Side Scan Sonar picture.

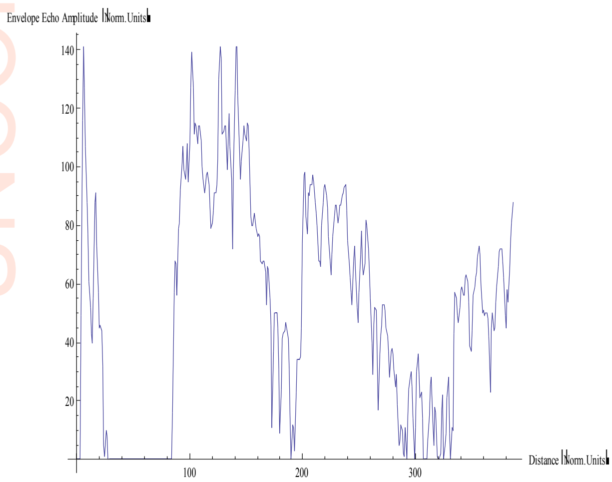

Figure 10: Corresponding envelope of the returned echo relative to the red line.

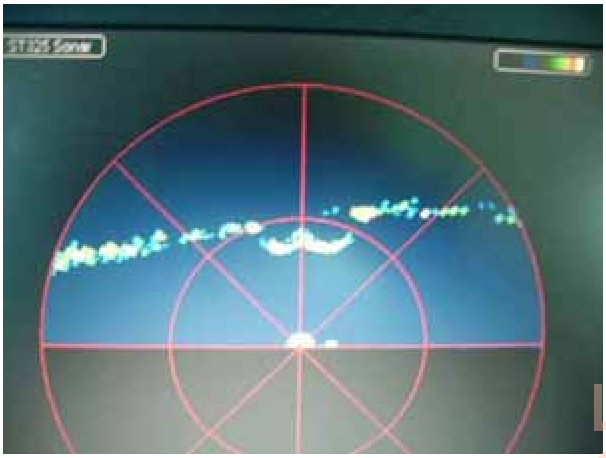

Figure 11: Marbles wreck: Sonar picture.

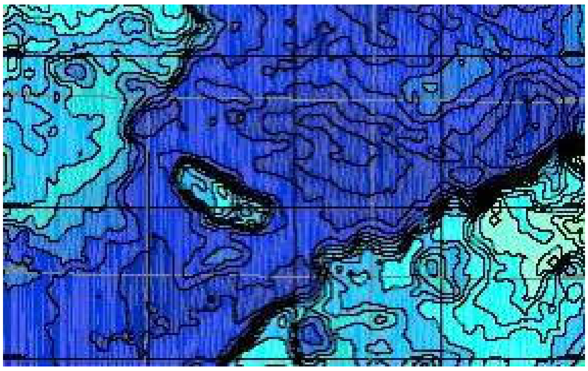

Figure 12: Marbles wreck: bathymetric profile.

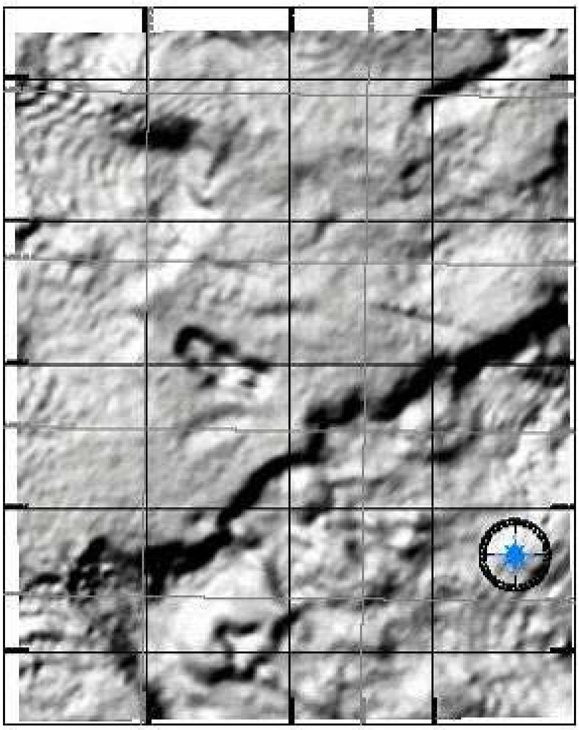

Figure 13: Marbles wreck: shaded relief picture.

Miseno wreck

Figure 14: Miseno wreck.

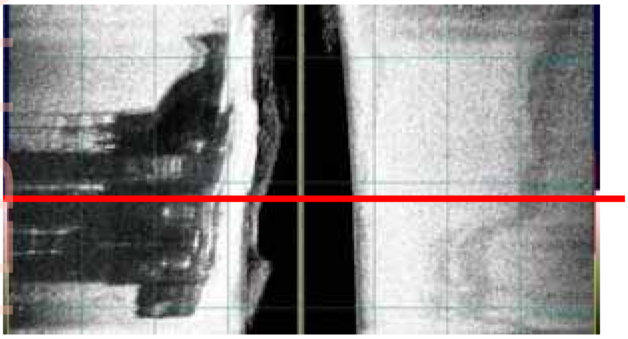

Fig. 15 – Miseno wreck: Side Scan Sonar picture.

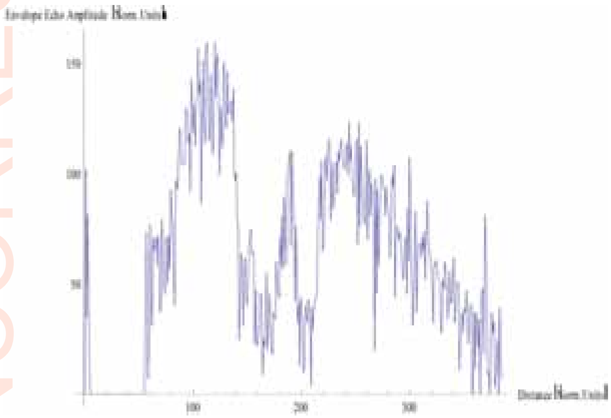

Figure 16: Corresponding envelope of the returned echo relative to the red line.

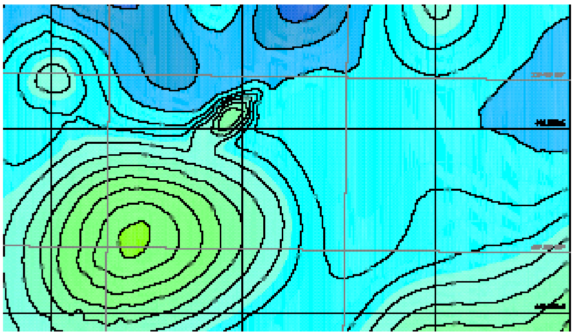

Figure 17: Miseno wreck: bathymetric profile.

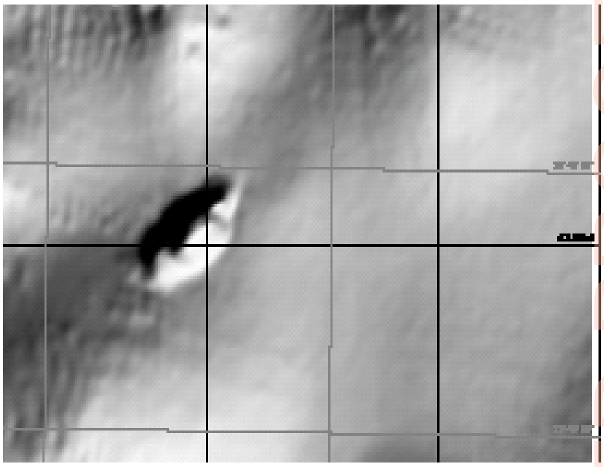

Figure 18: Miseno wreck: shaded relief picture

Pila di Bacoli site

Figure 19: Pila di Bacoli.

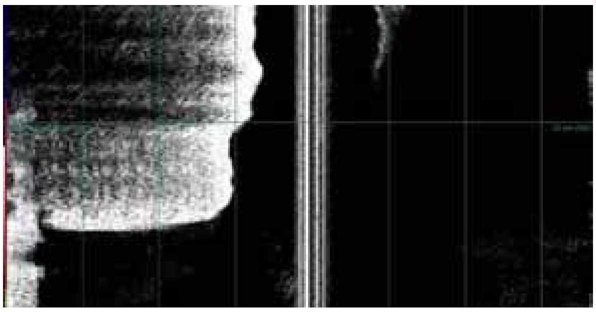

Figure 20: Pila di Bacoli: Side Scan Sonar picture.

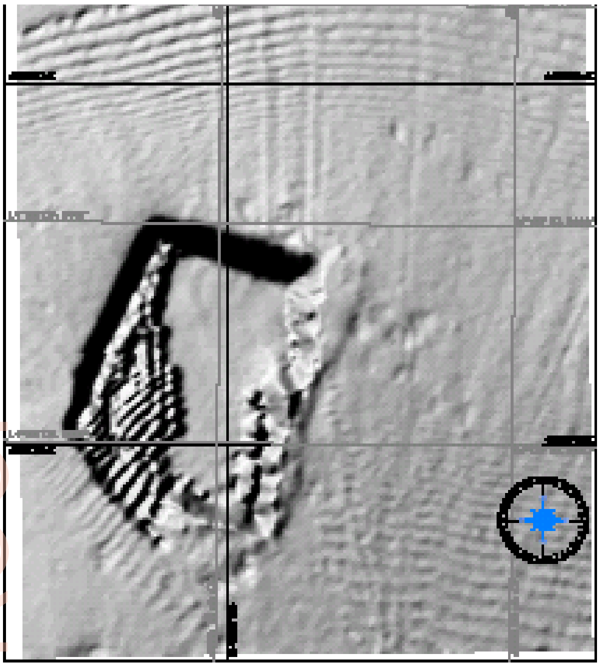

Figure 21: Pila di Bacoli: shaded relief picture.

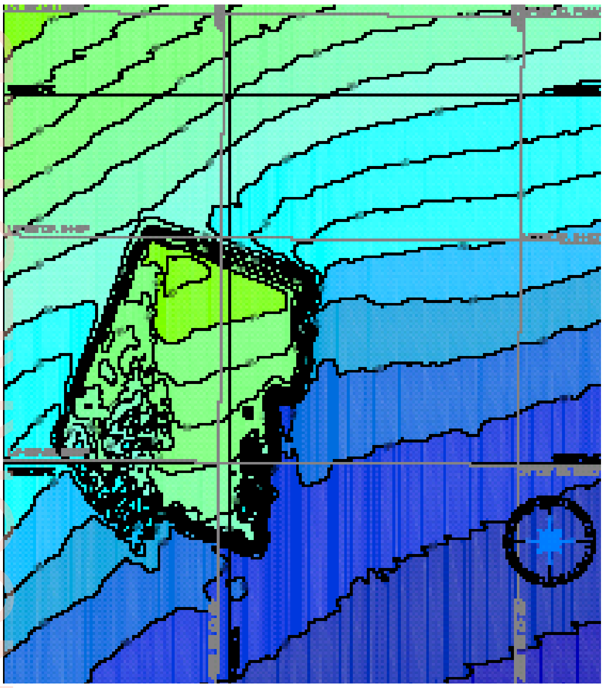

Figure 22: Pila di Bacoli: bathymetric profile.

Agrippa Postumo's villa

Figure 23: Agrippa Postumo's Villa: outside.

Figure 24: Agrippa Postumo's Villa: under side.

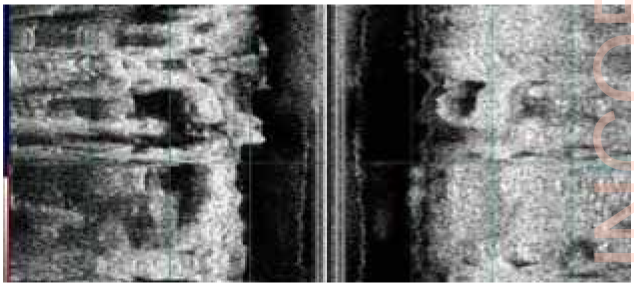

Figure 25: Agrippa Postumo's Villa: Side Scan Sonar picture.

6. Conclusions and plans for the future

In this paper we described the II marine campaign of the Tecsis project leaded in the Napoli's bay and some pictures are presented; our intention was to give a sharp look on the possible contribution of robot technologies for the study and conservation of the cultural heritage. A lot of data was collected and the material is still object of investigation to build 3d mosaic pictures, synchronize video image with acoustic image and to improve the control technique of the robot to achieve the remote museum concept. This will be object of a more technical publication in a next future.

7. Acknowledgments

The authors are grateful to all researchers who have participated in the marine campaign, in particular Luciano Blasi, Giacomo Bonanno, Roberto Cenni, Ramiro dell'Erba, Claudio Moriconi, Claudio Poggi, Domenico Suriano.

CONSERVATION OF THE WALLPAPER FROM GOZZE PALACE, DUBROVNIK

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In 2001 Croatian Conservation Institute took over the conservation of the Gozze palace wallpapers. The value of the historic wallpapers as a part of interior design in the past was recognized then. That was the basic initiative for the research of the existence of historic wallpapers on the Croatian territory.

Gozze palace is located in the protected heart of the old town of Dubrovnik on the address 2 Gunduliceva poljana, which suffered many changes through time. One of the owners was the Basseglli-Gozze family who furnished four first floor rooms with wallpapers. Mr. Palo Gozze was in Paris in 1810 and that was a significant moment of choosing the style and fashion for the palace interior decoration with wallpapers. Today the Friends of Dubrovnik Antiquities are the owners of the same apartment. Three east side palace rooms are connected so that the central one leads to the southern on one side and the northern on the other side while the western room is situated in front of the central drawing-room.

The central drawing-room walls are decorated with the wallpapers manufactured by Zuber & Cie from Rixheim, France, called «The Lady of the Lake» or «The Sights from Scotland» and made after the model whose author was Julien Michael Gué from 1827. The wallpapers consist of 29 scene bands (originally 32) with the following lower and upper border.

On the southern side there is an adjoined room decorated with the wallpapers called «The French Gardens» or «Little decor» (probably the second edition from 1830/40), printed after a model by Pierre Antoine Mongin from 1822 also manufactured by Zuber & Cie from Rixheim. These panoramic wallpapers are divided into three figurative scenes (totally 24 bands out of originally 25), framed with bordures which simulate wooden carved frame.

«The Floral Room» is the working title for the western room draped with floral patterned wallpapers following the lower bordures with figurative and architectonic motive (dated between 1850. and 1860.).

The last restoration and conservation project work was on the wallpapers from the northern room by the title «Little northern room».

The tests on separating the wallpapers from the wall were conducted on the «Little northern room» wallpapers. Two layers were found at that occasion. In the lower older layer there were found the wallpapers , dated as the oldest from around 1810 and they consist of the basic structure of wallpaper decoration – parapet, dado, bordure, filling and frieze. The upper more recent layer of non-rococo wallpapers dates to the period after 1850.

Laboratory research was done on the paper base patterns. The textile fibres identification was conducted by microscopic examination and comparison with the standards.

The wallpaper layer separation tests showed that they needed to be separated «in situ», because the mounting methods was not same. After demounting the wallpapers were transported to the workshop where they were first dried and then wet cleaned.

Further conservation treatments phase followed the standard paper conservation procedure so the tears consolidation was done by thinner japanese paper bands (Bib Tengujo 12 g/m²; Japico). The missing parts reconstruction was done by the Japanese paper thick as the original paper. After the mentioned treatments the whole band of wallpapers was lined on the Japanese paper (Kozu Shi 32 g/m²; Japico).

To start with remounting phase is necessary to explain that wallpaper mounting need to satisfy a few demands the protection against possible mould and salt appearing on the room walls, reversibility and the question of presenting both wallpaper layers. The technique was adopted from two methods SHOJI Japanese paravan and the standard remounting method of gluing the wallpapers on a flaxen fabric.

More methodical Croatian wallpaper research is in progress.

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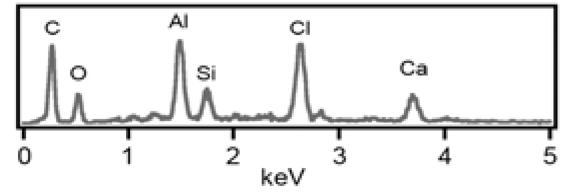

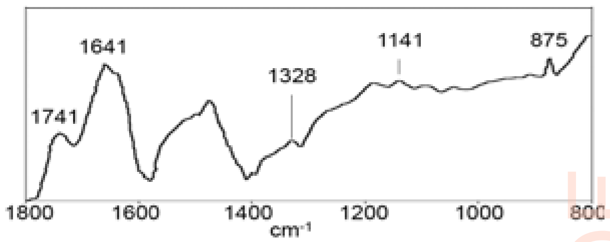

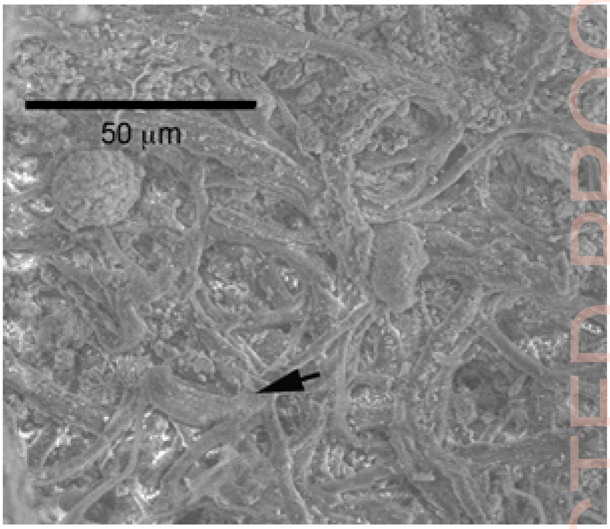

CALCIUM ALKOXIDES: A NEW PROMISING ROUTE FOR CONSOLIDATION OF DETERIORATED LIMESTONE

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Restorers, firstly, and conservation scientists have always had to face the problem of stone deterioration, an issue that has become more and more urgent since atmospheric pollution due to human activity has worsened the effects of natural environmental agents.

Many products have been proposed and applied: they can be grouped in two main categories, the organic and the inorganic materials. Organic materials included synthetic polymers, extensively used in the past and still widely applied, with an efficiency in preventing further deterioration to be drastically reconsidered; they frequently undergo chemical modifications induced either by environmental conditions and by the substrate itself, which cause loss of efficacy and irreversibility of the treatment.[1-3] Inorganic materials are supposed to be more suitable because of their physico-chemical compatibility with the stone: they have been traditionally applied since the beginning of conservation and recently drastically reconsidered.

In our laboratory we have synthesized and tested calcium alkoxides for the strengthening of limestone with the aim of a durable and compatible treatment.[4] Linear and branched calcium metallorganic compounds have been designed, synthesized and their potential as stone consolidants evaluated.

Alcoholic solutions or suspensions of $Ca(OCH_3)_2$ have been studied by NMR and IR techniques to evaluate their stability towards hydrolysis and alcoholysis and the conversion products have been characterized by XRD measurements. In order to study the behavior of the calcium alkoxide and its transformation to calcium carbonate inside pores and cavities, we choose to treat glass frit (generally used for chemical filtration; experimentally calculated pores diameter 5-15 µm) as porous substrate. This choice is to avoid misleading interpretation of morphological FEG-ESEM observation and EDS analyses on treated stone specimens as a limestone substrate and the effective consolidant have both the same mineralogical and chemical composition.

In order to verify the consolidation effects, the same solutions have been applied on artificially aged Carrara marble specimens (5x5x1 cm^3) by capillary imbibition (contact time: 2h) from the wider surface side. The application was repeated every 24 h for three times. For comparative purposes, ethyl silicate (TEOS), solution of $Ba(OH)_2$, $(NH_4)_2CO_3$ and alcohol suspension of $Ca(OH)_2$, prepared according to literature,[5-7] have been applied by the same procedure. Consolidation efficiency on marble specimens treated with the different products has been evaluated by measurement of ultrasonic velocity (USV) before and after treatments.

The consolidation efficiency (C.E.) has been evaluated with particular emphasis to the following requirements: *i)* physico-chemical compatibility of the applied products with the substrate; *ii)* morphology and distribution of the inorganic products inside the pore network, i.e. evidences of consolidant adhesion to the substrate and/or cracks and fissures, powdering deposition, intergranular links, etc.; *iii)* low product invasiveness, as a detrimental consolidation effect is the pore saturation instead of a coating formation on the pore walls because it doesn't ensure termohygrometric equilibrium of outdoor stone with the environment.

The C.E. has been expressed as:

$C.E. = (US_f - US_{nt})/P_f$,

where: US_{nt} and US_f are respectively the ultrasonic velocity (km/s) measured before and one month after the product application; P_f is the amount of the final product, expressed in mg inside marble substrate after treatment, calculated according to quantitative reactions.

Due to space limitation, exclusively the results obtained from $Ca(OCH_3)_2$ and comparison with TEOS and $Ba(OH)_2$ will be discussed.

The transformation reactions occurring between $Ca(OCH_3)_2$ and environmental H_2O and CO_2 have been investigated by infrared measurements: few drops of their alcoholic solutions have been placed on a gold flat surface and reflectance IR spectra have been collected after alcohol evaporation at different times until complete conversion of the alkoxide, occurred after one to two months after the treatments. Micro-FT-IR investigations confirmed the formation of $CaCO_3$ as the final product in all cases although two different reaction pathways can take place (Figure 1). XRD measurements allow identifying the crystalline phase of the final products, which resulted to be calcite and vaterite.

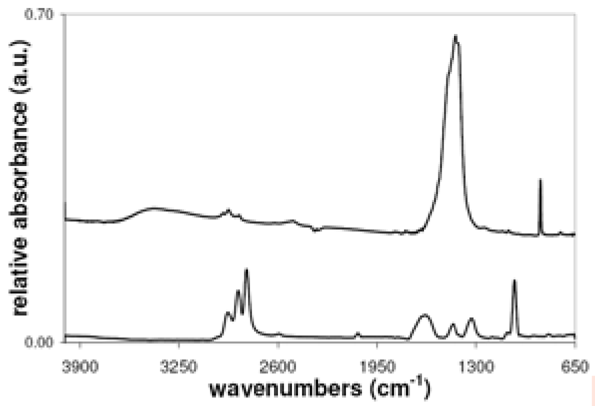

Figure 1: IR study of reaction of $Ca(OCH_3)_2$ with atmosphere. The spectra show the absorbance bands of $Ca(OCH_3)_2$ (lower one) just after deposition and the calcium carbonate absorption after complete conversion of the alkoxide (upper one). A detailed description of the different absorbance can be found in reference 4.

FEG-ESEM and SEM morphological observations, performed either on surface and on transversal section of glass frit and marble specimens, aimed at investigating the carbonate formation from $Ca(OCH_3)_2$, were carried out two months after treatments. They show a homogeneous film of roundish and platelette-like crystallites grown on the grains (Figure 2). The coating strongly sticks to the surface without any formation of the ungrafted particles and its thickness ranges from 50 nm to 1.5 □m. similar observation performed on the same substrates treated with TEOS (Figure 2), show a thick deposition on the surface and an uneven impregnation of the pores. Furthermore, the shrinkage occurring during TEOS polymerization a

Table 1: Amount of different applied products related ultrasonic velocities, measured on marble specimens before and after treat ments, and C.E. (Consolidation Efficiency).

product	applied amount (mg)	v_i untreat. Marble (km/s)	v_f treated marble (km/s)	□v %	C.E. (km/sg)
$Ca(OCH_3)_2$	4.0 ± 0.6	1.1 ± 0.2	1.3 ± 0.1	18	51
TEOS	188.5 ± 19.5	1.1 ± 0.3	3.8 ± 0.6	245	50
$Ba(OH)_2$	39.8 ± 1.0	0.9 ± 0.1	1.4 ± 0.1	56	11

nd silica formation is responsible for the extensive fissured network of the silica coating.

The consolidation efficiency, evaluated on marble specimens through ultrasonic velocity measurements before and two months after treatment with the different products (Table 1), shows that the increase of ultrasonic velocity, measured after marble treatment, strongly depends on the amount of applied products: 4 mg of $Ca(OCH_3)_2$, 39.8 mg of barium hydroxyde and 188.5 mg of TEOS respectively induced a positive variation of ultrasonic velocity of 18-56 and 245% with respect to untreated marble. Notwithstanding the high amount of amorphous silica introduced inside pores and the corresponding increased ultrasonic velocity, the silica coating appears highly fissured; thereby its function is more similar to a filler rather than to a consolidant (Figure 2).

To estimate the consolidant efficiency C.E. of the applied products, the ratio between the variation of ultrasonic velocities (measured before and after treatment) and the amount of the final product deposited inside the pores was calculated. The obtained C.E. data for $Ca(OCH_3)_2$, TEOS and $Ba(OH)_2$ clearly show a better performance for the alkoxide compared to the other inorganic products, with the following performance scale: $Ca(OCH_3)_2$ > TEOS >> $Ba(OH)_2$.

The properties of these novel materials are still under investigation especially to improve their stability and solubility; the preliminary encouraging outcomes make Ca-alkoxides good candidates to become new compatible and durable materials for the strenghtening of limestone and a newsworthy replacement of currently used materials.

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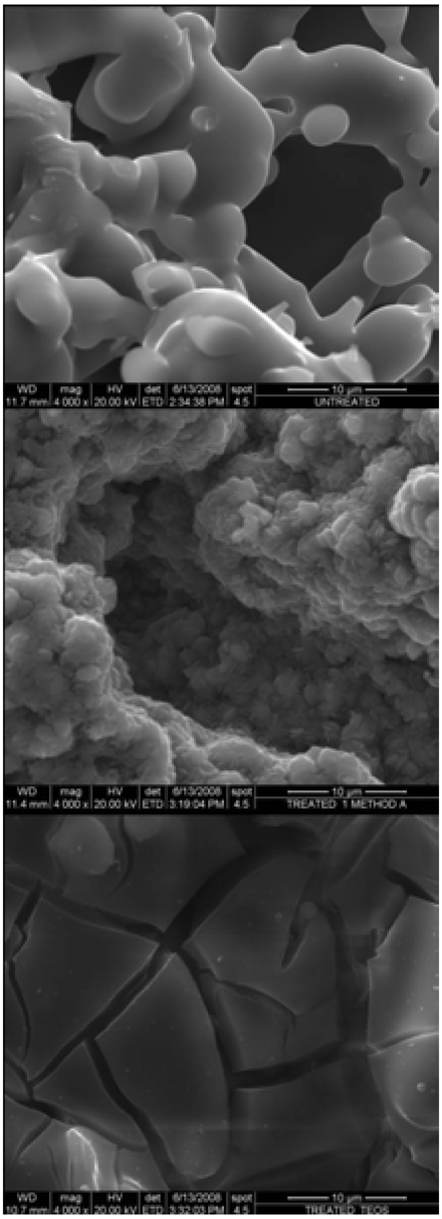

Figure 2: Secondary electron images collected on silica frit untreated (up), treated with $Ca(OCH_3)$ (middle) and TEOS, (4000-fold magnification) (bottom). The $CaCO_3$ coating from alkoxides appears more homogeneous and more adherent to the substrate in comparison to the silica cracked coating from TEOS deposition.

THE CHURCH OF THE VISITATION OF THE BLESSED VIRGIN MARY IN VOĆIN - MODERN METHODS IN ORIGIN PARTS RECONSTRUCTION

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Subject of the paper is the precise reconstruction of the genuine parts of a destroyed building like vaults and vaults ribs for facsimile rebuilding of the church. Gothic church of the Visitation of the Blessed Virgin Mary in Voćin is as remarkable monument of medieval build heritage in Region of Slavonia, as the most important sacred place of Our Lady of Požega diocese. The Church was built at the end of the 15th century together with Franciscan monastery and belongs to a period of late gothic style in Middle Europe – Czech Republic, Slovakia, and Hungary. In the region of western Slavonia this church represented the highest quality (survived) example of the late gothic architecture.

In 1991, during the Croatian Fatherland war, the building was totally destroyed by Serbian army aggressor. After liberation, in 1996 elimination of ruins and clearing of the remaininig fragments begun, followed by conservation research in 1999. In 2003, the first plans and designs for the reconstruction were finished and rebuilding of the church started. The genuine stone material (blocks, carved parts as decoration etc.) was almost ruined, so it was decided for facsimile reconstruction of the church.

The first notable devastation of the church occurred after Ottoman's conquers at the first half of 16th century. During the building of the near fortification, the many stone blocks of the monastery, as well as the lower parts of church, were taken from their original place and used for it. Latter, these holes were filled by various materials, especially after the renewal of the church in the late 18th century. During this renewal, the floor level was raised and the church was covered with the roof, which remained till the beginning of the 20th century. Very fundamental renovation of the church begun at the beginning of the 20th century, when the interior and the cap of the bell-tower (that was destroyed by the thunder at the 1906) were renewed in the new gothic style. At the end of the second world war the church was burned, and after that till the late 60's of the last century, only the walls of stone remained at the place. The start of the reconstruction was very hard because of the actual politic conditions in Croatia at this time. In early 80's the church was reconstructed. Ten years after, the church was destroyed, but this time - completely.

Investigating the ruins of the church, many original gothic parts of the church were found and conserved. Documented are levels of all floors (the baroque as well as the gothic one), and the lower parts of gothic portals with very well ornamented architectonic plastics. At the over-foundation walls, the church kept its form, so they were used as a base for renewal. From the destroyed parts of the church, no one piece of the main portal was kept and retured to its original place, because of the extensive demining and site consolidation processes. Other parts of stone plastics, mainly church-windows and wall pieces of vault ribs have been scattered along the surrounding, and because of the inadequate manipulation, warehousing and because of the inferior quality of the stone (sandstone), they fell apart. All pieces of the stone plastics were measured and documented, but by means of computers we intend to reconstruct the whole church together with all genuine parts, that it had. For making of the reconstructed church model, the old well-known methods of construction of the Gothic vaults were used, as well as their simulation by computers. Most recent methods of 3D-measurements were applied to reconstruct the elements of stone plastics and to make their facsimile out of substituting material as exact as possible. For that purposes the use of computer-driven CNC milling machine for stone was intended. There were many methods we used in researching and surveying of the stone remains of the church. As by destroying of the church the main focuses of the explosions was nearby walls, the parts of wall ribs of vault were completely destroyed, and other elements very damaged. For the reconstruction of the original position of left-over stones, the documentation created during cleaning and sorting of stones was used, as well as the old photographs of the church taken before the damage. The church vaults are very specific. There are many reconstructions of the nave vault tried, concerning to founded rests of it. Mostly, all reconstructions rely on existing wall ribs, where two of them come out of wall plane very shallowly, forming the curvature of nave vault surface. More detailed exploration had never before taken place, so the previously mentioned method of the construction of the vault ribs was taken "as is". Only after detailed analysis it became obvious that there was a third, transversal rib that significantly simplifies the whole net of vault ribs, and reduces it to the net of the rhomboid vault fields. Exit of the third rib from the wall surface is set unexpectedly high, in respect to two lateral ribs and their overlap in the manner of late Gothic. For the correct reconstruction of the vault, a very detailed and accurate measuring of the remaining pieces of the profiled stone blocks was acquired.

For the architectural reconstruction of the gothic (barrel like) vault of the nave optical scanner (Minolta Vivid 9i) was used. 3-D models of measured stone blocks of vault ribs were created using PolyEdit software. These data were exploited in the CAD model reconstruction of the original nave vault, and further, as architectural plans for this part of the building. Spatial CAD-models of blocks, scanned by non-contact 3D digitizer, have been set to their original positions (virtually, by using of CAD-software) in respect to one of the vertical wall rib. The integral model of wall ribs of one vault heel was assembled this way. Measurements of angle between the rib and the wall surface, as well as the radiuses of curvature of ribs have given slightly different results and have varied from 19° to 22°, in other words from 610 cm to 790 cm. The most probable data are chosen for the reconstruction of whole nave vault.

THE INFLUENCE OF METAL WEIGHTING ON THE STABILITY OF SILK

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Silk is a culturally important textile, found in many artefacts of historic significance, including clothing, upholstery, banners and decorations (Figure 1). Therefore it is important to have an understanding of the behaviour of the material in order to conserve these objects for future generations. Unfortunately silk is a fragile material and is prone to degradation through a variety of mechanisms, and 'weighted' silks appear to be particularly susceptible to damage[1-6].

Figure 1: Silk objects from the Karen Finch Reference Collection, Textile Conservation Centre; reproduced by permission of the Textile Conservation Centre, University of Southampton.)

Weighting is a method of processing common to many European silks dating from the Middle Ages onwards. Historically silk was sold on the basis of weight; organic agents such as sugars, waxes, gums and protein glues, came to be used as a fraudulent means of replacing the material (and thus value) lost during degumming (removal of sericin), or even of loading the fabric significantly beyond its original weight[3,4,6-8]. Subsequently, weighting became an accepted processing method, imparting a particular texture and drape, and by the late 18th century the organic species had been superseded by treatment with metal salts (particularly those of tin, lead and iron) which form insoluble complexes within the fibres. This remained common practice through to the 20th century.

Unfortunately these weighting agents have long been believed to be implicated in the relatively rapid deterioration of the textile, leading to characteristic 'shattering' (splitting along the lines of the warp and the weft) as seen in Figure 2, but the evidence to support this has been largely anecdotal. There are several proposed mechanisms by which weighting may lead to the enhanced degradation of the material: They may act as photocatalysts, promoting the natural susceptibly of silk to damage by light. Certain agents are known to be acidic or amphoteric, potentially leading to hydrolysis. The accumulation of the metal salt aggregates within the fibre may act as an abrasive at the microstructural level, causing the physical disruption of the fibre over time. The principal damage may result from the harsh conditions required by the weighting processes (exposure to high temperature acidic or alkaline solutions for periods of hours), as opposed to the subsequent presence of the salts within the material. It is also known that the most extreme level of weighting were often used for cheap, lightweight silk fabrics, in order to mimic the qualities of more expensive materials, so the weakness of these materials may lie in the original nature of the fabric itself. Finally, the damage may be caused by the application and subsequent influence of other treatment methods employed alongside weighting, most notably bleaching.

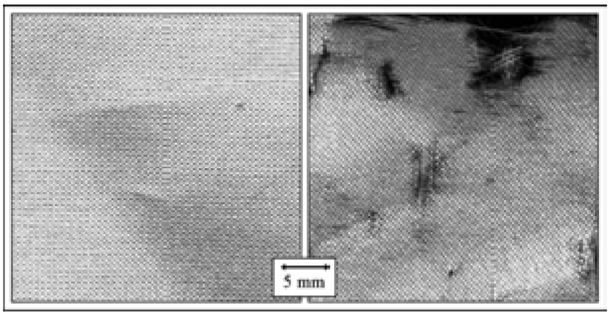

Figure 2: Undamaged and deteriorated silk.

Therefore, the aim of the research has been to assess the manner in which weighting agents interact with silk and influence its behaviour. Initially surrogate samples were prepared using contemporary weighting recipes[8], and these materials, along with historical examples, were assessed using light and electron microscopy, vibrational spectroscopy and liquid chromatography to determine their physical and chemical nature. Subsequently the way in which these agents then modify the stability of the material under various conditions was studied, employing surrogate specimens subjected to both thermal and light ageing, and comparing their properties to those of the historical fabrics, in order to determine the mechanisms by which weighting promotes deterioration.

The ultimate goal of the research is to better understand these valuable textiles and thus to inform future conservation, display and storage strategies.

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ASSESSING THE PHYSICAL STATE OF HISTORIC TEXTILES VIA NIR SPECTROSCOPY

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Textile artefacts, such as garments, upholstery and decorations, form an important aspect of our cultural heritage, but are susceptible to degradation by a wide range of physical and chemical effects. Ideally these textiles would be stored or displayed in a way which would avoid potentially damaging stresses, but this is not always possible, due to both practical and aesthetic considerations: Tapestries and banners, for example, are best appreciated when hung as originally intended, and clothing when exhibited on a mannequin that mimics the form of the original wearer (Figure 1). When textiles are displayed in this manner, there is the danger that the resulting stresses may contribute to deformation or deterioration[1,2]. Furthermore, the complexity of construction of some items means that even if kept in storage it is not necessarily possible to relieve all of the distortions and tensions that may lead to damage. Therefore, it is potentially of great value to a conservator or curator to be able to assess the mechanical forces at work in an object.

Figure 1: Typical textile artefacts susceptible to physical damage.

Our work has demonstrated that the physical stresses in a textile may be assessed indirectly using near-infrared spectroscopy in combination with multivariate analysis. NIR spectroscopy is particularly suitable for use in collections and displays as it is possible to carry out rapid, non-invasive, in situ analyses of samples via a fibre optic probe. To carry out the research, spectra were initially recorded from 'ideal' textile specimens, subjected to known loads applied using a tensile tester. Multivariate analysis was then employed to interpret the data and draw out correlations from which predictive models were built. Using this approach, we have already shown the way in which the properties of a simple silk model may be determined (Figure 2) and subsequently applied to a range of surrogate objects of various constructions. This work has now been broadened to include a variety of other fabrics, namely wool, linen and nylon, representing a range of physical microstructures and chemical compositions.

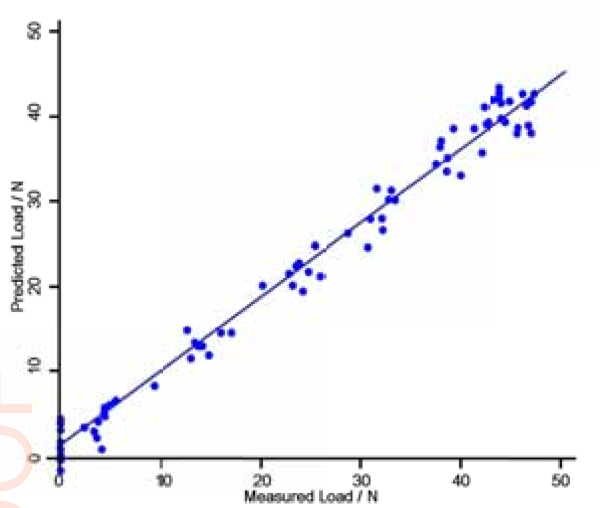

Figure 2: Plot of predicted against measured load for silk.

The current research has been based around multivariate models constructed using data from relatively simple samples (plain weave and undyed). It is, however, recognised that 'real' objects may present a greater challenge, due to dyes and other treatments, fibre blends and complex weave structures. Such variations may prevent the derivation of absolute physical parameters from an object, but the method will still permit relative measurements to be made, highlighting areas of special concern within an object. With further work, and a wider range of reference materials, it may be possible to construct models which will allow the quantitative investigation of these more problematic artefacts.

Our initial investigations have, therefore, illustrated the possibilities of a technique that will potentially be of use both as a diagnostic tool to highlight those objects in greatest need of immediate attention, and to determine the suitability of particular methods of display.

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THE TECHNOLOGY OF THE PREPARATION OF THE FINISHING LAYER OF THE BAROQUE FAÇADE IN THE NOVO CELJE COURT

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1. Introduction

The use of natural gypsum in building use has been known since the time of the pyramids in ancient Egypt.[1] Due to the high solubility of gypsum in water (2.6 g/l at 20 °C) it is mostly used as building and decorative material inside buildings even though historical materials research shows the frequency of its use also in the external humid climate of the broader European region.[2] In Slovenia, the lime-gypsum suspension was first noticed in the construction of the finishing façade colour layer during the baroque court Novo Celje research. The Novo Celje baroque court is a mighty building which dates back to the years 1756 and 1764 when it was used as a summer mansion to count Geisruck, a popular minister of the Austrian-Hungarian empress Marie Therese.[3] The building has been abandoned for two decades and now the local authorities have started to renovate it together with conservators. It is the most important court in Slovenia as far as the quality of inbuilt materials are concerned (Figure 1).

2. The purpose and research methods

The problems that occurred during characterization of the original finishing colour layer were connected to the accumulation of gypsum on the border between the first and second colour layer. It made us pose the question about the origin of sulphate ions. The answers could have been either creation due to the external factors, especially acid rain, or the chance of gypsum being added to the lime-gypsum suspension. Supposing that the accumulation of the sulphate ion is not a consequence of anthropogenic pollution it was necessary to answer the question how the lime-gypsum suspension had been prepared in order to be piled up to the façade in the layer that does not exceed the thickness of around 400 µm. Using the back-scattered electrons (BSE) image mode of scanning electron microscopy (SEM) and the energy dispersive X-ray technique (EDX), as well as X ray-powder diffraction and isotopic analyses, the structure of the original finishing layer was assessed and the micro-characteristics of material, developed during slaking lime with the addition of gypsum, was ascertained.

3. Results and discussion

3.1 The characterization of the baroque finishing façade layer

The façade layer is made of two layers of mortars, rough and fine, and four finishing colour layers. The original colour layer of the Novo Celje court baroque façade is yellow-brown and it is unevenly thick, around 400 µm It is a mixture of calcite-dolomite lime and gypsum (Figure 2). The line analysis transversally to the layers was used to establish the distribution of the gypsum in the individual layer (Figure 2).

The possibility that the crystallization of gypsum is a consequence of the reaction between lime binder and acid rain is very small, even more so because pollution in baroque times, around 250 years ago, was not that heavy to produce a 100 µm thick layer of secondary gypsum. Salts also tend to be removed from materials surfaces during the reaction between acid rain and lime binder.[4] The possibility of gypsum crystallization as a consequence of the effect of outer factors was also dismissed because gypsum crystals on the border between the first and second colour layer are crystallized well and with good cohesion.

Figure 1: The view of the Novo Celje court from the north.

3.2 Preparation of the new mixture

On the basis of the findings about the baroque colour finishing layer a substitute mixture was developed. We used two raw materials, traditional slaked lime and natural gypsum from the only known gypsum deposit in Slovenia - Dovje. Lime was broken into particles and then it was mixed with gypsum. The dry mixture was homogenized and water was added while stirring continually. The slake lime reaction is an exothermal process. The temperature depends on the reactivity of lime and cleanliness of gypsum. It also depends on the lime slaking temperature, on the quantity of added water and on the ration between quicklime and gypsum.[5] Yellow pigment was added into the lime-gypsum suspension and applied to a pilot wall with lime mortar. If we compare surfaces of both finishing layers after appliance it can be concluded that the surfaces are rugged and that traces of applying suspension with a brush are visible. The technology of suspension application with a brush is actually the same technology that does not allow the suspension to bind too quickly which would happen in case natural gypsum and lime putty were mixed.

4. Conclusions

It was proved with different analysis methods that gypsum in the finishing colour layer is of natural origin therefore it is the basic raw material for the preparation of lime-gypsum suspension. Brush traces on the façade surface are proof of technology of the application of the thin finishing layer. For the use of façade renovation technology of lime-gypsum suspension was developed which stems from benefiting from the heat that is released while lime slaking for the use of transforming natural gypsum to hemihydrate. In the future for the production of quality substitute lime-gypsum material optimizing the technological process will be needed as well as observing the factors of the chemical reactions in the system lime-commercial gypsum-water.

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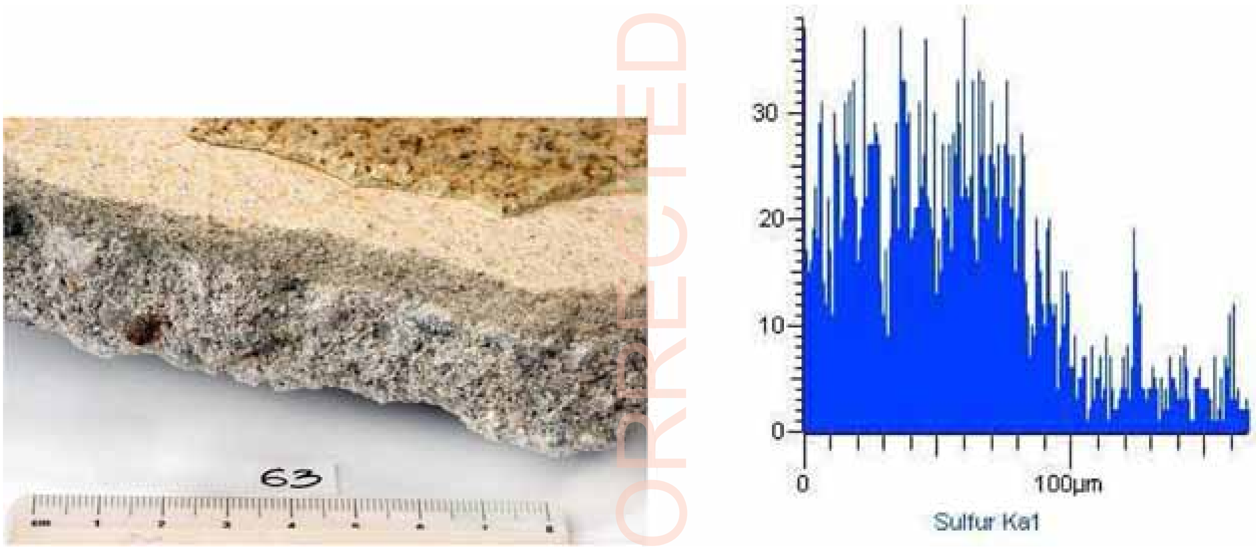

Figure 2. Colour layers (top) and scan profile (bottom) for the sulphur ions transversally to the yellow-brown first colour layer.

IMPACT OF MOISTURE CONDITIONING ON POLYCHROME WOOD WITH TEMPERA

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Abstract

Moisture conditioning approach has been carried out for the characterisation of tempera panel painting. The interface between painted layer and wood support was observed under different environment causing variations on wood equilibrium moisture contents. The reciprocal behavior of the components of this composite under different environmental conditions was analyzed. A composite made of materials (wood + gypsum and animal glue + tempera) has different physical behavior under varying environmental conditions. The result of this research is useful for the passive preservation strategy for polychrome wooden cultural heritage, such as deciding environmental condition and simulation for estimating how the panel paintings will react from one environment to another. The variation of wood moisture content causes volume shrinkages/swelling that polychrome layer can only partially follow. Hygroscopicity is a most important property for the wood support, because the moisture held in wood (moisture content) affects all other properties, physical and structural characteristics, influences the biodegradation process, and interacts with the polychrome layer and with the wooden support producing detachment, deformations, fissures, and cracks. In this paper we present some aspects of the impact of the moisture content between polychrome layer and wood support. Some physical parameters were considered to evaluate the influence of moisture content on the polychrome wood.

1. Introduction

Cultural heritage objects of the polychrome wood type represent a very important segment, imposing protection and conservation. In the polychrome wood group objects there are besides panel paintings, also sculptures, furniture, iconostases, trinities, ethnographic objects etc.

Environmental factors

The longevity and durability of organic materials such as polychrome wood is known to be directly related to the aggressiveness of the surrounding environment, and especially sensitive to atmospheric humidity (relative humidity, RH), temperature, light, and microbiologic agents. Humidity as an external factor can accelerate aging processes and cause shrinkage and swelling. The degradation process of the artefacts can develop to both high and low humidity, mainly when other factors occur (radiation, microbiologic attack etc.), resulting cumulative effects. The threat from high humidity is primarily generating fungal growth and the enhancement of dimensional variations and chemical reactions in the wood due to the presence of water. The damage from low humidity is less observable in that the wood structure withstand to changes induced by gradients in low moisture content.

Hygroscopicity is the most important property for the support of panel painting, because the moisture held in wood affects all the physical-structural and mechanical characteristics and influences the biodegradation and biodeterioration processes, interacting differently or by cumulative effect with the polychrome layer and with the wood support, producing deformations, fissures, cracks and detachments. When discussed the old polychrome wood, we focus on the matrix complex structure (cellulose and lignin composition), anisotropy, hygroscopicity, the age of the wood, the conservation state, the presence of the biological attack etc. There is a correlation between hygroscopicity and the other characteristics of the wood. The polychrome layer and the wooden support react in different ways to the atmospheric humidity, modifying their characteristics in different ways. Moreover, the hygroscopicity of the wood support is different from that of the polychrome layer, which is reflected in the variation of the interface characteristics and in the frictions between polychrome layer and wood support, resulting deterioration processes.

Storage condition

The polychrome wooden objects are laying inside old buildings (museums, historic buildings, churches, monasteries etc.), where is very difficult to control every moment the inside microclimate atmospheric humidity, as this vary continuously, being determined by the local environment (outdoor microclimate), the thermal protection of the building, other inside building materials and objects etc. Consequently, it should be used the passive preservation by air-conditioning. Even in this situation, it should be known the influence of the humidity variation on the interaction between wood support and the preparation layer of the painting. In order to do that, it is very important to know the species and the chemical, physical-structural and mechanical characteristics of the wood, which are influenced by atmospheric humidity. This is the first compulsory step of the scientific conservation toward the passive preservation and to take measures to the climatic protection of the polychrome wooden objects.

In this study, we used small parallelepiped samples of tempera painting wood and evaluated the impact of moisture conditioning on the four species wood support, especially the interface between wooden support and polychrome layer.

2. Experimental

The first step in this study was to prepare the samples. The second step was to establish environmental requirements and parameters and conduct the moisture conditioning experiment. And finally, the third step was to interpret the physical parameters of samples such as density, moisture content (MC), porosity, and shrinkages and understand how these parameters affect samples.

Following these steps, it will be clarified what will happen between wood support and polychrome layer. In this paper we present some aspects of the impact of the atmospheric humidity between polychrome layer and wooden support. Some parameters were considered to evaluate the influence on moisture content of the polychrome wood.

Materials

Experiments were conducted on samples of fir (*Abies alba* Mill.), poplar (*Populus* sp.), lime (*Tilia* sp.), and oak (*Quercus petraea* L.) wood support because they were most widespread and important species used to manufacture the wooden supports of panel paintings and polychrome woods for the Cultural Heritage. All samples of each species were obtained from the same plank, in order to be well matched and reduce the problems due to the natural variability of wood. The number of samples is 8 samples for fir and poplar, 10 samples for lime and oak. The panel was prepared with gypsum + animal glue layer and polychrome tempera painting layer. Then it was cut to the small parallelepiped of samples of 5x5x2 cm (Fig. 1). The direction wood is that poplar and lime samples have sub-tangential width and fir and oak samples have sub-radial width (Fig. 2). References were also prepared.

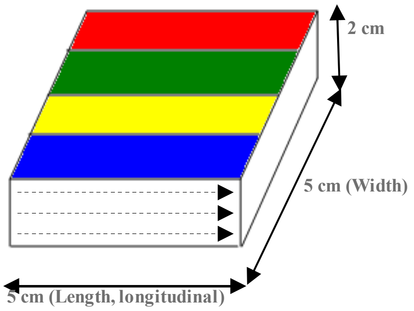


Figure 1: The sample size.

Methods

The interface between painted layer and wood support under different environment (Relative Humidity 100% → 85% → 65% → 25%, Temperature 20 °C), causing variations on wood equilibrium, was observed. Samples were maintained at each environment up to reaching the constant weight. And finally, the samples were dried in the oven-dry until the constant weight, measuring the variation of the three dimensions of each sample. The measurement (weight and three dimensions) can also allow calculating the influence on wood of preparation and tempera layers.

The sides of samples were scanned in order to observe and evaluate the detachment between painted layer and wooden support. The four side surfaces were scanned in each RH level in order to observe the difference between support and polychrome layer.

Physical parameters of samples such as density, moisture content (MC), porosity, and shrinkages were calculated with the following formula:

MC (%) = $(W-W_{od}) / W_{od} \times 100$: W = the weight of specimen of wood in the conditions of humidity desired ("original" state), W_{od} = the weight of the same specimen in the oven-dry state;

Density (ρ) = m / V: m = mass, V = volume;

Shrinkage = $(l_1 - l_2) / l_1 \times 100$: l_1 = the length before shrinking, l_2 = the length after shrinking;

Porosity (Z) = $(1 - \rho_0/1530) \times 100(\%)$: ρ_0 = oven dry density, $\rho_0 = W_0 / V_0$ (kg/m^3).

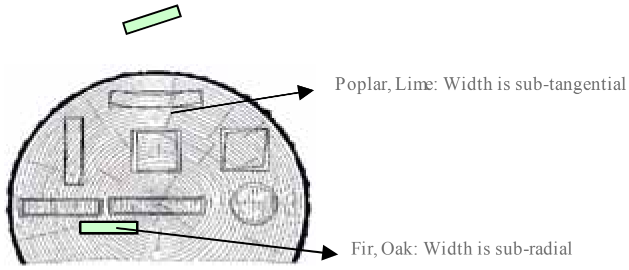


Figure 2: Characteristic shrinkage and distortion of flats, squares, and rounds as affected the direction of the annual rings. From US forest Products Laboratory.[1]

3. Results

The passage from high relative humidity to low relative humidity is that wood strives to maintain equilibrium with the moisture in its environment. Fluctuations in the relative humidity result in changes in the moisture content in wood. These moisture content variations generate the swelling and shrinking of the wood substance, that polychrome layer can only partially follow. The effect of these processes is due to the fact that the polychrome layer cannot follow the deformation of the wood support. The scanned images of each sample help us to see what happened between panel painting support and polychrome layer (Photos 2-5). It was clearly observed that detachment occurred when the RH was 25%. The detachment was clearly observed with following photos, however not all samples were evidentially observed.

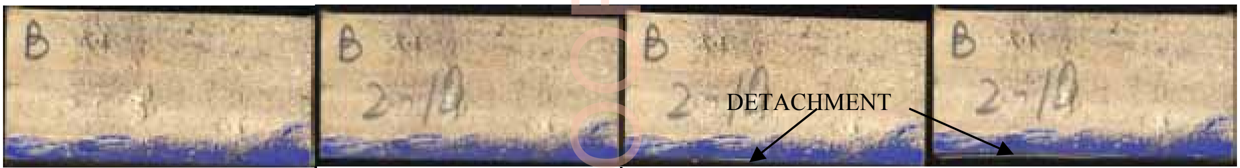
In fir sample (Photo 1) the detachment was 14.80 mm long and the width movement of wood support was 1.50 mm. In poplar sample (Photo 2) the final detachment was 29.12 mm and the width movement of wood support was 2.93 mm. In lime sample (Photo 3) the sub-detachment was observed and the width movement of wood support was 2.81 mm. In oak sample (Photo 4) the detachment was 22.20 mm and the width movement of wood support was 2.39 mm.

The 1% MC difference generates width movement of wood support, fir (sub-radial, 0.08 mm), poplar (sub-tangential, 0.16 mm), lime (sub-tangential, 0.13 mm), oak (sub-radial 0.13 mm).

Figure 2: Phenomenon of hygroscopic state: under stable environmental conditions, the equilibrium MC of wood support (RH 100%→85%→65%→25%).

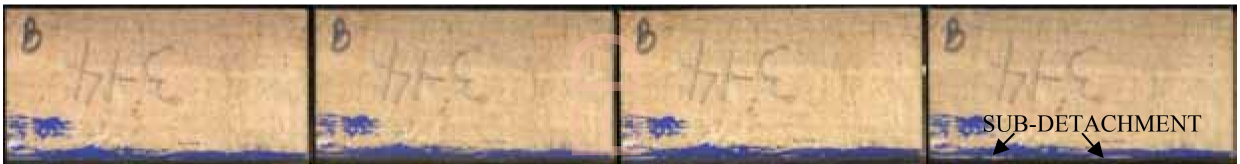
100%, 24.6%, 52.00 mm	85%, 20.0%, 51.70 mm	65%, 15.9%, 51.27 mm	25%, 11.2%, 50.46 mm

Photo 1: The scanned image of Fir. The value under the images are, from left to right: RH (%)/MC (%)/Width of wood support (mm). The detachment starts in correspondence with a knot.



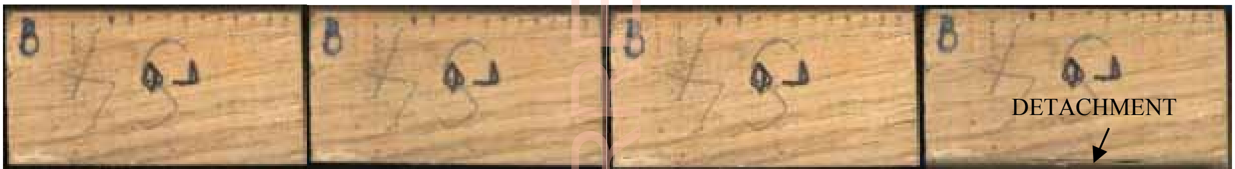
100%, 24.4%, 52.02mm	85%, 19.0%, 51.15 mm	65%, 14.9%, 50.53 mm	25%, 5.4%, 49.09 mm

Photo 2: The scanned image of Poplar. The value under the images are, from left to right: RH (%)/MC (%)/Width of wood support (mm).



100%, 27.4%, 53.49 mm	85%, 19.5%, 52.64 mm	65%, 14.5%, 51.87 mm	25%, 5.1%, 50.68 mm

Photo 3:The scanned image of Lime. The value under the images are, from left to right: RH (%)/MC (%)/Width of wood support (mm).



100%, 23.6%, 52.69 mm	85%, 19.6%, 52.14 mm	65%, 16.3%, 51.61 mm	25%, 6.0%, 50.30 mm

Photo 4: The scanned image of Oak. The value under the images are, from left to right: RH (%)/MC (%)/Width of wood support (mm).

MC, density, and volume shrinkage were calculated in each RH condition. There are differences depending on species and between polychrome samples and references (naked wood, Tables 1-3) Equilibrium MC is affected by wood species, especially at high relative humidity (Fig. 2). The higher MC samples have, the bigger the density of wood they have (Fig. 3). The density of wood varies, depending on the amount of wood substance (cell wall) and voids present (porosity). The porosity is directly related with density (Table 4). The bigger density has smaller porosity. The magnitude of shrinkage is bigger with higher MC and bigger density (Fig. 4). Each physical parameter has direct relationship with MC. The values of references are smaller than polychrome wood on the whole.

4. Conclusions

The impact of moisture conditioning on the four species wood support was tested with tempera. The size of wooden support is varied under different moisture conditioning, the painted layer cannot completely follow its deformation, and consequently this leads to degradations and deteriorations, caused by detachment, that affect the polychrome stratification of the panel painting and eventually the connections between the different layers composing the panel painting. Because wood is hygroscopic and anisotropic material, while painted layer is less hygroscopic and isotropic.

After observing scanned images and calculating physical parameters, the following conclusions were drawn to evaluate the impact of moisture conditioning on the four species wood support:

- Depending on species the 1% MC difference generates different movement. Fir (sub-radial, 0.08 mm) is much less than other species, such as poplar (sub-tangential, 0.16 mm), lime (sub-tangential, 0.13 mm), oak (sub-radial0.13mm). In general Wood shrinks most in the tangential direction, about one-half as much across radial direction. Taking into account that, oak has the biggest impact of the dimensional change for wood support under moisture conditioning.

- Detachment was observed not from the edge but from the middle of panel.

- The knot (defect) promotes detachment more than normal state wood.

- A less hygroscopic painted layer has retarding influence for MC. The values of references are smaller than polychrome wood on the whole.

A further approach could be the analysis of the behavior of the connections between layers.

5. Acknowledgement

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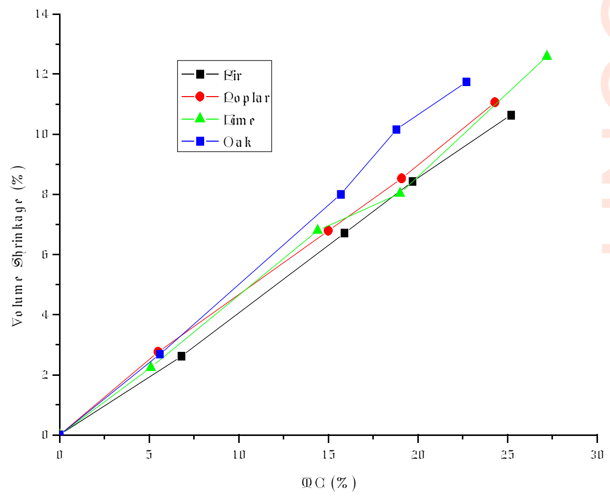

Figure 3: Phenomenon of hygroscopic state: under stable environmental conditions, the density of wood support (RH 100%→85%→65%→25%).

.Table 1: MC of wood support (%).

RH	100%	85%	65%	25%
Fir	0.40	0.39	0.39	0.37
Reference	0.37	0.36	0.35	0.34
Poplar	0.52	0.51	0.50	0.48
Reference	0.49	0.49	0.48	0.46
Lime	0.43	0.43	0.42	0.40
Reference	0.42	0.41	0.40	0.39
Oak	0.82	0.81	0.81	0.78
Reference	0.76	0.75	0.75	0.73

Table 2: Density of wood support (g/cm^3).

RH	100%	85%	65%	25%
Fir	25.2	19.7	15.9	6.8
Reference	22.2	17.6	14.1	5.5
Poplar	24.3	19.1	15.0	5.5
Reference	21.4	17.4	13.5	4.9
Lime	27.2	19.0	14.4	5.1
Reference	23.9	17.4	13.3	4.8
Oak	22.7	18.8	15.7	5.6
Reference	22.9	17.9	14.5	5.3

Table 3: Volume shrinkage of wood support (%).

	Volume shrinkage (%)			
	100%	85%	65%	25%
Fir	10.6	8.4	6.7	2.6
Reference	8.6	6.7	5.4	2.4
Poplar	11.1	8.5	6.8	2.8
Reference	9.8	7.6	6.4	2.3
Lime	12.6	8.0	6.8	2.2
Reference	10.3	7.8	5.8	2.2
Oak	11.7	10.2	8.0	2.7
Reference	12.5	9.7	7.8	2.7

Table 4. Porosity of wood support (%).

Fir	77
Poplar	69
Lime	75
Oak	50

SALT REDUCTION THROUGH POULTICING. WHICH FACTORS REALLY MATTER?

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The use of poultice materials to reduce the salt content of salt deteriorated objects is a long established technique in conservation, however, due to the complex nature of salt problems within historic structures the result of such interventions can be variable and unpredictable. Desalination is a multi factorial problem: the amount and depth to which salts are mobilised, where they are transported to, can be affected by the inter-relationship between the poultice and the substrate, the environment and also the distribution of salts. To this end, more information is needed regarding the significance of the various factors at play, the manner in which they interact, and how they affect the treatment outcome. To unravel the complex nature of this problem, screening experiments are at first needed. Consequently, as part of the European Project 'DESALINATION' (Project n. 022714 - Assessment of Desalination Mortars and Poultices for Historic Masonry) a series of fractional factorial experiments were undertaken to assess the effect of:
- the drying conditions
- the pore size of the substrate material
- the type of salts present in the substrate
- pre-wetting
- the use of an intervention layer

The testing programme (Tables 1) was constructed using a 2 level fractional factorial experimental design (6 factors; resolution VI; 1/2 fraction; no replicates; two blocks). Using this approach it was possible to assess the significance of the various factors tested, and also that of their two factor interactions.

The substrate cores were saturated with salt solutions and then freeze dried, to obtain dry samples with a homogeneous salt distribution. The sides and base of the samples were sealed with wax film, following which they were then prepared with the relevant prewet/intervention layer/poultice combinations according to the experimental design. The samples were then exposed under the specified environmental conditions for two weeks, at which point samples were taken for analysis of the salt distribution (measured by means of ion chromatography) within the substrate and poultice.

The salt content data was subjected to statistical analysis (first regression analysis and then analysis of variance (ANOVA)), to identify the magnitude and significance of the various experimental factors under consideration, and also their interactions with each other (two-factor interactions). Furthermore, thermodynamic analysis was undertaken to characterise the crystallisation behaviour of the remaining salts (in particular, the relative humidity at which crystallisation of the salt mixture would commence (RHXn)), and determine whether this had altered from the original salt mixtures present.

Table 2 summarises the significant factors and interactions for a range of experimental responses. The results of this test show that up to a depth of 20 mm, the RH, support type, and the poultice type all had a significant effect on the substrate salt content after extraction. In general the tests resulted in significantly more salt extraction from the calcium silicate brick than the clay fired brick (experimental factor B), while the effect of the different poultice types was different depending on the drying conditions (as shown by the significant two factor interaction AD): the cellulose achieving better extraction at 85% RH than at 50% RH, whereas the performance of the Kaolin-sand was unaffected by RH.

However, it was found that at and beyond a depth of 20 mm, none of the experimental factors in this test proved significant. Indicating that the manipulation of the factors examined may not play a significant role in determining the treatment outcome at depth, but that they are of significance for superficial salt extraction, and hence the treatment of objects with sensitive surfaces, such as wall paintings and polychrome sculpture and architectural surfaces.

Regarding selective extraction of ions the results showed that selective extraction does indeed occur, and can cause significant changes in pre- and post treatment salt behaviour. Moreover, the current findings indicate that the effect appears to be dependent on the salt mixture composition and support type. At present the underlying causes of this effect are not known, since it is clear that it is not solely due to solubility constraints, but that perhaps to some degree, ion exchange or differences in ion mobility may play a role. Further work, planned as part of the Desalination project, will study this effect on a wider range of support types and salt systems, to elucidate the underlying reasons for this behaviour, and to investigate if the post treatment behaviour of residual salts can in any way be pre-determined. Nevertheless, it is clear that the potential effects of selective salt extraction should be considered prior to carrying out a salt reduction treatment—particularly so in the case of objects with sensitive surfaces such as wall paintings.

Table 1: Factors and levels.

Factor	Parameter	- level	+ level
A	RH	85%	50%
B	Support	Brick	Calcium silicate brick
C	Saltmix	$NaCl/NaNO_3$ (1:1)	$NaCl/KNO_3$ (1:1)
D	Poultice	Cellulose	Kaolin/sand
E	Prewet	yes	No
F	Intervention layer	yes	No

Table 2:
Summary of significant factors and interactions.

Response	Factor/interaction	P value
SUBSTRATE: total salt 0-2 mm	AD (RH/POULTICE)	0.013
SUBSTRATE: total salt 2-5 mm	SUPPORT	0.026
	AD (RH/POULTICE)	0.046
SUBSTRATE: total salt 5-10 mm	SUPPORT	0.033
SUBSTRATE: total salt 20 mm	NONE	
SUBSTRATE: total salt 30 mm	NONE	
SUBSTRATE: total salt 40 mm	NONE	
POULTICE: total salt	SUPPORT	0.007
	POULTICE	0.013
	AD (RH/POULTICE)	0.088
	BF (SUPPORT/INTERVENTION LAYER)	0.079
	DF (POULTICE/INTERVENTION LAYER)	0.025
SALT MIXTURE: RHXn SHIFT 0-2 mm	SUPPORT	0.000
	AC (RH/SALT MIXTURE)	0.039
	AD (RH/POULTICE)	0.027
	BC (SUPPORT/SALT MIXTURE)	0.000

A = RH; B = SUPPORT ; C = SALTMIX;
D = POULTICE; E = PREWET; F = INTLAYER

ACOUSTIC MICROSCOPY APPLIED TO ART OBJECTS ANALYSIS

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1. Extended abstract

In the current work the application for first time of the acoustic microscopy to the analysis of art object is presented using a prototype system that is developed in the frame of InfrARtSonic project (www.infrartsonic.org). The state-of-the-art description related to acoustic microscopy [], supported the decision to use this method in order to non-destructively identify the stratigraphy in specific regions of Interest (ROIs) of artworks. Using acoustic microscopy, we can obtain the depth profile of the layers in the stratigraphies of art objects. For each point of the artwork residing inside a specific ROI, the remote probe of the device is able to scan with a step resolution of 1μm.

In order to estimate the basic characteristics of the final developed device (operating frequency and geometry of the transducer) and algorithms of the system the acoustic wave propagation in paint layers of artworks using Finite Difference Method was performed. The simulation of the wave propagation in the paint layers of artworks required the measurement of the acoustic characteristics (velocity, and impedance) of the materials that exist in the paint layers of the under investigation objects. For that purpose special reference samples were created in order to indicatively measure those characteristics. At the same time real stratigraphies were developed simulating the painting techniques existing in art objects [], [], []. Digital images of these stratigraphies were acquired using optical microscopy aiming to the study of the wave propagation in such multilayered structures. The described methods were iteratively used during the development phase resulting to the optimal determination of the characteristics of the final and definite characteristics for some crucial parts (ie transducer) and the algorithms that are finally be used with the system. The procedure that is used for the processing of the data that are provided by the acoustic microscope is displayed in figure 1.The application of Wavelet and Hilbert Huang transforms to the a-scan signals are performed in order to identify the number of the layers that exist in each point of the ROI[].

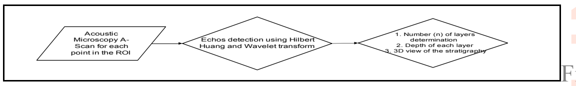

Figure 1: Acoustic microscope contribution to the overall device operation.

The proposed system was tested in real reference samples simulating art objects stratigraphies as well as real art objects providing the depth profile from stratigraphies compromised by three successive layers. In most of the cases the existence of the interface between the first and the second layer was clearly revealed. Based on the results of the simulations the final prototype device was developed (see figure 2).

Figure 2: The InfrArtSonic prototype device that was developed part of it is the acoustic microscope module (www.infrartsonic.org).

The system was also used for a wall painting fragment, scanning an area of 4x4 mm, (Figure 3). This area includes two brush strokes, which are displayed on a 3D reconstructed «image» from the acoustic microscope. In the same figure, the rectified corresponding A-scans are displayed in different points of measurement, one over the brushstrokes, in which the second echo from the sub layer is also evident, and the other over the surface without the brushstrokes, where we can observe only one echo. In the second case the echo is received later, because the surface in this point is located at a bigger distance from the transducer compared to the point where the brush strokes are located [].

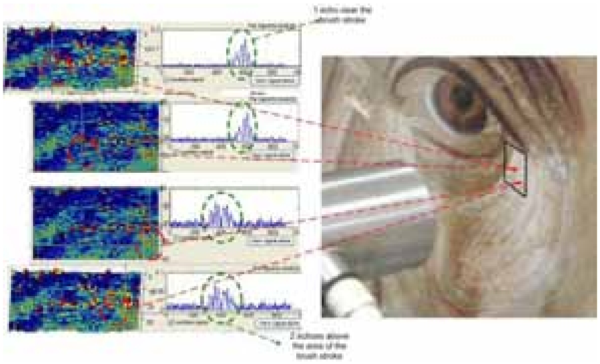

Figure 3: Echoes revealed form a wall painting fragment. There is a clear distinction between the echoes coming from the upper brush stroke and the following echo generated by the interface between the brush stroke and the underlying layer[].

2.Acknowledgement

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STABILISATION OF PAPER CONTAINING COPPER

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1. Introduction

Copper ions, which constitute certain historical pigments such as malachite and verdigris, catalyse oxidative decay of cellulose, leading to paper brittleness. The damage, referred to as "copper corrosion", endangers many historical manuscripts, drawings and maps.

To prevent oxidative decay of materials, antioxidants are employed. However, there is currently no available treatment, which would address the problem of copper corrosion. This is partly due to the solubility of the malachite and verdigris in water, which calls for a non-aqueous approach. Recently, an EC co-funded project InkCor proposed the use of bromide antioxidants for non-aqueous stabilisation of iron gall inks.[1-3] We have therefore decided to evaluate the effects of several antioxidants on the degradation of paper, with the copper pigment verdigris.

2. Experimental

Verdigris was produced according to the literature.[4] 15 g of gum Arabic was dissolved in 25 mL of deionised water, after which 10 g of the pigment was added. The mixture was applied to the model paper, made from historical rag paper, using silkscreen printing technique. Samples were then pre-aged in a climatic chamber (Vötsch Climatic Chamber Type VC 0020) at 55 °C and cycling relative humidity (between 35% and 80% RH every 6 h) for two weeks. After pre-ageing, the samples were treated using a solution containing 0.05 mol L^{-1} $(C_2H_5O)_2Mg$ (denoted as MgEtO) and 0.03 mol L^{-1} of antioxidant in ethanol. The following antioxidants were used: tetrabutylammonium bromide (TBABr), 1-benzyl-3-butylammonium bromide (BBABr), 1-ethyl-3-methylimidazolium bromide (EMIMBr), 1-butyl-3-methylimidazolium bromide (BMIMBr), 1-butyl-2,3-dimethyl-imidazolium bromide (BDMIMBr) and 1-hexyl-3-methylimidazolium bromide (HMIMBr) and 1-hexyl-3-methylimidazolium chloride (HMIMCl).After the treatment, samples were aged at 80 °C and 65% RH.

Viscometry, which is a standard technique to follow cellulose degradation at 80 °C and 65% RH could not be used due to the presence of copper pigments. Instead, a method based on size exclusion chromatography of cellulose carbanilates[5] was adapted for paper with copper pigment. Relative average molar masses were determined using a Hewlett-Packard series 1100 chromatographic system. The column thermostat was set to 35 °C and a UV detector was used. PS standards were determined at 210 nm and CTC at 235 nm. The injected volume was 50 □L. The columns used were a 5cm Guard GPC MixedBed and two GPC MixedBedLinear, both by Jordi F.L.P. The eluent THF was pumped into the system at a rate of 1 mL min^{-1}. The chromatographic data were processed with HP G2182AA data analysis software. The polystyrene standards (PS, Polymer Standards Service) were prepared as mixed standards in three separate solutions containing in total 0.1 g L^{-1} of standards in THF. The first standard solution contained PS of the following peak molecular weights (Mp): 1,090,000 g mol^{-1}, 130,000 g mol^{-1}, 17,800 g mol^{-1} and 1,620 g mol^{-1}, the second contained 2,570,000 g mol^{-1}, 246,000 g mol^{-1}, 34,800 g mol^{-1} and 3,420 g mol^{-1} and the third 579,000 g mol^{-1}, 67,000 g mol^{-1} and 8,400 g mol^{-1}. All chromatographic results are expressed as weight-average molar mass of CTC (MW) relative to polystyrene standards.

Weight average degree of polymerization (DP_w) of samples was obtained by dividing the average molar masses by molar mass of the carbanilated glucosidic monomeric unit (537 g mol^{-1}). DP_w values were used to determine degradation rate constants according to the Ekenstam equation.[6]

3. Results

The results demonstrate (Figure 1) that a successful stabilisation of paper with verdigris may be achieved using bromide antioxidants. Paper with verdigris treated with a solution alkali alone was 1.7 ± 0.3 times more stable than the untreated control. An addition of tetrabutyl ammonium bromide antioxidant to the treatment solution significantly increased paper stability (8 ± 2 times) as compared to the untreated control. A similar extent of stabilisation was observed in case of 1-benzyl-3-butylammonium bromide (BBABr), while imidazolium antioxidants were less effective. No negative side effects, such as colour change of the pigment or paper were observed.

4. Conclusion

It is demonstrated that paper containing corrosive copper pigment verdigris can be successfully stabilised using an alcoholic solution of a bromide antioxidant, e.g. tetrabutyl ammonium bromide, and an alkali magnesium ethoxide. Although no negative side effects were observed, it is advised that the effects of the treatment solution on paper and pigment are verified on a number of historical papers.

.Figure 1: Degradation rate constants of untreated paper containing verdigris (Untreated) and the one stabilised using prototype non-aqueous treatments. The papers were aged for 168 h at 80 oC and the 65% relative humidity. Treatment solutions contained either alkali (MgEtO), or a combination of an alkali and antioxidants tetrabutylammonium bromide (TBABr), 1-benzyl-3-butylammonium bromide (BBABr), 1-ethyl-3-methylimidazolium bromide (EMIMBr), 1-butyl-3-methylimidazolium bromide (BMIMBr), 1-butyl-2,3-dimethyl-imidazolium bromide (BDMIMBr) and 1-hexyl-3-methylimidazolium bromide (HMIMBr) or 1-hexyl-3-methylimidazolium chloride (HMIMCl).

5. Acknowledgement

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A SHORT REVIEW OF RESEARCH ON HISTORIC WALLPAPER IN CROATIA

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A few different specimens of historic wallpapers that have been collected so far provide some general information concerning this type of applied arts. With respect to the places where they were found they cover almost entire Croatia. The main intention of this research was to demonstrate that wallpapers represent an equal part of interior decoration. They represent stylistic features which go hand in hand with other decorative arts and contributed to the creation of historic interiors.

In relation to archival sources, we have not been able to carry out systematic research yet. In addition, historic circumstances have often led to the loss, destruction and removal of such information. There is also almost no existing literature on wallpapers. Wallpapers are occasionally mentioned in connection with other topics, and a synthesis still remains to be written. It is possible to draw comparative conclusions on the basis of selected examples and assumptions, or perhaps in relation to the rest of an interior. Most samples are discovered during conservation-restoration works. Because of their fragility and because of the function which depended on fashion, wallpapers are more often subject to destruction than any other element of an interior. Textile wall-hangings or decorative leather is more often preserved, e.g. in Sv. Petar u Šumi, the Franciscan monastery in Košljun on the island of Krk, or in the treasury of the Franciscan monastery in Dubrovnik.

The basic impulse for dealing with this topic was the conservation and restoration treatment programme on the unique wallpapers in Bassegli-Gozze palace in Dubrovnik. Among others, there are the so called „panoramic wallpapers“, the only remaining specimen in Croatia. Because of the fragility of materials and huge dimensions, it took several years to complete the demanding project. It was also the first of its kind carried out in Croatia and has raised interest in wallpapers in this region and encouraged new research. The project is carried out by the Department for Paper and Leather of the Croatian Conservation Institute, and supported by foreign experts, e.g. Dr Bernard Jacqué, curator of Le Musée du Papier Peint in Rixheim, France.

In connection with the topic of panoramic wallpapers, it is worth mentioning the castle Klenovnik near Varaždin. In this context one should pay particular attention to 1920s photographs. The relatively large areas of murals, or rather painted wall panels, in which the themes of Eldorado and Isola Bella can be recognised. These are characteristic of wallpapers of the second part of the 19th century by one of the busiest of French manufacturers, Zuber et Cie. It was from this factory that the already mentioned Dubrovnik panoramic wallpaper came. The organisation of the wall surfaces is mirrored in the concept of wallpaper decoration (and vice versa), except that the wooden parapet and the stucco frameworks of the illusionist scenes are replaced by dado, borders and friezes. Whether or not there were ever wallpapers in this building has not yet been established; however, investigations are under way. The hypothesis that there were wallpapers in Klenovnik is not very unlikely taking into account that its owners were the Counts of Drašković, whose status and links with foreign countries during the 18th and 19th centuries allowed them to decorate the interiors of their other two residences – Opeka Castle and Trakošćan in a considerably luxurious style. In comparison with those mentioned earlier, these cases – the first one dated to the 1st quarter of the 19th century and the second one after 1860s – show us a different wallpaper type: fine combination of ornaments, floral motives with bands and architectural details indicating a landscape or ornamental, monochrome and flocked wallpaper. In approximately the same period the sequence of wallpapers in the Bishop's Palace of Đakovo was hung. Initial research work carried out in the Paper and Leather Workshop of the Croatian Conservation Institute in Zagreb showed that there were four layers of paper, with two interlining layers or linings. It should be pointed out that particularly Đakovo wallpapers represent an exceptionally interesting example: a range of wallpapers through a period of one hundred years, i.e., from the beginning of the 19th to the beginning of the 20th century, which is certainly worthy of our consideration.

The houses of Zagreb middle-class families and the town houses of the aristocracy were certainly well supplied with textile and paper wall coverings. As elsewhere, it is likely that a lot of material has been damaged over time or was removed. No systematic research has been carried out yet. Therefore, we shall introduce the wallpapers in Zagreb from the beginning of the 19th century to the beginning of the 20th through only four examples currently known to us.

The fragments of wallpapers from the Archiepiscopal Archives of the Cathedral, the Priester House (Strossmayerov trg 2) and from the building in the Upper Town, in Brezovačkoga ulica 6-8 illustrate typical wallpaper production fairly widespread in 19th century Europe. The internal decoration of the rooms of various purposes in Villa Feller in Jurjevska ulica is also well worth mentioning. The original appearance of the interior is known from old photographs. The wallpapers, an illustration of Jugendstil in wallpaper decoration, are comparable with certain Austrian and German specimens from 1910-1920.

Apart from these, one should still certainly pay attention to the wallpapers created after World War II, particularly the 1960s and 1970s designs, which are still to be found around Zagreb. Starting with the large panorama wallpapers with their paintings, via various kinds of figural and ornamental compositions, we arrive at a very special type of wallpaper – the small and charming papers most commonly known as Dominopapiere (because of the way they are combined), Bogenpapiere (because of their production from a folio sheet of paper) and Buntpapiere (because they were lively and colourful). We could almost say that Buntpapiere are to wallpapers what miniatures are to paintings. Their production started at the end of the 16th century, developed during the 17th and was most vigorous in the 18th century, in the small and mainly family-run workshops in France, Germany – with very active producers in Nürnberg and Augsburg – and Italy. Apart for the decoration of walls, Buntpapiere was also used for covering various objects – books, boxes, cases and so on.

Such papers were discovered during conservation and restoration of two reliquaries from the 18th century from the Ozalj Local Museum (in the Textile Department of Croatian Conservation Institute). In their motif and colour patterns, they are cognate to the products of the already mentioned South Germany workshops. At their bottom there is an inscription: IN AVGSB. BEY IOH WILHE MEYER NO. 16. Thanks to the information obtained from Professor Jacqué, we know that the said Meyer was active in the period between 1740 and 1780 and a fragment with a print almost identical to ours is in the Art Collection in Augsburg.

These few specimens allow us to hypothesise that wallpapers were mainly procured as imports from French, German or Austrian workshops, for decoration of the residences of the gentry, of religious buildings or of the houses of the more prosperous bourgeois families. They were more common during the 19th century. At the moment, it is essential to stress the significance of historic wallpapers because they reflect the style. We hope that awareness of this will contribute to more wallpaper conservation and restoration programmes, and to the replacement of wallpapers in their original buildings or in museum displays.

RESEARCH ON TECHNIQUES USING FOR THE RETROFITTING OF HISTORICAL MASONRY STRUCTURES – CASE STUDY DENIZ PALAS BUILDING

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1. Introduction

Historical structures are complex, made of diverse materials and have sophisticated geometry. Due to the use of different materials such as stone, brick, mortar etc. they are called composite and are complex structures. Because of this complexity, the study of historical structures requires a general and flexible approach which takes into consideration the impact of history, in particular.

All structures, historical or new, have to show structural stability and resist all kinds of loads. In the case of new constructions safety is guaranteed by technical codes, which are mostly not applicable to historic structures. Historic structures have important values, not just from the structural point of view but also from the artistic and historic points of view, that should be preserved. Therefore, when historic structures are restored or retrofitted, particular techniques must be applied.

In Turkey, 96% of the surface is under seismic risk. A large part of the country is seismically active with large numbers of masonry buildings. Many of these buildings have not been constructed by taking into account seismic loads or using codes and rules like new buildings. Because of this reason resistance evaluation of historical structures during earthquakes, particular techniques should be used and if necessary they should be retrofitted. Most of these buildings are vulnerable against earthquake loads.

2. Damage types of masonry structures

Masonry structures are those made of units (bricks, blocks or stones) joined by mortar and in some cases the joints are left unfilled. These materials have very low tensile strength and may easily show cracking on the bearing elements and are thus intended to work mainly in compression. Bearing elements of masonry structures are walls, pillars, columns, arches, vaults and domes. Masonry structures suffer from environmental factors, antropogenic deterioration, climate etc. which lead to damage. Damage is usually represented by cracks, crushing, crumbling, and breaking away of elements, and permanent deformation.

Cracks of structural elements are first generally examined. The crack is a fissure or separation of the material visible to the human eye. It can be caused by tensile strains due to external loads or restrained deformations. The most important threat for this type of damages are earthquake loads.

The design of earthquake resistant buildings is ensured by codes and regulations for newly constructed buildings but there are no codes for historical structures which are vulnerable to earthquake loads. There are some retrofitting methods for strengthening of this kind of structures. The goals of seismic retrofitting are to correct deficiencies in overall structural concept and in behavior of structural elements and nonstructural elements.

3. Case study - Deniz Palas building

Deniz Palas Building is a historic multi storey masonry building. This building is located in Istanbul which is one of the main earthquake zones in Turkey. Deniz Palas was built in The Art Nouveau style in the 1920s and was originally an apartment building. The façade and most of the architectural and structural elements are protected.

According to the Turkish Earthquake Resistant Design Code (2007) masonry buildings have been allowed to be built in the 1st grade earthquake zone as two-storied buildings at most. Beside this, three-storied building construction has been allowed in both the 2nd and the 3rd grade earthquake zones and four-storied ones in the 4th grade earthquake zone. In this context, retrofitting of the Deniz Palas building for possible future earthquakes was determined, according to the static calculations by obeying the rules of the code.

Deniz Palas building has one lodge, one ground floor and six normal stories. Beside restoration, retrofitting has become imperative because of an increase in the number of users after changing of the function of Deniz Palas. The function of the building was changed from an apartment to a cultural and arts center.

During the restoration, interventions are made based on prevention of historical values. Static calculations were done particularly. For this purpose, foundation retrofitting was made primarily and some critical walls were sheathed with concrete. Due to the transformation the necessity for a place as a lounge for cultural activities has arisen. Thus a wide area which was retrofitted by steel columns has been gained by demolishing some inner walls. In order to strengthen the floors the existing beams were kept and steel I profile beams were added between them. In addition to these applications a fire escape has been adjoined because of the number of building users and a bigger elevator shaft has been constructed in a different place than the existing one, which has been changed to a room.

All these retrofitting applications were done by conserving the engravings and plasterboards in some rooms and without any interventions on the façades. Thus the Deniz Palas which is on a 1st grade earthquake zone, would be safe for possible future earthquakes and bear the loads within the limits of safety and cultural heritage would be carried over to the next generations.

4. Conclusion

It is very important to preserve and conserve historical structures which are the most important evidence of human history and a past life style. There are many techniques and methods in the field of conservation and preservation of historical structures. One of these techniques was used in the Deniz Palas Building. An increase of loads by changing the function of the Deniz Palas building and earthquake risk were the main purposes of the retrofitting of the structure. In this sense walls were sheathed by concrete, floors was strengthened by steel I profiles and concrete and foundation are reconstructed.

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AN INTEGRATED APPROACH TO THE CHARACTERIZATION OF HISTORICAL MORTARS OF SOME SLOVENIAN MONUMENTS

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1. Introduction

The analysis of historical mortars refines our knowledge of mortar composition and thus gives important information about the technology of mortar manufacturing of some period, indicates provenience of the applied raw material and eventually enables us to reconstruct original mortar. Mortars are composite materials, comprised of aggregate, binder and sometimes of special additives, which could react with the binding material and modify its properties. Characterisation of historical mortars is most often carried out for particular case studies. This study summarizes some results of historical mortars research that was part of several conservation-restoration projects or archaeological excavations during the past few years in Slovenia, performed by Institute for the Protection of Cultural Heritage of Slovenia.[1-4] As systematic long-term collection of data about historic mortars can provide additional knowledge, creation of specific databases of historic materials, based on international cooperation and networks seem to be an important task for the future research on historic materials.[5]

Schemes of mortar characterisation have optical microscopy as a fist step in identifying the aggregates, of the various mineral additions and binder type. These procedures describe several analytical techniques for further qualitative and quantitative analysis, like SEM-EDX, DTA/TGA, FTIR and Raman spectroscopy.[6,7] The identification of inorganic components in the mortars is well mastered, while the identification of organic ones is marginalized.[8] In several cases gas and liquid chromatography were used for analysis, but these methods are not usable for samples containing lower quantities of proteins.[8] FTIR can also caharacterize organic materials into classes, but if the concentration of the organic material is low and if there are IR-active inorganic compounds present, the signal from the organic component can be masked.[9] However, peptide mass mapping by MALDI-TOF MS and Enzyme –Linked Immunosorbent Assay (ELISA) can be used for the identifications of proteins.[8,9] Usually the choice of the appropriate analytical technique depends mainly on the questions that have to be answered, on the amount of the material available.

2. Experimental

Samples

Samples of mortars were collected from various Slovenian historical monuments, which are dated from Roman times to Baroque period. Thus, bedding mortars of mosaic and wall paintings, mortars for incrustrations, rubble masonry mortars, joint mortars, renders and facade mortar were investigated. Sampling was carried out from both the interior and exterior of the monuments. Representative samples were selected according to the historical time of construction as well in their application purposes, as seen in Table 1.

sample	type of mortar	location	historic period of construction
GNK1	bedding mortar, wall painting	archaeological site NUK, Ljubljana, roman insulae	1st - 4th c. AD
GNK2	bedding mortar, wall painting	archaeological site NUK, Ljubljana, roman insulae	1st - 4th c. AD
GNU1	mortar floor	archaeological site NUK, Ljubljana, roman insulae	1st - 4th c. AD
GNU10	mortar floor	archaeological site NUK, Ljubljana, roman insulae	1st - 4th c. AD
GNU6	masonry mortar	archaeological site NUK, Ljubljana, roman insulae	1st - 4th c. AD
GNU30	masonry mortar	archaeological site NUK, Ljubljana, roman insulae	1st - 4th c. AD
ANM22	render	archaeological site Mošnje, roman villa rustica	1st - 4th c. AD
ANM67	masonry mortar	archaeological site Mošnje , roman villa rustica	1st - 4th c. AD
ANM138	bedding mortar, wall painting	archaeological site Mošnje, roman villa rustica	1st - 4th c. AD
ANM142	decoration polished render	archaeological site Mošnje, roman villa rustica	1st - 4th c. AD
ANM134	bedding mortar, floor mosaic	archaeological site Mošnje, roman villa rustica	1st - 4th c. AD
HTM1	bedding mortar, wall painting	archaeological site Hotel Turška Mačka, Celje	2nd c. AD
AHZ1	bedding mortar, wall painting	Antique house, Zloganje pri Škocjanu	4th c. AD
SN-L228	render	St. Nicholaus Church, Ljubljana	1703-1706
RO107	joint mortar	Robba fountain	18 th c.
SSR51	facade mortar	St. Rok Church, Šmarje pri Jelšah	18th c.
JAL1	incrustration mortar	St. Jacob Church, Ljubljana	18th c.
JAL2	render	St. Jacob Church, Ljubljana	18th c.
JES2	facade mortar	St. Mary Church, Jesenice	18th - 19th c.
FRK59	bedding mortar, wall painting	St. Valentine Chapel, Ljubljana	19th c.

Table 1: Samples of the investigated mortars.

Methods

Thin sections of mortar samples were studied with optical microscopy by means of a standard petrographic microscope (Olympus x60).

The samples were carbon-coated and then examined by Scanning Electron Microscope (SEM JEOL 5600 LV). Interest areas of samples were analysed for chemical composition with an Energy Dispersive X-ray Spectrometer (EDX).

For a better understanding of the nature of the binder, a binder-enriched fraction, which in principle contains a majority of material from the binder in mortars, was prepared. Samples were disaggregated by careful crushing to avoid destroying the aggregate particles and sieved below 63 μm. Fraction between 0 and 63 μm should comprise the binding material.[10] Then the fine fraction passing through the sieve was first analysed by X-ray Powder Diffraction (XRD), using X-ray diffractometer Philips PW3710 equipped with Cu Kα radiation and secondary graphite monochromator. Data were collected at 40 kV and current of 30 mA in the range from 2 to 70° 2θ, with speed of 3.4°/min. Mineral phases were determined with computer program Philips X´Pert software. Afterwards, ATR-FTIR spectra of this enriched binder were recorded with a Perkin Elmer ATR/FT-IR spectrometer, Specter 100. Thirty-six signal-averaged scans were acquired from the samples. Samples were examined in the 4000-675 cm^{-1} region.

3. Results and discussion

Characterization of these mortars based on petrological and mineralogical composition of used aggregates and binders. The compositional variation of historic mortars differ according to their geographical position, time period, as well the application purposes.

Aggregate

Results indicate that used raw materials normally come from local resources. In most cases river sand of the local areas was used as an aggregate. Petrological and mineralogical composition of used sand depends on the geological background and thus on geographical position. Aggregate with prevailing carbonate component, represent by limestone and dolomite, was recognised in the case of a roman *villa rustica* near Mošnje, where fluvial sand deposit of the Pleistocene terasae of Sava River was employed for its construction (Fig. 1a). Silicate component prevails in mortars around Ljubljana (Fig. 1b). Frequently lithic fragments of igneous, metamorphic and sedimentary rocks, including feldspars, quartz and micas are present. Application of crushed rocks aggregate is not so frequent in investigated samples. Crushed carbonate particles were observed only in an outer mortar layer of roman wall paintings in Ljubljana.

As regards samples of renders and masonry mortars, the grains of aggregate are generally rounded in shape, and varied in size and composition. The shape of the finer fraction is angular, owing to the silicate nature of the grains. Aggregate in mortars from walls is poorly sorted, while aggregate in renders is well sorted. Aggregate size distribution was selected according to their use.

With investigating silicate/carbonate component ratio in masonry mortars of roman *insulae*, it was possible to confirm different time construction phases, which differ in aggregate composition. Thus, in sample GNU6 carbonate fraction prevails over the silicate one, while in sample GNU 30 carbonate fraction prevails over the silicate one, proving two distinct sources of aggregates.

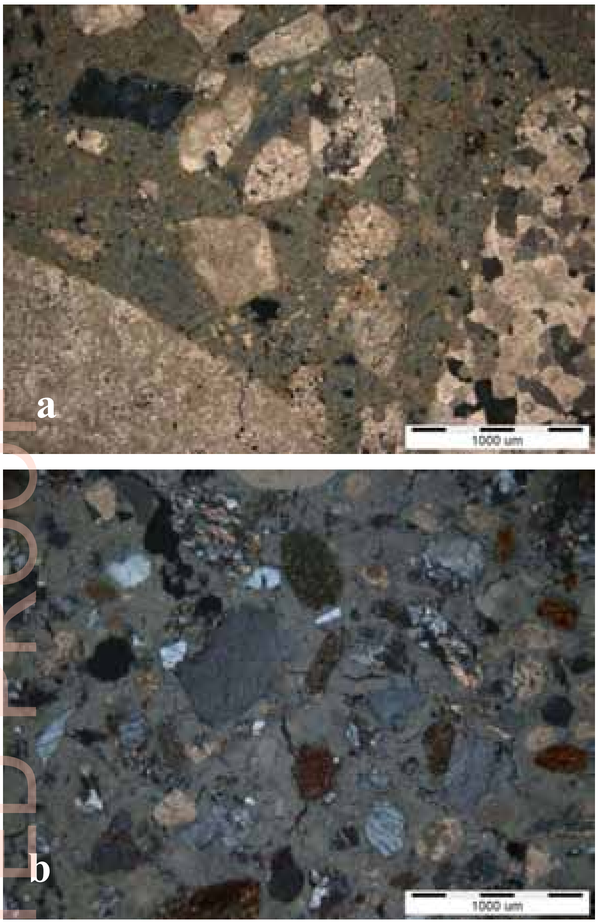

Figure 1: Petrographic examination of thin sections of mortars. a) carbonate aggregate in sample ANM 67, crossed polars. b) prevailing silicate aggregate in sample FRK 59, crossed polars.

Sometimes special aggregate is added with aim to endow the mortar properties or while some special effect are required. Thus, particles of angular coarse grained calcite were recognised in outer layers of roman decorative mortars (sample ANM 138, ANM 142, GNK1). Presumably these particles represent crushed marble, which was added to the mortar mixture with intention to improve polishing effect, as reported by Vitruvius.[11] Outer layer of white polished mortar (ANM 142), thickness of approximately 7 mm, is composed exclusively of these particles (Fig. 2b). Aggregate is well sorted, size of these particles rise up to 2 mm. On the contrary, in outer layers of roman red wall paintings (ANM 138) just few particles are present. Furthermore, we were able to determine special additives, such as blast furnace slag particles (Fig. 2a) and crushed bricks (Fig. 3a). It is not surprising that slag particles are found in sample, taken from object in Jesenice (JES 2), where ironworks operates. Mortars with crushed brick particles (ANM 138, ANM 134) were used in the roman baths. Wood particles are also present in some samples (Fig .3b), but the intentionally addition of these particles our case it is not sure. It is widely known, that slag and crushed brick are latent hydraulic materials, which could conduct the pozzolanic reaction.

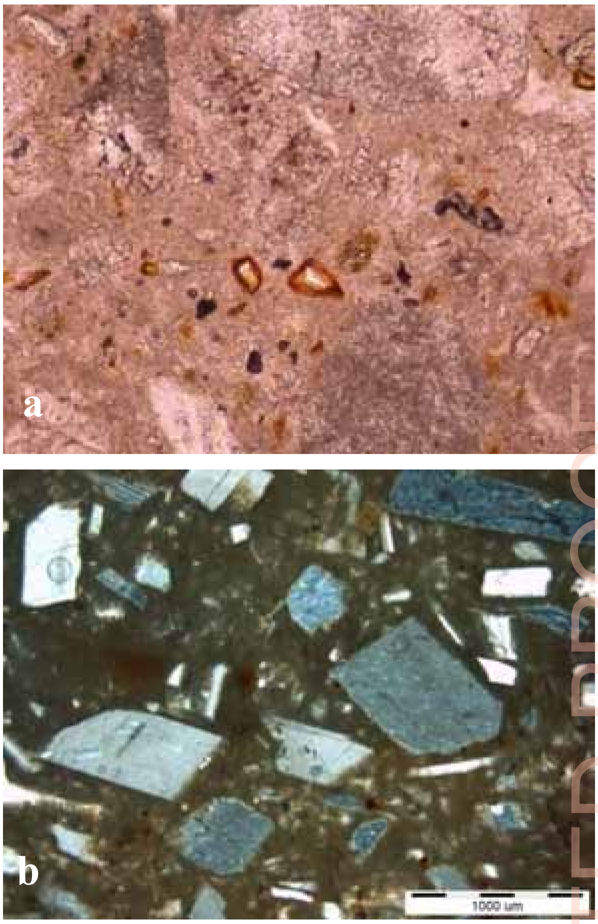

Figure 2: Petrographic examination of thin sections of mortars. a) blast furnace slag particles in sample JES2, crossed polars, x20. b) crushed coarse grained calcite particles in sample ANM 142, crossed polars.

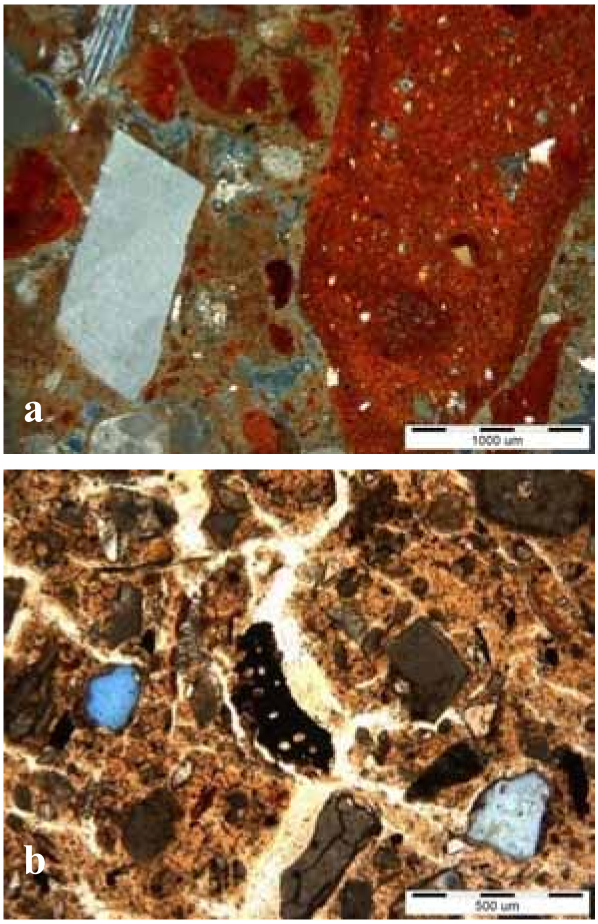

Figure 3: Petrographic examination of thin sections of mortars. a) crushed brick particles and coarse grained calcite in sample NAM 138, crossed polars. b) wood particle in sample JAL 1, parallel polars.

Binder

Most samples represent typical lime mortars. Samples contain lime lumps that vary in their size and quantity. In case of mortars used for roman wall construction, we presume the use of hot lime technology, which also explains a high strenght of the walls. This could be proved by presence of big lime agglomerates in mortars that indicate *in situ* slaking. Depending on the particular application purposes, hydraulic mortars were used as well. Therefore, mortars with crushed bricks were used in the roman baths, where waterproofing was required. EDX analysis of binder evidenced the presence of Ca, Si and Al, which could indicate the presence of some compound of calcium and aluminium or compound of calcium, aluminium and silicium (possibly in hydrate form). These mortars show characteristic compact matrix (Fig. 4a). Evidently, the content of crushed brick, especially brick dust, conducted pozzolanic reaction. It has been reported that brick dust with dimensions less than 75 µm should be considered as a binder owing to the pozzolanic reaction of these particles with lime.[12-15] Normally, bedding mortars, renders and plasters contain well sorted aggregate of smaller particles than masonry mortars. Around bigger latent hydraulic grains we can observe a reactivity rim (Fig. 4b).

The FTIR spectra of analysed binders show characteristic bands of carbonate phases at around 1415, 873, and 712 cm^{-1}. Furthermore, the characteristic peak attributable to silicates at 1030 cm^{-1} was found in most of the samples. With FTIR it was possible to determine also the presence of quartz and dolomite. These data are in accordance with XRD results. The IR band at around 3447cm^{-1} due to free hydroxyl ions is present in all samples of mortars that contain brick powder. These samples show also the strong band around 1000 cm^{-1}. The water might also be bound to hydraulic compounds, like silicate and aluminate hydrates. We were not able to determine any hydraulic components by XRD. Carbonyl band at 1691 cm^{-1} (sample RO 107) and C-H stretches at around 2941 and 2859 cm^{-1} (JAL1 and RO 107) suggest some presence of organic additives to the binding media.

4. Conclusions

Characterisation of presented samples of mortars was part of a numerous investigations whether for conservation-restoration interventions or archaeological projects. Results on composition are of crucial importance for the suitable conservation-restoration intervention, while the archaeological field is interested in the chronology, provenience of the raw materials and on the production processes. Finally, these data have a significant documentation value, which in our case represents comprehensive information on the mortars of various application purposes from Slovenia region, varying geographically and in time period. Thus, obtained data contribute to the idea to design, create and implement the Slovenian database of historical mortars. Possibility to compare them would improve the knowledge about historical mortars also in general. Composition of mortars differs regarding to their application purpose, geographical position and time period. The majority of historical mortars are lime mortars. Mortars, that contain special additives, such as crushed brick particles or slag, are hydraulic mortars.

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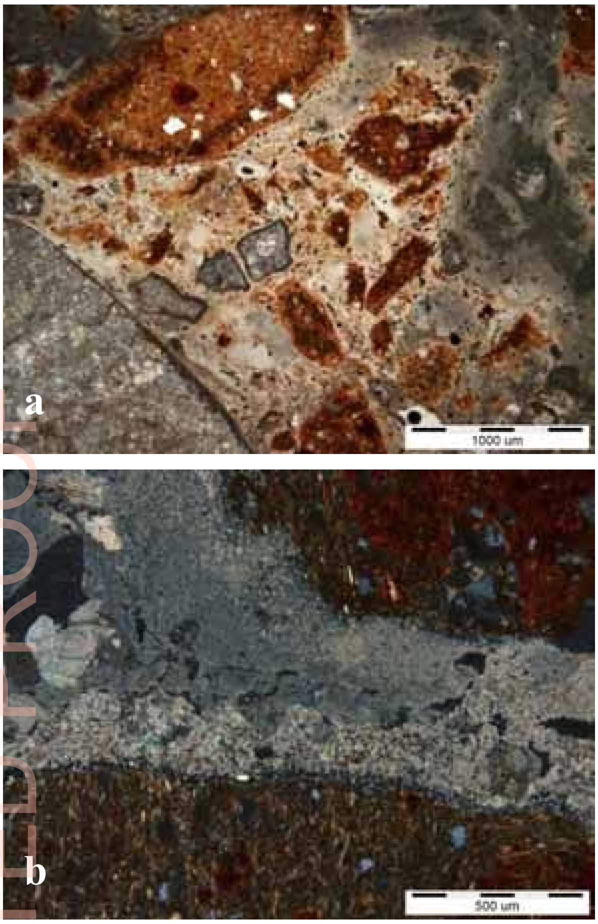

Figure 4: a) compact matrix in a sample with brick powder (ANM 134), crossed polars. b) reactivity rim around brick particle, crossed polars.

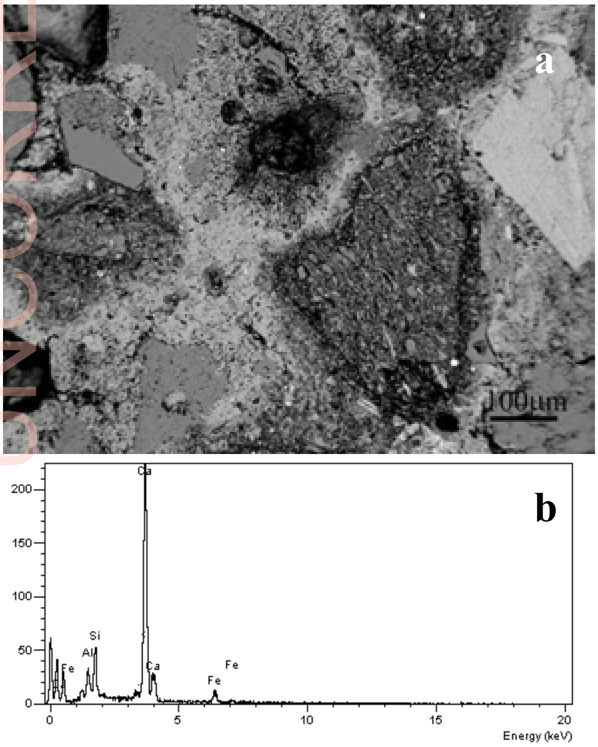

Figure 5: a) hydraulic binder in a bedding mortar with powder of brick. SEM, BE. b) SEM-EDX spectra of a binder.

A COMPARISON OF PIGMENTS APPLIED IN AN ORIGINAL PAINTING BY EL GRECO AND IN A COPY BY AN ANONYMOUS FOLLOWER

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Doménikos Theotokópoulos (1540-1614), known as El Greco, was a famous painter, sculptor and architect of the Renaissance. He was born in Crete, the island which in that time belonged to the Venetian Republic. Stylistically, it was a centre of Post-Byzantine Art in which El Greco was trained. In 1560s he travelled to Venice and Rome. During his stay in Italy, he enriched his style with elements of Mannerism and Venetian Renaissance. In 1577 he moved to Toledo in Spain where he worked until his death. In this last period of life he produced his best works, today spread among different museums and collections. He had many followers and his works were copied extensively.[1,2,3]

The Fine Arts Museum in Seville, the second most important gallery in Spain, has in its collection two interesting canvas paintings. The first one is the original work painted by El Greco towards 1600, *The portrait of his son Jorge Manuel* (Figure 1). The second one is *The portrait of Fray Hortensio Félix de Paraviccino* (Figure 2) painted in the second half of the 16th century by an anonymous follower of this famous Greek painter.

The comparison of both portraits was of interest, especially regarding the pigments applied. The focus of the work was to identify any differences that would permit to distinguish both painters on the basis of applied materials and techniques used. None of these artworks were in the restoration process at the time of the project, which is why the non-destructive XRF technique was chosen.[4] It permitted the study of both paintings in situ. The analysis run by this technique offers elemental results by detecting chemical elements with Z number higher than 13. On these basis, the majority of inorganic pigments can be identified, while the organic ones can not be confirmed by this technique.[5,6]

In the original El Greco painting *The portrait of his son Jorge Manuel*, the most significant chemical elements are Pb, Cu and Fe. In many spectra also Ca and Mn appear. Also very low peaks of Hg can be detected. The high presence of Pb in all spectra identifies some lead based pigment (lead white, massicot, minium or litharge – not possible to distinguish with XRF technique applied[4]) used in the preparation/ imprimation layer, as well as the pigment for white parts of vestments.[7,8] It is possible that a small amount of cinnabar was added. Mn, Fe and Cu show the use of umbra and some copper based green pigment for the dark greenish background (Figure 3).

The dark colour of the vestment was probably painted with some organic black pigment – the count rates of Fe, Cu and Pb are lower than those of the background and there is no new chemical element in the spectra taken from this area. The painter must have used this black pigment also for his signature on the right side of the painting. The carnation was made with lead white, mixed with a very small amount of cinnabar and probably some carmine, red organic pigment, used also for the lips of the protagonist (Figure 4a). The palette in protagonist's hands was painted with yellow ochre, while the colours on it are lead white, yellow ochre, umbra, red earth and carmine.[7,8]

Figure 1: El Greco: The portrait of his son Jorge Manuel (ca. 1600).

The results of the second painting, made by an anonymous author, The portrait of Fray Hortensio Félix de Paraviccino, gave similar results. There must also be a preparation/ imprimation made of some lead based pigment, while the dark background was painted with a mixture of umbra and some copper based green pigment. Nevertheless, the presence of Cu is much higher in the original work as in this one (Figure 3b). Also some other differences were identified. The carnation was made with lead white and some cinnabar as in the original El Greco, but the analysis showed also a low presence of smalt (Figure 5). This blue pigment was found also in the hair and beard. The lips of the protagonist were modelled by red ochre and cinnabar, and not with carmine (Figure 4b). Umbra was used for the hair and the dark dress, maybe also some organic black was added to obtain a darker colour. In some areas low peaks of Ti, Zn and Ba can be observed, showing posterior interventions with modern pigments Ti and Zn white.

The XRF results of both paintings showed the use of lead white, yellow ochre, umbra, some copper based green pigment and probably an organic black. But they also revealed an important difference in the use and the presence/ absence of pigments between both paintings.

1. Acknowledgement

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Figure 2: Copy of El Greco by an anonymous author: The portrait of Fray Hortensio Félix de Paraviccino (2/2 16. cent.).

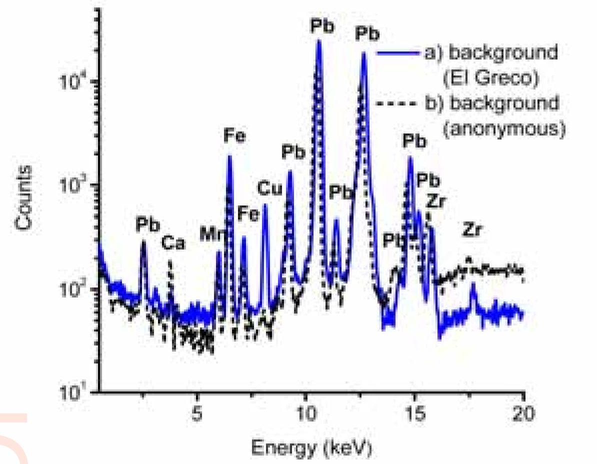

Figure 3: Comparison of two XRF spectra taken from the background of both paintings. a) El Greco's background (straight line) contents more Cu based green pigment, while b) in the anonymous one (dot line) there is a very low content of it and Ca peaks are higher.

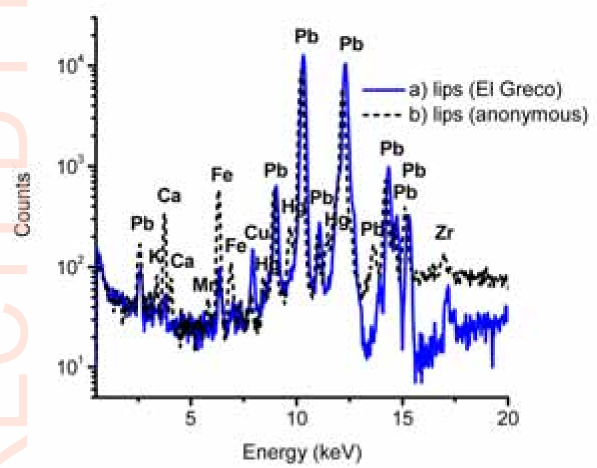

Figure 4: Comparison of two XRF spectra taken from the lips of both protagonists. a) Juan Manuel's lips on El Greco painting are made of some red ochre (Fe) y probably carmine (no XRF results). b) Paraviccino's lips are painted with red ochre (higher Fe peaks) and cinnabar (Hg).

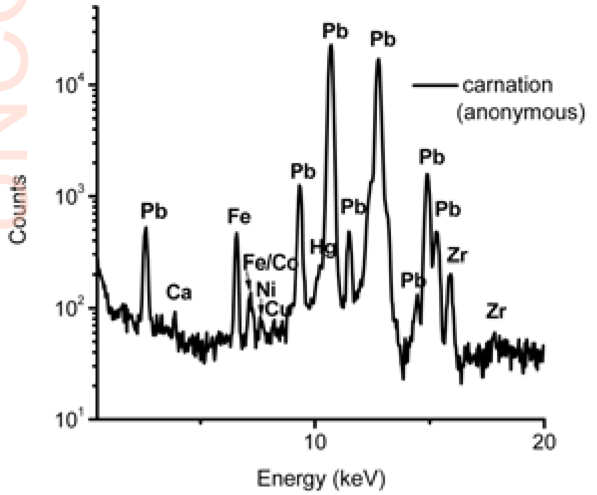

Figure 5: XRF spectrum of the Paraviccino's carnation. A small presence of smalt (Co, Ni) can be observed, added to the Pb white, ochre (Fe) and cinnabar (Hg) mixture.

DIFFERENCES AND SIMILARITIES IN THE MATERIALS AND TECHNIQUES OF MEDIEVAL MURAL PAINTING IN THE COASTAL REGION OF SLOVENIA

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In the coastal area of Slovenia many medieval churches are conserved, the majority of which are richly decorated with mural paintings. These are very different in style due to different stylistic tendencies that have been meeting there during the Middle Ages; the Italian, the central-European and the local one. Up to now they have been studied only from the art-historical point of view,[1, 2] almost no material research has been carried out. The purpose of this study was to find out, if these paintings are diverse also in their technical execution and in material used, such as support and pigments. Another question of interest was, if the real fresco technique can be found in paintings influenced by Italian art (Trecento and Quattrocento tradition), while the lime technique in those murals which show the central-European artistic expression.

To answer these questions, several mural cycles were chosen, covering the time, the area and the style. The parish churches of St. Stephan in Zanigrad (1400-10) and of Virgin's Nativity in Pomjan (1410-20) show artistic influences of Venetian and Paduan art of the early 14th century. The parish church of Sts. Peter and Paul in Nozno (1/2 15th cent.) reveal South-Tyrolean artistic language of the time around 1400, which can be found also in mural paintings of the parish church of St Briktius in Volarje (2/4 15th cent.). On the other hand, the parish church of Virgin's Assumption in Vremski Britof (1445-50) reveal connection with the north of Europe, specifically with Salzburg's painting of the second half of the 15th century. Mural cycle in the parish church of St Thomas in Famlje (1450-60) is, again, connected to Venetian painting of the second quarter of that century (Figure 1).[2]

All paintings were first precisely studied *in situ* and second, tiny samples of mortars and pigments were taken from specific areas. In order to know the composition of mortars, the selection of pigments and the technique of mural paintings, these samples were ground or prepared as cross-sections[3] and then studied by different instrumental techniques: OM, SEM-EDS, FTIR and XRD.[4-6]

The composition of mortars of first four cycles is very similar; they are made of lime and sand. The *intonaco* is always rich in lime and well polished. In Zanigrad and Pomjan the yellowish colour show presence of clay, demonstrated also by XRD results (Figure 2). Only in Volarje a high quality mortar of lime and crushed marble or lime rock was found (Figures 3 and 4).

In almost all of these paintings local presence of lime-wash was confirmed. Differently, in Vremski Britof and Famlje, two geographically close localities, the mortar is characterized by a high quantity of sand, which is also badly washed and conserves impurities (Figure 5). The lack of lime causes bad consistency of mortars which tend to pulverize. There is no lime wash in any of those two mural cycles.

Figure 1: Mural paintings in the parish church of St Thomas in Famlje (1450-60).

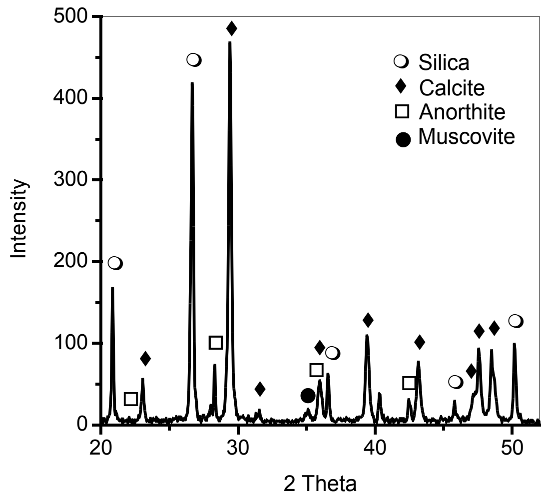

Figure 2: XRD diagram for mineralogical analysis of powder sample of a mortar made of lime and sand.

Figure 3: Selected optical micrograph of a mortar made of lime and crushed marble or lime-rock. Volarje (x50).

In comparison with other mural paintings around the Slovene territory, these surprise with worm and vivid colours. The pigments applied are mostly all of inorganic origin, which are convenient for fresco painting: lime white, yellow and red ochres (Figure 6), green earth and umbra.[7-9] Malachite was confirmed as a green pigment only in Vremski Britof, while the presence of blue azurite can be identified by some typical changes of this pigment, caused by atmosphere influences, which were observed already in situ. In Zanigrad and Vremski Britof the presence of lead based pigments was discovered, most probably lead white. The black pigment is of organic origin.

The painting technique[9,10] used is a combination of *a fresco* and *a secco*, only in earlier paintings there was also lime technique applied. The work was started on a fresh mortar, on which the preparatory drawings, incisions and under-layers were made. On this base the painters continued the work *a fresco*, *a secco* or using a lime technique, depending on the conditions of the mortar's humidity. The proportion of each technique varies greatly from painting to painting. The higher *a secco* part was found in two younger mural cycles (Vremski Britof and Famlje), which are also in the worst condition. The colour layers are lost in big part, due to the pulverization of the pigments applied.

The detailed results reveal that the geographically closer paintings are technically similar and that the local tradition was stronger than foreign influences.

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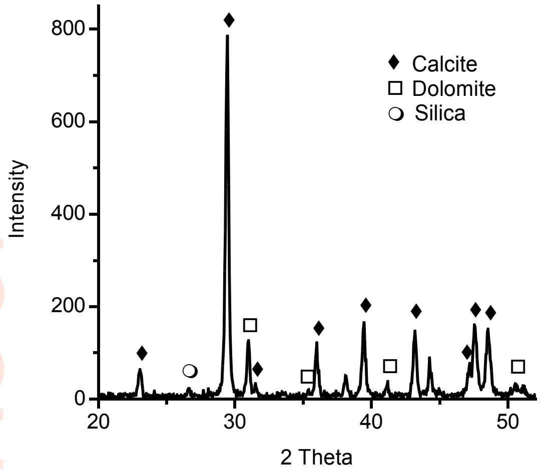

Figure 4: XRD diagram for mineralogical analysis of powder sample of a mortar made of lime and crushed marble or limerock.

Figure 5: Selected optical micrograph of a cross-section (x50) of a mortar made of lime and sand. Vremski Britof.

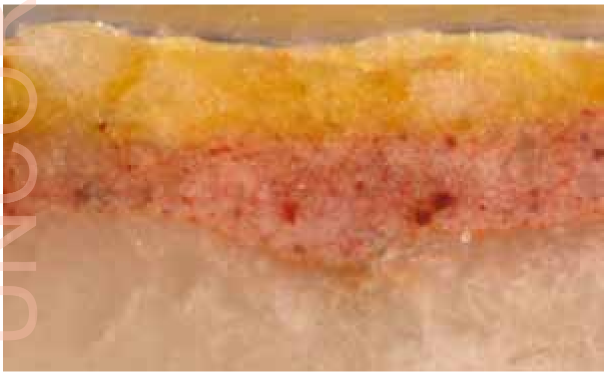

Figure 6: Selected optical micrograph of a cross-section (x200) of two colour layers made by yellow (upper layer) and red (middle layer) ochre. Nozno.

COMPOSITE ARTWORKS: ART HISTORICAL AND SCIENTIFIC ANALYSES

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1. Introduction

The composite art objects are common in the library, archive or museum collections. These objects are made of two or more different inorganic (e.g. metalwork, ceramics, enamel) or organic materials (e.g. books, manuscripts) and a combination of both organic and inorganic materials (e.g. paintings, polychromed sculpture). Each material reacts differently to the conditions of display, storage, or changes in temperature and humidity, and so forth, setting up physical stresses and causing complex interactions between them and with environmental conditions that may cause deterioration. Therefore, composite artworks required an extensive conservation research before the treatment. In a multidisciplinary field like preservation the examination, interpretation, and conservation of cultural, historical and art objects have to be included. The knowledge of both, the humanities and sciences, is essential in order to understand the creation and production of the material culture in the past and present contexts and ensure its long-term preservation. The historical knowledge enables us to view an artwork from the aesthetic standards of its time of origin and to understand a certain style or the period of art. When the objects are religious and sacral artefacts the iconography and social aspect are important. Additionally, connoisseurship can suggest the desirability, quality, and the extent of treatment necessary for maintaining the individuality of the artist and the individuality of the work. If it is necessary for the conservation work, the artist´s original intentions could also be investigated.[1] By studying the physical structure and chemical nature of the artwork, we can understand the artist´s techniques and materials and their present condition. This knowledge is needed for the selection and use of the conservation materials and methods. Scientific investigations are also valuable in differentiating the original parts of an artwork from later additions, former conservation treatments or falsifications.

The examples of the application of art historical and scientific research in the establishment of authenticity and the investigation of the artist´s techniques and composite materials, and state of preservation are discussed.

Figure 1: Detail of miniature (dog head) showing the way of painting, drawing lines, and typical damages.

2. Examination of composite artworks

Multiscale and multidisciplinary approaches to the research are a prerequisite to any detailed examination of the objects. The first step is considering the social and historical influences and how they are reflected in the artworks. The different imaging techniques such as ultraviolet fluorescence, infrared reflectography, and X-radiography can help historians and curators find the answers. Resulting from these investigations, many questions are raised concerning the nature and origin of the materials, composite material processes, manufacture of an object, alteration and preservation of the objects, and so on. To try to answer these questions, it is necessary to use various types of analytical techniques for detailed characterization of the materials.

2.1 The case study of *Gloria in Excelsis Deo*, miniature painting on parchment by Juraj Julije Klović

The miniature work on parchment *Gloria in Excelsis Deo* by Juraj Julije Klović (known as Guilio Clovio) is a part of the complex composite object composed of two individual artworks merged together into the new artwork (drawing *The Holly Family Under the Oak*) which was glued to a wooden support in 18th century.[2] According to the authorities *Gloria in Excelsis Deo* was part of an illuminated sheet of parchment dated around 1530 when Klović worked for Cardinal Marino Grimani.[3] Illuminated border is decorated with floral, figural and grotesque motifs in a refined and elegant style using short, light strokes and dots to coloured the drawing (Figure 1). The technical examination of the miniature with imaging techniques (in the UV/VIS/IR light) and stereomicroscopy showed that the artwork was restored in the past. The characterization and differentiation of the pigments were done to address issues of attribution and conservation. The portable X-ray fluorescence (XRF) spectrometer was applied for this purpose, and analysis indicated the following pigments: blue (smalt, identified by the element Co and ultramarine, identified by Si and S), red (vermilion, identified by the elements Hg and S; and red ochre, identified by element Fe), green (Cu based pigment), yellow (lead-tin yellow, identified by elements Pb and Sn), brown (mixture of Fe and Mn oxides, identified by the elements Fe and Mn) and white (lead white and calcium carbonate, identified by the elements Pb and Ca) as it is shown in Figures 2.

2.2 The case study of *Ahuramazda on the Nile*, comic strip drawings by Andrija Maurović

Examining Maurović´s comic strip drawings from the Graphic Arts Collection of National and University Library and his distinctive visual style, the cinematographic effects in comics that was pioneering work in his time is evident. His comics were advertised as novels in picture due to their interesting and dynamic action sequences like a movie. His heroes expressed his view of the relationships between man and nature.[4] To understand Maurović´s style, the cultural background of the newspaper readers in Zagreb and Croatia in the first half of 20th century should be kept in mind. The present research work was done on the comic strip *Ahuramazda on the Nile* which Maurović drew at the time of the Second World War for the magazine Zabavnik (1944). The story that took place in Greece, Egypt and Persia in 6th century BC at the time of the Persian Wars is a mixture of romantic and realistic elements, and historical facts.

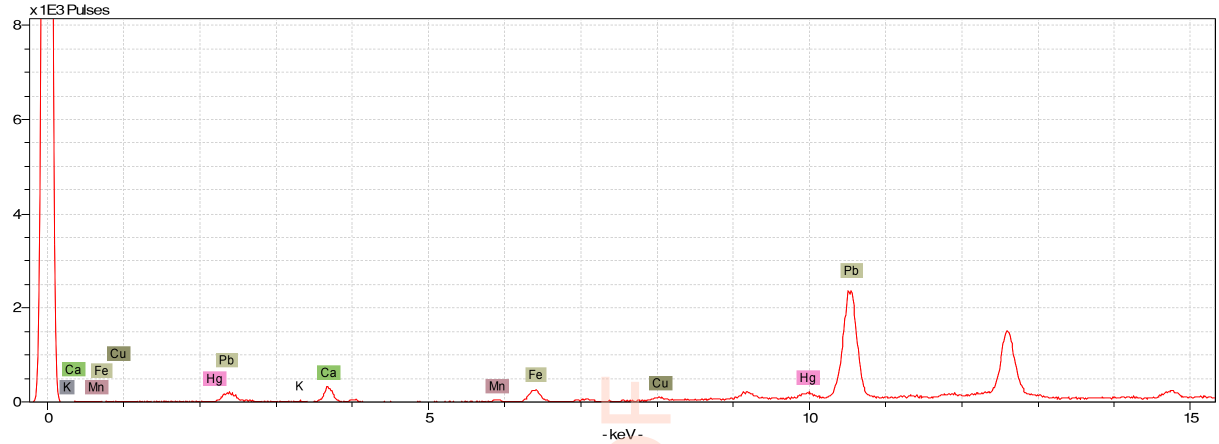

Figure 2: XRF spectrum of the whitish area containing lead white (element Pb).

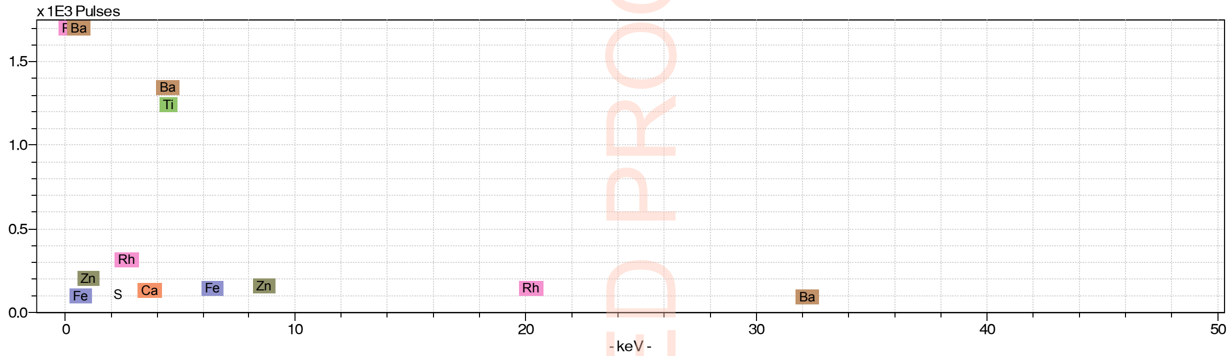

Figure 3: XRF spectrum of drawing paper containing Ba and Ti (barium carbonate and titanium oxide)

The comics are drawn on the white watercolour paper with graphite pencil (sketches) and black ink using a pen and a brush. The colour work is done with blue watercolour. The text was written by hand and typewritten on separate pieces of paper which were attached with glue.

Partial characterization of the materials of the comic strip drawings *Ahuramazda on the Nile* by Andrija Maurović using X-ray fluorescence spectrometer indicated the presence of barium carbonate and titanium oxide as main inorganic constituents of the drawing paper. Figure 4 shows the results of XRF elemental analysis of the drawing paper.

2.3 The case study of the paintings by Master HGG from St Catherine´s Church in Zagreb

An extensive historical and stylistic analysis of the impressive opus of the paintings by Hans Georg Geiger von Geigerfeld (Master HGG, born in Slovenia) found in Slovenia and Croatia preceded the technical and scientific research of his artworks.[5] The results of the structural and chemical analysis of five paintings (restored in the last century) from St. Catherine ´s Church in Zagreb show similarities in ground structure and in the construction of the blue and red layers, particularly in the extensive use of smalt, lead white, cinnabar, charcoal black, azurite and earth pigments. The complex combinations of painting materials required the removal the paint microsamples. The examination and analysis of the cross-sections were conducted using the polarized light microscopy, UV fluorescence and PIXE spectroscopy. The cross-sections taken from the sky areas demonstrate similar paint composition: chalk, ground containing lead white with additions of earth or black pigment and a layer of smalt and lead white. In the greyish blue layer, cobalt was detected at 0.,8 - 2.97 wt%, while a potassium level was 5.37 -11.87 wt%. Figure 5 shows the results of PIXE analysis of the ground and the blue layer from the painting of *St Nicholas*. Taking into account the high level of heterogeneity of the artworks, it must be emphasized that the microsamples and the analytical results given from a spot analysis cannot be representative.

The presence of trace elements such as copper, magnesium, sodium, manganese, iron, bismuth, arsenic and nickel are common for seventeenth century smalt. They are impurities of the cobalt ore. Chloride is often detected with lead white, probably introduced during the production processes of lead white. A thin whitish or light gray-brownish surface deposit could be observed on some areas of the smalt/lead white containing oil paint. It is assumed that the surface degradation of the paint is due to the migration of ions (potassium, lead) from the lead white- and smalt-rich areas as a result of natural aging[6]. In Figure 6, the expansion of white underlayer that affects the stability of the paint layer is evident.

3. Conclusion

In order to properly preserve the composite objects, it is necessary to understand their condition and significance, and also the knowledge and skills needed to produce them. This requires an interdisciplinary collaborative approach. Advanced analytical methods are an essential prerequisite in such a case, as they allow us art historical investigations as well as preservation studies.[7] The results of the studies have contributed to increased knowledge about artworks and provided useful information for future conservation works.

4. Acknowledgement

The authors express their thanks to the colleagues from the National and University Library in Zagreb for technical assistance and valuable discussions.

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BUILT HERITAGE IN INTEGRAL SAFEGUARDING OF THE KARST CULTURAL LANDSCAPE

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Abstract
At the European and global scale the Karst – the region lying in the hinterland of Trieste on the plateau between the Vipava Valley, Adriatic Sea, Soča River, the Brkini and Istria – is mainly distinguished by its geographical characteristics. It is renown, as a phenomenon related to specific appearance of subterranean caves and exceptionally permeable porous rock formations. Simultaneously the Karst is becoming increasingly more identifiable as cultural landscape with preserved natural and cultural heritage and distinct built heritage and identity, similarly to e.g. Tuscany and Provance. Comparative research has proven that on the Slovene scale, the density of identified cultural and natural heritage is the highest. Since built heritage in the Karst cultural landscape plays the most prominent role it would be sensible to direct development aspirations of the entire area into systematic and integral safeguarding, which includes intensive renewal of built heritage and the establishment of a protection zone. The stated goals can be achieved only by public participation with the local population.

1. Introduction
Because of its transitory position at the northern most tip of the Adriatic Sea, the Karst has always had strategic significance in history, since this is the place where important routes cross, both in the East-West and North-South direction. Its strategic position has in various historical periods been of interest to various forces, thus the area today presents a variety of cultural heritage, which speaks of the cultural mixing in this border area between Italy and Slovenia. The Karst's cultural landscape is rich with findings from various historical periods: the Palaeolithic, Mesolithic, Neolithic and so called "Castello culture" – fortified hilltop settlements (Fig. 1) built from the second millennia BC till the arrival of the Romans[1]. Evidence for continuous settlement of the Karst, are also the Roman system of public streets (viae publicae) and several documented complexes from the Roman period (villa rustica). Many other remnants, expressing continuous presence of mankind in the Karst, are from the late antique period till modern times.

We can establish that with adaptation to nature and interventions on nature mankind has established a dynamic balance with nature, which is today seen in specific and unique cultural landscape. The key part of this characteristic cultural landscape is built heritage. Formerly the autochthonous Karst architecture was above all marked by rational and functional relations to all creation, which in conjunction with use of readily available building materials provided an unique aesthetic charm. People used only easily available materials found nearby that they managed to salvage from nature. Stone was abundant, while timber was rare and precious[2].

What we presently admire as the Karst architectural treasures are densely built villages and specifically designed farms – homesteads. The adaptability of village development to the micro-climatic and landscape features in the Karst can be witnessed everywhere by any sensitive observant. Villages, especially the larger ones, are composed of separate parts in such a way that fertile land enclosed by the built structures was preserved. Mostly they were used for vineyards and orchards.

Figure 1: Volčji Grad, site of Halstatt ancient fort had been extraordinary shaped and integrated into landscape characteristics.

Figure 2: Village Skopo, the adaptability of village development to the micro-climatic and landscape features in the Karst can be witnessed everywhere

Natural depressions were often used for water retention – so called: *kale* and *lokve*. Even built rows of houses in exposed parts of villages were designed to protect the other parts of the village from the prevailing wind – the *bora*. Exceptional ingenuity and experience can be seen in settlement layouts, although they were never planned by architectural bureaus. Villages developed and grew through centuries; new buildings always locked into extant building rows and sensibly complemented them (Figure 2).

Most village cores preserved their nineteenth century structure. The layouts of Karst villages give an impression of truly urban settlements. Their structure can possibly be compared to nearby towns along the Adriatic coast. Windy streets, perimeter housing rows, monumentally designed entrances into courtyards, external stairways with balconies and street crossroads, together with other settlement landmarks, such as bell towers and other devotional objects, are so typical and distinct places, give the observer unforgettable sensations. In village cores most of the buildings are connected into mighty building complexes – the Karst homesteads. These are usually enclosed by tall perimeter walls. We enter the courtyard – locally called *borjač* – through a stone portal, usually richly decorated or treated by a stone mason (Figure 3). Other typical stone masonry works can be found in the courtyard, such as rain water cisterns – *štirne*, which were formerly the only source of drinking water, should be mentioned.[3]

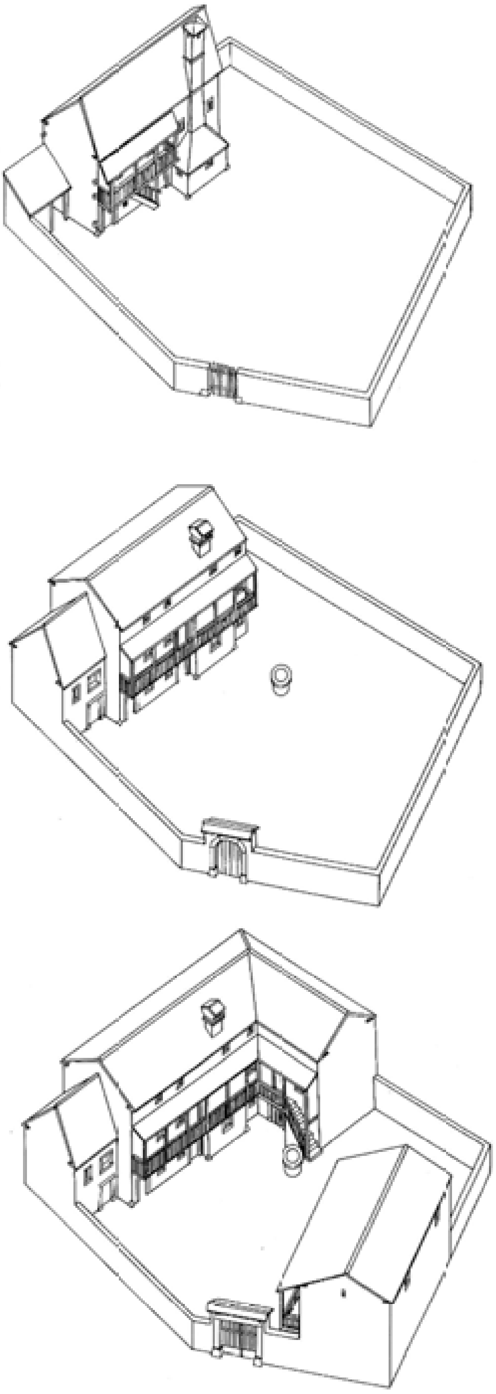

Figure 1: A tentative reconstruction of the typical spatial and design development stages of a Kras homestead in the framework of the fixed boundaries of a building plot.

The oldest testimony of settlement in the Karst area can be found outside the villages. These are typical prehistoric settlement remnants on higher grounds of the plateau. Medieval castles and even younger palaces can also be found in the Karst area; besides the fortifications built during the times of Turkish raids, they represent a distinct attraction and specificity of the region.

2. Findings

The incidence of identified cultural and natural heritage demands the formulation of long-term safeguarding strategies and modernisation of pertaining philosophy. The four centres of cultural and natural heritage in the Karst, which also represent the mainstay of local distinctness, are: The Škocjan Caves Regional Park, Stud farm Lipica, Štanjel village and Glinščica Valley.

The Škocjan Caves are above all a natural phenomenon of exceptional global value, which can compare to the Grand Canyon, Great Barrier Reef, Galapagos and Mount Everest … Proof is evident in its listing in the Register of world cultural and natural heritage (1986) within the Convention on world cultural and natural heritage (Paris, 1972).[4] The Škocjan Caves park – lying in the centre of the Karst – is annually visited by almost 100.000 people from all over the world.

Even the Lipica stud farm, founded in 1580, is not known only as the cradle of all Lipizzaner horses world wide. Its century-old cultivated landscape oasis represents a gem in the image of the Karst cultural landscape.

The Štanjel settlement, with its specific development, has a dominant role on the edge of the Karst. This small town, formerly encircled by a defensive wall, defended itself as a fortified village during the times of Turkish raids. With an integral heritage safeguarding project devised according to contemporary principles of museum activities, this presently largely unused building stock could be transformed into an "eco-museum", thus encouraging revitalisation and reconnection of the environment, community, still living in the settlement, and heritage (Fig. 4).

Figure 4: Štanjel, medieval and Rennaissance castle architecture on Kras summarized contemporary achievements integrating them into the landscape.

The Glinščica Valley (Val Rosandra in Italian) is a landscape park lying near the city of Trieste where we can marvel at exceptional examples of water erosion of Karst rock formations. The picturesque canyon attracts nature lovers, cave researchers, climbers and leisure seekers from Trieste and beyond. Besides the natural features in the valley we can also see the water ducts of ancient Tergeste.

Besides the stated dominant cultural and natural heritage, which are already very established tourist attractions, there is evidence on numerous and varied units of cultural and natural heritage on either side of the Karst – in Italy and Slovenia. Since built heritage in the Karst area plays the most visible role, it would be sensible to direct future development aspirations of the entire area into systematic and integral safeguarding.

3. Conclusions and key recommendations for achieving integral safeguarding of built heritage in the Karst cultural landscape

a) Renewal of the built heritage

To preserve the Karst in the sense of the European Landscape Convention investments into maintenance and renewal of the building stock and comprehensive rehabilitation of village centres have to be intensified. Rehabilitation of villages and renewal of particular specific areas have to be conducted as joint projects of the local community and property owners. The primary renewal leader should be the local community – municipality, which should take onboard care for the comprehensiveness of rehabilitation actions, management of public areas and public utilities infrastructure. Investments in internal settlement development should have the absolute priority over investments that imply expansion into virgin areas. Settlements should expand only if there are no more possibilities for internalised rectifications. Thus permanent investment can be ensured, as well as improvement of living qualities of Karst villages. To achieve the stated goals an in-depth analysis of the recently completed national census of properties has to be undertaken as soon as possible. Rough estimates actually show that almost twenty percent of all properties in the Karst region are either vacant or unused!

In conjunction with the expected needs it is necessary to exponentially burden owners of unused buildings and vacant building plots in the settlements. Systematic measures should be applied to stimulate renewal of buildings and offer the yet unused potentials on the property market on the one hand and to simultaneously prevent and/or diminish the passive attitudes of present owners (in most cases already inheritors) to their properties. Funds for financing renewal have to be introduced, based on principles of public-private partnerships, together with interested commercial investors.

Hereby local authorities should do everything that is necessary to enable the establishment of consultancy centres that will help people preserve the characteristic architecture and landscape. Local authorities should endeavour to execute the proposed development projects and thus strengthen internal settlement development, but also enable exploitation of resources from EU funds.

We have to maintain the vitality of historical village cores in the future, rehabilitate them and adapt them to modern living conditions. Areas of new developments have to be curtailed to the utmost and limit the extent of building land to the needs of local inhabitants and well-grounded development needs of local communities. It is important to compact the new, extensively developed new parts of settlements and to integrate them with the extant village cores and landscape. The advantage has to be given to renewal of the extant building stock and internalised development, contrary to irrational and senseless expansion of new developments in the form of satellite settlements.

b) Establishment of the safeguarded Karst area

The devising of new relations with space and heritage can be achieved by establishing a protected area, which could connect the Krast across borders. Within the framework of the protected area extant opportunities would strengthen and new opportunities emerge for the development of entrepreneurial potentials linked to marketing of local products and the so called territorial capital, seen as preserved natural and cultural heritage. Within the park economic, tourism and agricultural activities, which wouldn't endanger long-term preservation of natural and cultural heritage, whose progress is aligned to principles of sustainable development, could still develop.

All key development issues in the Karst area – but also issues concerning cultural sovereignty and identity, as well as issues concerning safeguarding measures, in the sense of preserving national and cultural identity – can be achieved by proclaiming a protection area.

The first opportunity for establishing a protected area stems from the UNESCO framework. The Karst area in Slovenia was already listed in the experimental UNESCO World heritage list from 1994 under the heading "Classic Karst"[5]. Such listing is the possible and compulsory preliminary step for future listing in the UNESCO World heritage list. The sensible action would be to continue the procedure of listing the Classic Karst in the UNESCO World heritage list, but also, with respect to the changed Operational Guidelines for the Implementation of the World Heritage Convention, to recheck the listing proposal, which can be changed or amended if necessary.

The second opportunity arises from the continuation and upgrading of the Karst pilot project, done in conjunction with the Cultural heritage Department of the Council of Europe. The project lasted for several years and in its results was the proposed establishment of a protected area, the recommendation being to follow the French model of regional nature parks. The model stands on a founding act – contract or agreement –that is the fruit of mutual interests and partnerships between the state, regional and local authorities, as well as local population, which is built on an agreed development vision. Local communities of the Karst area have already accepted a "Common development programme", which nevertheless ahs to be developed, expanded and upgraded in the future.

c) Public participation of the local inhabitants is crucial

The successful establishment of a protected area significantly depends on timely and equal participation of interested publics. The concept of so called participative democracy is founded on access to information and mutual adoption of spatial-environmental decisions. Slovenia and Europe are obliged to operate in this manner according to the ratified international documents – the Aarhus Convention[6] from 1998 and adopted Torremolinos Charter from 1983, which speaks about public participation in early stages of planning processes.

Public participation is of utmost importance in the development of new spatial plans. The local population has to be informed already in the earliest – starting phases of planning and document preparation. Even the selected contractors developing the new documents have to be directly and beforehand educated about the needs and desires of the local communities. Joint workshops are probably the most suitable form of creative cooperation. Thus even the introduction and establishment of referendums about spatial development, spatial management and larger planned spatial interventions, as the type of decision-making on the local and village level, shouldn't be seen as something unusual in Slovenia. However, respect for adopted overall documents, strategies and laws, is essential.

Only in this manner can true participation of the local inhabitants as an organised public be ensured in decision making. Thus we can also strengthen individual acceptance of responsibilities for ones' own space and condition suitable spatial development of settlements.

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POPART: A EUROPEAN PROJECT ABOUT THE PRESERVATION OF PLASTIC ARTEFACTS IN MUSEUM COLLECTIONS

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1.Abstract

During the twentieth century artists have used synthetic polymers to create important pieces that are recognized nowadays as masterpieces. Unfortunately, some artefacts are degrading faster than had been expected and their medium to long term preservation constitutes to present a challenge to those who care for such items. There is an inherent lack of knowledge and agreement about the way we can exhibit and clean these artefacts in order to arrest or lower their deterioration rate. In 7th framework programme (FP7) of the European Community (EC) for research and technological development, a truly international project called POPART is addressing these issues. Its objective is to develop a European wide accepted strategy that improves preservation and maintenance of plastics objects in museum collections. It focuses on three dimensional museum objects as these frequently exhibit physical degradation, due to the inherent instability of the synthetic polymers, such as cellulose nitrate, cellulose acetate, poly(vinyl chloride), polyurethane etc. Based on scientific studies and experiences gathered from partners, it is proposed to evaluate and establish good practices for exhibiting, cleaning and protecting these artefacts for future generations to enjoy or study.

2. Introduction

Ever since synthetic materials were created, they have been used in the design and fine arts world and may represent a significant part of a museum collection in values and/or numbers. A common misconception is that plastics last forever. Ten years ago, surveys carried out in Victoria and Albert Museum and in the British Museum identified more than 7500 synthetic polymer containing objects and among them more than 12% required urgent conservation decisions. This number might be considered as a low figure, as it has to be realized that the survey takes into consideration only the final stage of deterioration process, when the deterioration becomes outwardly visible by physical changes that have induced deformation, shrinkage, cracking, surface deposits, discoloration or gloss changes. These survey results do not mean that the 88% of the collection will stay in a 'good' condition for long; the deterioration of plastics has an induction period followed by accelerated degradation that results in a rapid destruction of the object. Film archives have experienced this problem. It has been shown that cellulose triacetate deterioration takes around 40 years in a temperate climate before being detectable by an acetic acid smell – the characteristic smell of vinegar - and physical distortion of the film base. Before 1980, no film archives were really aware about this so called "vinegar syndrome". Shortly after the year 2000, it became the major problem for the film archives over the world. Finally, it must be accepted that the degradation of plastics is due to irreversible chemical reactions. Although it cannot be reversed it can, given the right conditions, be slowed down. In 1993, a committee of curators and conservators, representing six major museums of modern and contemporary art in the Netherlands concluded that there were no generally accepted methods and criteria for solving the conservation problems of non-traditional objects of modern art and there was little insight into the nature and use of modern materials. Knowledge concerning the composition and ageing of modern materials was difficult to access. It is a priority to develop a strategy for the preventive conservation and maintenance of modern artefacts collections. To support such urgent needs, the European Commission has approved the funding of a collaborative research project in the framework of the work program topic "Damage assessment, diagnosis and monitoring for the preventive conservation and maintenance of the cultural heritage". This POPART project (Preservation Of Plastic ARTefacts in museum collections, grant agreement n°212218), will officially start in October 2008 and finish March 2012. It gathers 12 partners from scientific research laboratories, museums, SME's and conservation laboratories and 9 countries from Europe and North America.

3. Objectives of the POPART project

3.1. Identification of plastic objects

In order to establish long term preservation strategy, it is necessary to evaluate the risks. This can be done only after the identification of the chemical nature of the objects and a better knowledge about its physical and chemical stability. An experienced conservator might be able to distinguish one plastic from another by the smell, sight or feel, but for most conservators or curators, destructive tests that include burning and dissolving samples are necessary for identification of the base polymer. One objective of the project is to develop and evaluate analytical tools and methodologies for identification the nature of polymer of plastic objects in museums such as Near Infra-Red spectroscopy (NIR), Fourier Transform Infra-Red spectroscopy (FTIR) to Pyrolysis-Gas Chromatography-Mass spectroscopy. The project will focus particularly on portable analytical equipment available on the market.

3.2. Condition report of modern material collections, monitoring and survey methodology

During ageing, many polymers exhibit typical deterioration patterns. Survey of museum collections will be carried out in order to determine collection condition. Chemical and physical degradation in the form of discoloration, change in opacity, crazes, cracks or changes to surface texture and distortion will be documented. Such surveys will help to determine further priority and samples for analysis of degradation products and for cleaning. It will serve as a reference to assess frequency and type of deteriorations found in collections. Analysis will be carried out to identify the nature of the deposit found on some objects and off gassed products. Case studies that suffer discoloration or physical changes will be monitored in order to better assess the impact of the environment. Field measurement on museums artefacts will be carried out using non invasive spectroscopic characterization.

3.3. Risk assessment for some polymer families

Conservators of plastics and scientists agree that the four synthetic polymer types that require attention in all collections are: cellulose nitrate, cellulose acetate, poly (vinyl chloride) and polyurethane. Degradation paths for poly (vinyl chloride) have been investigated and reported along with cellulose nitrate and cellulose acetate. These polymers have been studied extensively, primarily in the field of conservation of movie films. This prior knowledge has to be extended to 3D objects through this project. In the case of polyurethane, a lot has already been completed. Research on polyurethane will be carried out in order to find markers of deterioration, risks for museum staff and collections associated with off gassing using chromatographic methods, chemiluminescence and thermal analysis. Influence of humidity, temperature, oxygen on the deterioration rate will also be evaluated.

3.4 Evaluation of conservation treatments

Repair or interventive conservation of plastics is very underdeveloped and will be addressed in this project. Some exploration on consolidation processes using in situ gamma ray polymerization will be investigated for very fragile artefacts (such as polyurethane foam) along with coatings on objects that require a protective layer. Almost all plastic artworks need surface cleaning during their useful lifetime. However, many plastics are highly sensitive, especially when deteriorated, to solvents including water. Inappropriate treatments may result in irreversible damage. This project will evaluate mechanical, aqueous and non-aqueous cleaning techniques for their effectiveness at removing dust and their long term effects on stability. All the data and knowledge gathered will be discussed in order to assess risk and define strategy for conservation. From these results, a strategy for exhibiting, storing, documenting and cleaning plastics objects in museum will be established.

4. Acknowledgement

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THE MICROCLIMATE IN THE LANCISIANA LIBRARY IN ROME

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Abstract
The Lancisiana Library is one of the most important historical libraries of medical science in Italy. In March 2003 serious plaster detachments in frescoes occurred in the vault of the Library main Hall (hereafter simply named Library Hall) revealing the urgency of structural restoration works for the building. The unexpected emergency and the consequent need to move the full heritage to a new site, required to rapidly get at a detailed picture of the Library microclimate to be assumed as a reference in establishing suitable conditions for the future preservation environments. The microclimate analysis of the Library Hall was based on the internal thermo-hygrometric existing data and on the data recorded outside by a weather station located nearby the building. At the same time, a measurements campaign started in the so called Warehouse Hall, located in the same building, where the heritage had been moved in. Finally a new Conservation Hall, adjacent to the Main one, has been recently restored in order to hold, when ready, part of the collection. Consequently, its microclimate is presently studied. In this work, we present some results from the performed microclimate analysis that can aid to develop suitable environmental conditions in the Library Hall and in the contiguous new Conservation Hall.

1. Introduction

The Lancisiana Library at the present is one of the most important and ancient cultural institutions in activity in Rome. It is located in the Monumental Complex of "Santo Spirito in Saxia", near Vatican City. This complex is situated in an area occupied in the Roman age by the Villa of Agrippina Major (Germanico's wife and Caligola's mother) and since 727 A.D. by the "Schola Saxonum": the refuge centre for pilgrims arriving in Rome to visit the tomb of the Prince of the Apostles. The complex, destroyed by fire and pillaging, was rebuilt according to the will of Pope Innocenzo III in 1198 who decided to use it for helping the sick as well as a shelter of the poor and the "proietti" (babies abandoned at birth by their mothers). The Hospital of Santo Spirito housed, fed and protected homeless, pregnant, orphans, sinners and the victims of persecution, and it has always benefited of the lavish attention of all Popes. Moreover, the presence of the Anatomical Theatre attracted artists and scientists, among whom we remember Michelangelo and Leonardo da Vinci, who chose to frequent the theatre for their studies of anatomy. The Library was founded in the years 1711-1714 by Giovanni Maria Lancisi (1654-1720), the doctor of Pope Innocenzo XI and illustrious scholar, who made of it the heart of his scheme for the advancement of scientific culture. Opened at the presence of Pope Clemente XI, it includes two large rooms: the first one is formed by an atrium and a vestibule, the second one is the original nucleus of the Library and has sixteen wooden shelves (ordered by Lancisi himself).[1] During the XX century the Library was almost abandoned, before a new opening, in the year 2000, with extended gratitude from the international scientific community. The Library holds about 20000 books – among which there are 375 manuscripts – and a precious collection of ancient scientific instruments. Unfortunately, in March 2003, serious plaster detachments in frescoes occurred in the vault of the Library Hall, revealing the urgency of structural restoration works for the ancient building. The unexpected emergency and the consequent need to move the full heritage to a new site, required to give quick answers to numerous questions. Among these there was the microclimate analysis of the Library Hall and, as so as, of the Warehouse Hall, located in the same building, where the heritage had been moved in. The new environment has been continuously monitored and characterized in order to make its microclimate homogeneous and suitable for the books. Finally a new Conservation Hall, adjacent to the Main one, has been recently restored in order to hold, when ready, part of the collection (manuscripts and rare books). Consequently, its microclimate is presently studied.

2. The microclimate

The indoor microclimate study concerns the three halls where the library heritage has been, is and will be stored. We measured the temperature (*T*) and the relative humidity (*RH*) whose values are in some cases reported together with those of the calculated mixing ratio (*MR*), derived by mean of the Magnus-Tetens empirical expression of the saturation pressure.[2,3] Before the transfer of the heritage, the thermo-hygrometric data have been collected only inside the Library Hall, integrated with the data recorded outside by a weather station located nearby the building. During the following measurements campaigns, after the transfer in the Warehouse Hall, outdoor data have been also recorded, in order to characterize the building thermo-hygrometric response to the external climatic changes. Finally, an heating, ventilating and air conditioning (HVAC) system operates in the Conservation Hall and twelve thermo-hygrometric sensors, integrated in the *boiserie*, are connected by hidden cables to a data logger in order to allow a continuous monitoring.

The Library Hall

When the first measurement session started, in July 2000, the Library had just been re-opened to public access. In this microclimate monitoring, the thermo-hygrometric data were recorded by two sensors at two different levels and only inside the hall (Figure 1).

Figure 1: Library Hall. Position of the two sensors at 1 m (blue circle) and 5 m (green circle) above the floor.

The unexpected emergency and the consequent need to move the full heritage to a new site, required to rapidly get at a detailed picture of the Library microclimate and so the recorded data have been integrated and compared with those recorded

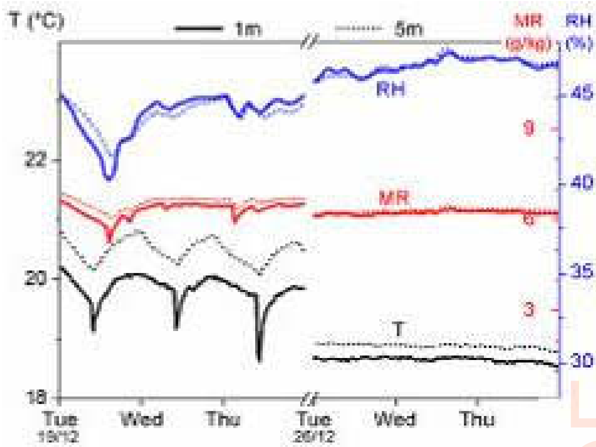

Figure 2: Library Hall. Temperature (T), Relative Humidity (RH) and Mixing Ration (MR) behaviour in December 2000, over three days of two consecutive weeks, before and after Christmas with the radiators on and off respectively.

Figure 3: Warehouse Hall. Books arrangement on the shelves.

outside the Library by the weather station "Osservatorio Metereologico del Collegio Romano", located nearby the Monumental Complex of "Santo Spirito in Saxia" (about 300 meters far from it). The microclimate inside the Library Hall was essentially due to the outside climate and to the effect of the radiators switched on in winter. A direct impact of people on its microclimate was not considerable, because without considering the presence of the librarian, in his office contiguous to the hall, very few persons used to frequent the Library. Anyhow it is evident that the opening or closing hours of the Library, and the consequent working activity in the structure, effected the inside microclimate daily cycles. The analysis of compared data have shown that the building well smoothes the outdoor temperature fast fluctuations. The first thermo-hygrometric analysis, carried out in summer time inside the hall, showed suitable stable *RH* values – ranging from 40% to 50% – that didn't seem to be influenced by the outside ones, but rather high temperature values very close, on average, to 30 °C. Moreover the *RH* is mainly linked to *T*, as supported by *MR* analysis, and it is slightly affected by mixing phenomena with external air.[4] Previously, the heating system had been working in winter and the combined impact of its effect and those of frequentation on the inside microclimate is shown by the chart of Figure 2. In the week before Christmas, every morning the radiators are switched on and, at the opening, cold air from outside spreads at floor level. Consequently, the diagram shows an initial sharp decrease in *T* and *RH* at the floor level, being the external air colder and drier than the internal one, while during the following hours (with the door closed) *T* values increase, due to the radiators action, and cool down again in the evening, when the heating system is switched off. In the week after Christmas, being the Library closed and the heating system off, the microclimate is characterized by stable thermo-hygrometric values – the *T* values at different levels stably differ of about 0.2 °C, showing a static vertical thermal gradient inside the hall – suitable for book preservation purposes.[5]

The Warehouse Hall

The indoor Warehouse Hall microclimate is quite stable – being the room always closed – and it is only dependent from the outdoor climate changes, because there are no radiators. Since the transfer of library heritage to this new site in the same building (Figure 3), the Warehouse Hall has been closed to the public and, at present, its frequentation is limited to the weekly presence of a cleaner and the occasional visits of the librarian. This situation makes the microclimate not much different from the typical one of a warehouse, where the impact of the frequentation can be usually neglected. More it is located on the ground floor level, with only an external wall on inner court surrounded by a porch and such conditions generate very stable *T* and *RH* values. Figure 4 shows the temperature changes, measured over a three days period, in March 2005, inside and outside the Warehouse Hall. The curves show that the daily variations of the internal temperature are only about one tenth of the external ones, due to the good thermal insulation conditions of the hall. It is worth to note that a similar situation is observed also in other seasons, so that *T* and *RH* values slowly vary in the ranges 18 °C-26 °C and 40%-55% respectively throughout the year[4].

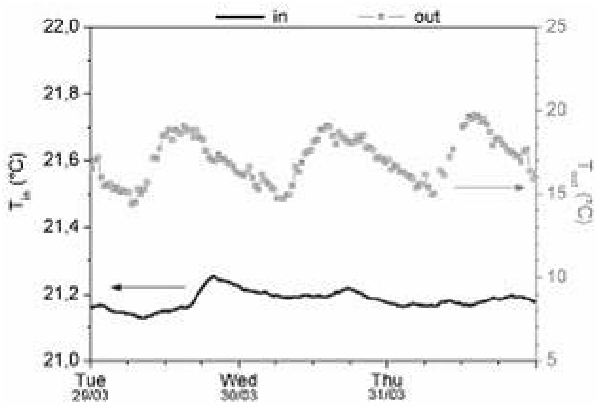

Figure 4: Warehouse Hall. Indoor (T_{in}) and outdoor (T_{out}) temperature measured in March 2005.

The Conservation Hall

The Conservation Hall is located on the first floor in the same building, having one external wall with a large window facing east. The north wall is contiguous to the Library Hall, where the above mentioned restoration works are now in progress. The remaining sides are adjacent to administration offices. Before its new destination, the hall had been used as a small warehouse and then as an office. After the unexpected emergency, it has been planned to restructure this hall, to make it suitable for the conservation and consultation of manuscripts and rare books of the Library. The effort is addressed to meet two fundamental, but opposite, demands: to conserve precious books in a suitable environment and to offer a comfortable place for the daily activity of the library. The project is clearly ambitious, but the first results seem to be close to initial target. The principal difficulty was to adapt the dimensions of the hall to its new multi-functions. For this reason, during the project a special attention was paid to the shelves, the materials and the new arrangement of the hall. As shown in Figure 5, the indoor architecture is modern, but with refined guide-lines among the sixteenth century Library Hall and the new adjacent hall. In the hall there are four working-stations, each with a table and a personal computer; in the centre, a table hosting eight working-stations can disappear below the floor, when unnecessary. Moreover, for the correct use of this hall, the lighting system has been divided on three independent areas and LED (Light Emitting Diode) are used as lighting source.

Figure 5: Conservation Hall. Indoor view during and after the works.

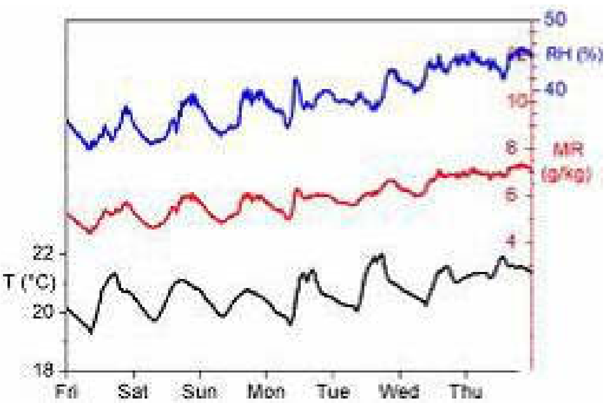

Figure 6: Conservation Hall. Temperature (T), Relative Humidity (RH) and Mixing Ratio (MR) behaviour from 22 to 29 February 2008.

For the security, this new Conservation Hall presents an anti-fire system and an anti-theft system, specific for books (RF-Id). After this general description of the hall, it is important to remark that a HVAC system is operating, equipped with particulate filters and gaseous contamination control devices, in order to prevent the negative effects of the off-gassing of the new construction materials[6]. To allow a continuous microclimate monitoring, twelve thermo-hygrometric sensors have been integrated in the *boiserie* at two different levels, 2 and 5 m above the floor respectively. All the sensors are connected by hidden cables to a data logger allowing for continuous monitoring. When required, the sensors can also be moved from their housing onto the surrounding shelves, in order to enable a single point monitoring of the whole perimeter. All the data are recorded on the relative database, in a Library server. For a professional management of this HVAC system, there is a sophisticated SCADA (Supervisory Control and Data Acquisition), specific software for the control and setting of the system. In the future, part of the library heritage (manuscripts and rare books) will be moved into this hall. Before that time, the microclimate must therefore be carefully studied and characterized. In particular, tests on the HVAC efficiency are currently running. In Figure 6, the thermo-hygrometric curves, extended on one week scale, are reported. They show daily *T* and *RH* fluctuations having coincident maxima and minima, due to HVAC system. At present, new settings are carried out on the system in order to provide the required stability of the thermo-hygrometric parameters.[7-9] The values of *T* and *RH* will be fixed around 20 °C and 45% respectively.

3. Conclusions

The microclimate inside the halls of the Lancisiana Library has been studied. The data analysis enabled to characterize the environmental conditions of the Library Hall before the heritage transfer and set compatible microclimate inside the temporary Warehouse Hall, where the books are now temporary held. In the new Conservation Hall, where manuscripts and rare books will be moved into, a HVAC system and a structured network of sensors operate providing thermo-hygrometric data needed to set a suitable preservation microclimate in the future.

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DESALINATION OF MASONRY STRUCTURES. FINE TUNING OF POULTICES TO SUBSTRATE PROPERTIES

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Salt crystallization is one of the most recurrent causes of damage in ancient buildings. Historic monuments are, more often than new constructions, threatened by salt decay because of the large amount of salts accumulated in the course of time, the frequent lack of maintenance, as well as by the occurrence of calamities in the past. Limiting the salt decay is therefore necessary for the preservation of our architectural heritage.

In order to have salt damage, both salt and moisture need to be present. This implies that removing one of these two factors will stop the development of salt decay. In some cases, as for example in situations where no salt supply is present anymore and the moisture source can not be easily removed, (partial) desalination of the masonry can offer a solution to slow down the development of salt damage and preserve the original materials. While desalination of movable objects following the bath method is a quite consolidated practice which gives generally satisfactory results, desalination of masonry structures is still a trial-error practice. Different desalination materials and methods are used, sometimes with questionable results, as shown by a recent review of this subject.[1] Better understanding of the desalination process is therefore needed in order to give a scientific base for the choice of the most suitable desalination material and method for each situation. In order to reach this aim the EC project DESALINATION (Project n. 022714 - Assessment of Desalination Mortars and Poultices for Historic Masonry), has been set up.

One of the objectives of the DESALINATION project is the development of a modular system of poultices, which can be adapted, i.e. fine-tuned to different types of substrates. Starting point is to make use of advection, i.e. the transport of salt solution due to differences in capillary pressures. This transport mechanism is faster than diffusion and the application on immovable objects is relatively easy. The principle of the foreseen modular desalination system implies the use of poultices whose pore system is adapted to the pore system of the salt laden substrate. In this way the efficiency of desalination can be optimized. In order to improve salt extraction, a poultice working by advection should have smaller pores than the substrate: in this case the salt solution transport will occur from the substrate to the poultice and salt accumulation in the poultice will result. Nevertheless, it is convenient that the pores of the poultice are not too small, otherwise advection would be slowed down with the risk of diffusion of the salt back into the substrate.

At the time, a first step in the development of the modular system has been taken by designing two component-poultices (kaolin and sand) with different pore sizes. A range in the pore sizes was obtained by varying the kaolin/sand ratio and the grain size distribution of the sand (Table 1). The pore size distribution of the poultices was determined by Mercury Intrusion Porosimetry (MIP) on poultices prepared and dried on a substrate. Besides, thin sections of the poultices were prepared and observed by Polarized Fluorescence Microscopy (PFM); point counting was performed to further evaluate the porosity.

The results of the MIP show that the total porosity of the poultices varies between 27 and 33% vol. The presence of the kaolin results in pores in the range of 0.3 μm, while the intergranular pores (due to the sand) vary, depending on the kaolin/sand ratio and the grain size of the sand, between 2 and 200 μm. It has been observed that increasing the kaolin amount leads to a higher amount of small (0.3 μm) pores (Figure 1a), while increasing the grain size of the sand shift the porosity towards coarser pores (Figure 1b).

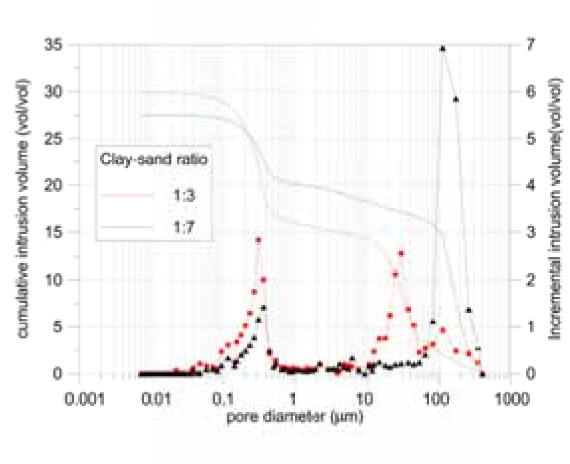
For some of the developed poultices, the salt and moisture transport between substrate and poultice system was studied by Nuclear Magnetic Resonance (NMR). Poultices having different pore size distribution were applied on a fired clay brick (main pore size = 7 μm) and on Bentheim sandstone (main pore size = 20 μm) in order to verify the hypothesized behaviour of the substrate/poultice combination. The NMR results confirm that an efficient moisture transport from a substrate saturated with salt solution to the poultice occurs when the poultice has pores smaller than the one of the substrate. The larger the amount of these pores, the more effective is the moisture transport. Besides, the NMR pointed out the risk of the use of clay based poultices for the desalination of very coarse substrates: the clay may occlude the pores and slow down salt extraction (Figure 2). Pilot desalination tests, performed using different poultices on a brick substrate, confirm the hypotheses at the basis of the model: poultices having pores smaller than the ones of the substrate assure the most effective salt solution transport from the substrate to the poultice. However, these experiments have pointed out that, if the substrate is not pre-wetted, poultices having only pores smaller than the pores of the substrate do not bring sufficient water in the substrate to dissolve the salt and activate desalination. In this case pre-wetting is necessary.

In a second phase, the research has been extended to 3 components poultices: cellulose/clay/sand mixes were studied and the effect of cellulose on the porosity and the pore sizes was assessed. The use of cellulose leads to a clear peak in the pore-

Table 1: Composition of the kaolin/sand poultices

poultice	kaolin: sand ratio by weight	grain size sand fraction (mm)	water content by weight
13S	1 : 3	0.08-0.5	0.22
13L		0.5-1	0.22
15S	1 : 5	0.08-0.5	0.2
15L		0.5-1	0.2
17S	1 : 7	0.08-0.5	0.21
17L		0.5-1	0.16

size distribution around 15 µm. These results obtained by MIP were confirmed by the study of the thin section by PFM.



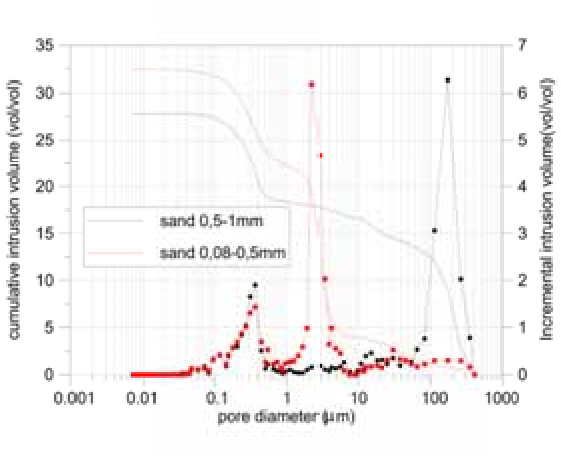


Figure 1: a: (up): Pore size distribution measured by Mercury Intrusion Porosimeter (MIP) of 1:3 and 1:7 clay/sand poultices with 0.5-1 mm sand fraction
b: (down): Pore size distribution measured by Mercury Intrusion Porosimeter (MIP) of two 1:5 clay/sand poultices with different sand fractions

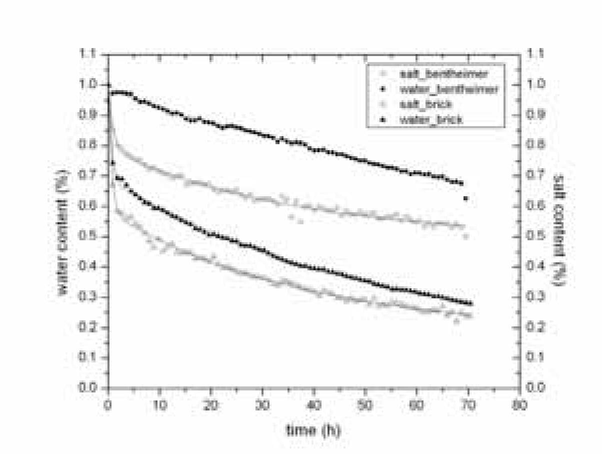


Figure 2: Total water and salt content presents in the brick and in Bentheim sandstone as a function of the drying time, during a desalination experiment. The results indicate that water flow and salt extraction are slower in Bentheim sandstone than in the brick: this may be due to kaolin particles partially occluding the coarse pores of the sandstone.

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DAMAGE ASSESSMENT OF ARCHIVAL PARCHMENT BY SCANNING PROBE MICROSCOPY, SPECTROSCOPIC, AND THERMAL TECHNIQUES

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Parchment in the form of archival material bears the testimony of recorded cultural history and this necessitates its preservation. To assist in this process it is important to develop methods of damage assessment which are preferably non-invasive and non-destructive, and which can provide information on the physico-chemical state of collagen, the main component of parchment. Within the EC-funded project "Improved Damage Assessment of Parchment" (IDAP) atomic force microscopy (AFM), micro-thermal analysis (µ-TA), and controlled environment dynamic mechanical analysis (DMA) were applied for the first time to accelerated aged and historical parchment samples.[1] The rationale for using a multi-parameter approach for damage assessment is based on the fact that collagen has a hierarchical structure. The main objective is to obtain information on damage at different structural levels in collagen. If a relationship between damage at the different levels can be detected then reliable non-invasive damage assessment methods would be established. Methods were developed for quantification of resulting data and a ranking in terms of recorded change in the historical samples compared to unaged samples was made.[2] The resulting data were compared with damage estimated from thermogravimetric and spectroscopic techniques (attenuated total reflection ATR-FTIR and ^{13}C solid state NMR). The mechanical response of historical parchment to programmed RH was also recorded as this is of intrinsic interest since moisture is used in the conservation treatment of parchment. Moreover conditions of controlled relative humidity are recommended for its long term preservation, as there is evidence that the state of hydration of the collagen polymer contributes to its stability.[3] For these measurements controlled environment DMA (Dynamic Mechanical Analysis) was used and the pre-dried samples were exposed to an increase in RH from 20-80% at a controlled rate (1%/min). The parameter selected for damage assessment by DMA was the rate of initial response to RH change within the first hour of testing.1 The most damaged sample, thermally denatured parchment, was found to give negligible response to RH and the unaged samples generally gave the maximum values. In the previous "Microanalysis of Parchment" (MAP) project other markers for collagen damage in terms of gelatinisation and cross-linking were established from measurement of viscoelasticity and hydrothermal stability of parchment using other modes of DMA measurement.[4] In the IDAP project samples ranked by DMA were then investigated by AFM and (µ-TA) and ATR/FTIR . ATR/FTIR showed that thermally denatured parchment tested by DMA showed a significant shift in Amide 1 and Amide II peaks (Figure 1). The corresponding atomic force microscopy images (Figure 2) show that the thermally denatured sample has a significantly reduced value for the periodic D spacing in collagen.

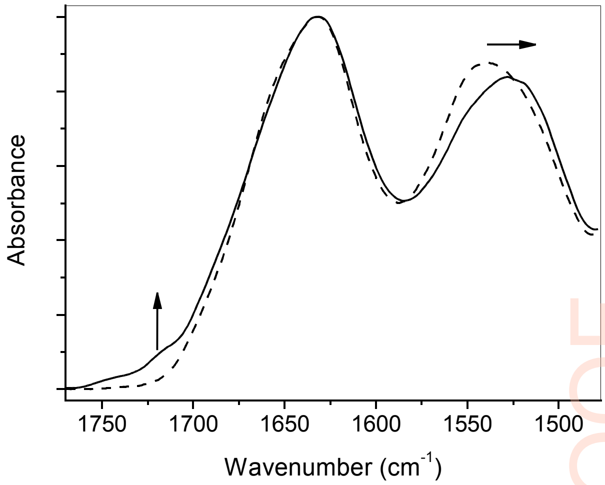

Figure 1: ATR/FTIR spectra (1800-1400 cm-1) of unaged parchment (full line) and thermally denatured parchment (dashed). Peaks correspond to Amide I-II.

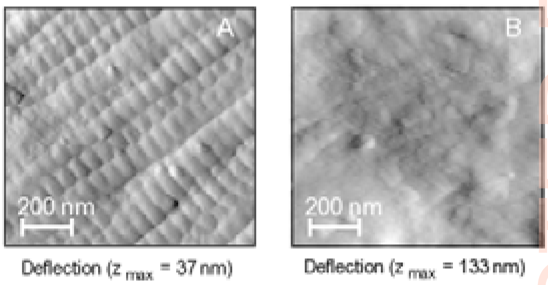

Figure 2: AFM images of unaged parchment (left) and thermally denatured parchment (right).

In ATR-FTIR studies of accelerated aged samples (SO_2) aged samples (4-16 weeks, 50 ppm at 50% RH) there was no noticeable shift in amide II but rather a reduction in the amide II peak which decreases already after the first 4 weeks of exposure. Mechanical analysis of the sample exposed for 4 weeks to SO_2 showed a decreased response to linearly increasing RH with respect to the control sample. This occurred also in the case of the thermally denatured sample as mentioned above where the effect was more severe and there was negligible response. AFM studies were also performed of these samples and this showed the effect of progressively increasing doses of SO_2. Exposure resulted in a progressive loss of D-banding in the collagen which reached a maximum in the 16 week exposed sample where there is complete loss of structure and the formation of a glass-like surface (Figure 3). Studies by Micro thermal analysis (μ-TA) also showed that alterations in the sample had occurred. Figure 4 shows the first derivative of the thermal power dissipation curves as calculated from the μ-TA and also a broadening of the observed peak. Measurement of the peak area in the temperature range 300-400 °C showed a reduction of almost 50% compare to the control sample.[2]

Markers established from the studies of accelerated aged samples were then used to rank damage in archival samples. Differences in damage were observed in samples selected from different archives (National Archives, Scotland, School of Conservation and Royal Library, Copenhagen,Archivio di Stato Florence)1 and from within the same archive for samples where there were differences in lipid (determined from 13C solid state NMR and inorganic content (determined by Thermogravimetry), and whether they had been previously used as manuscripts or bookbindings. This correlated to some extent with data from other techniques.1 The database that has been obtained in IDAP makes it possible to validate the approach using scanning probe microscopy (AFM and μ-TA). Knowledge of the RH response can contribute to improved conservation treatment of parchment since humidification is used to treat historical parchment and to improved display and storage of parchment. Further work is in progress with samples in the context of the Piedmont region research project "Old Parchment, Evaluation, Restoration and Analysis" (OPERA).[5]

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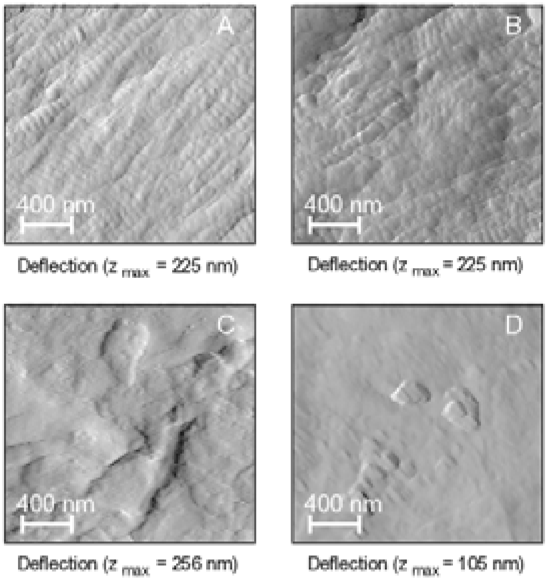

Figure 3: Clockwise from left : control, 2weeks, 4 weeks, 8 weeks and 16 weeks, SO_2 aged.

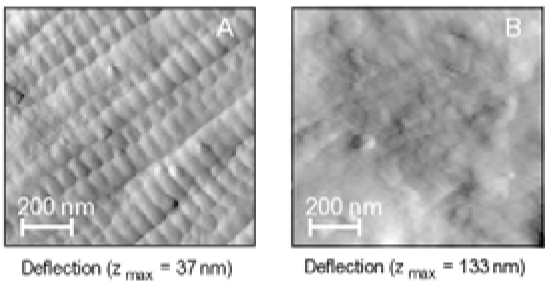

Figure 4: Micro-TA : First derivative of power curves for samples control (black), light aged CR05 (blue), and CR33 (red) treated 16 weeks with SO_2.

VERNACULAR BUILDING HERITAGE IN THE WESTERN BLACK SEA REGION IN TURKEY

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1. Introduction

There are three cities in the eastern part of Black Sea Region: Trabzon, Rize and Artvin. The vernacular architectural heritage of these cities has important value in terms of cultural heritage. This heritage has common characteristics because of the climate, topography and the usage of materials in the building construction. Thus, the architectural heritage of the region shows the perfect balance between the nature and human life. Nowadays, there is a need to understand the value of the vernacular architecture heritage in the region. The architecture is a response to functional requirements as well as environmental factors. Indeed, rural architectural of this region is a reflection of the cultural values of the society, behavioural patterns of the people and environmental factors from the past. The interiors of some of the big houses have significant ornamentation on their ceilings, doors and some furniture.

The aim of this study is to understand and appreciate this heritage through systematic surveying and documentation. Further aims are the establishment of an architectural typology based on the plan, façade and site plan, and materials use, with the goal to develop guidelines for new buildings in the region.

The research method is based on data collection on site and in the literature, about each city, and an analysis of this information. The historical development of this heritage has set up a background to this research. The results are presented in the form of pictures and drawings. This helps local people to develop consciousness about the importance of the regional heritage in terms of their past, present and future life. It is also very important to keep alive the local architectural identity. Architectural heritage is different from elsewhere around Turkey as well as in the world.

2. Regional characteristics

Topography and climate: climate of the eastern Black Sea region is mild and humid influenced by the sea. The mountain ranges which lie parallel to the coast also have an impact on the climate. The temperature does not reach extremes because of the effect the sea. The moisture level is over average due to the rain and due to the sea. Therefore, vegetation of the region is diverse and very dense. There are many endemic plants and special vegetation areas which are under protection.

3. Vernacular architecture

3.1 Building materials

Wood and stone are the major and common traditional building materials. Wood has been used in the past when there were enough resources in the natural local forests. The stone was commonly used in the villages where forests were far away. These two materials have been used together in different construction techniques. The local builders of the region reached perfection by establishing a regional architectural tradition using wood and stone in a very skilful way for a long time. The identity of regional vernacular architectural is distinct and reflects perfect utilization of wood and stone material both in the interior and in the exterior of various types of buildings structures (Figures 1-3).

Figure 1: Some examples of rural houses in Trabzon (Ozen, H.).

3.2. Timber

Timber as a raw material is produced from very hard wood. The main characteristic of wood is high stiffness in terms of formation. Wooden materials have high resistance to moisture and heat, and are durable. The varieties used are chestnut, ash tree, elm, beech and spruce. In addition, pine tree is also common. Wood is used for walls (bearing, strut, filler, partition walls and coating), floors (Beam and coating), frames (doors, windows and balcony balustrades), roofs (all roof structures and covers), furniture (every kind of furniture). The common usage in building construction: wood: roofs, stone and wood: living space walls, stone: basement walls, stone and soil: ground floors and foundations. The wall systems of houses are built from wood except for the ground floor (basement) walls.

Figure 2: Some examples of rural houses in Rize (Ozen, H.).

Figure 3. Some examples of rural houses in Artvin (Ozen, H.).

3.3. Stone

Stone is an important building material in the region because it is obtained easily in nearby streams and stone quarries. It is a very appropriate material in terms of providing a good transition with organic materials (wood) and prevents a high level of ground humidity. Limestone, andasite and basalts are commonly used stone types.

There are different buildings and structures in the region apart from houses: storage houses (serender), bridges, water mills and small village mosques (Figure 4). Especially the storage house type that is entirely made from wood, named "serender", has unique architectural characters in terms of structure and ornamentation.

Today, the lack of systematic documentation of this heritage and abandonment of the buildings due to migration from the villages to cities results in rapid destruction, demolishing and decay. Therefore, preservation of this tangible heritage is an important issue in the region in terms of their heritage value for all humankind. Because of the characteristics of architecture and the settlements which reflect the use of regional materials and technology in combination with the experience of local builders. There are various types of building types in the region such as houses, wooden storage buildings, barns, water mills, wooden mosques and stone arched bridges.

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Figure 4: Examples of different types of buildings and structures in the region (Ozen, H.).

NEW FINANCE MODELS FOR THE BUILT CULTURAL HERITAGE

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1. Introduction

The extended definition of culture heritage applicable today, reflected in an augment of legal protection, has undoubtedly increased the number of indispensible built heritage along with prevailing armed conflicts, nature catastrophes, but also the growing concern of the global legacy. For this reason the need to develop new financial solutions has become imperative in order to correspond to the persistent expanding up-keep requests. Finance supports available, developed in the 20th Century, characterized by a spontaneous growth of benevolence based on an obsolete economical approach is however in need of upgrading. With the aim to develop more sustainable solutions to cover the financial deficit requirement of the legacy, this thesis investigates conditions and the effects of private and public financial support as a comparative study of 27 conservation projects from nine countries active in 1990-2004. Further more are the characteristic means of financial support provided by funds and NPO´s analysed and finally alternative fiscal solutions reviewed conceivably adaptable for the built heritage, represented by the investment market and lottery funds. Since the built legacy symbolize more than artefacts the political dimensions of maintenance is also discussed and how diverse finance options have the ability to activate the personal commitment.

Previous overview studies, Pickard & Pickerill[1,2] emphasized the need to categorise the financial supports and measures available, but failed to scrutinise their actual effects in practice. This study aims to supplement previous findings since the inductive analysis take-off at the building sights evaluating the actual consequences of funding. Trupianos[3] focused on the nature and origin of fiscal support for heritage and highlighted the advantages in engaging both public and private sectors in Italy for an integrated funding, so called corporatisation. The importance of creating clear incentives for public and private financers to act is further discussed in this thesis along with the wider definition of finance as a political catalyst.

2. Methods

This thesis has been developed over a time period of 11 years, but represents three work phases; 1997-2000, 2004 and 2008.

The financial model analyse is based on the outcomes of following four surveys:

Survey I: A process analysis of building conservation intrinsic factors; object value, team, legislation, finance and outcome effects. A field study of 15 conservation projects in progress (1990-2000) from Denmark, Germany, Lithuania, Poland and Sweden. Licentiate study.[4]

Survey II: A comparative study of the financial structures in twelve restoration projects from Denmark, Germany, Great Britain, Norway, Finland and Sweden from the time period of 2000-2004.

Survey III: A sequential study of the financial support & methods provided by the private sector accessible worldwide for built heritage. A study analysis of the equivalent public support & means in Denmark, Germany, Great Britain, Norway, Finland and Sweden.

Survey IV: An investigation of alternative fiscal institutions.

2.1 Survey I; 1990-2000

The purpose was to establish a legible theoretical model of the practical conservation process through conservation projects in progress as a frame work for the finance study. The inductive analysis included five countries each representing a unique building conservation tradition which gave wide spectrum. The three building categories; manor house, church and a vernacular architecture, three objects from each country, united the case studies that all were in progress between 1990 and 2000. During this decade occurred one of the major changes in Europe which began with the fall of Berlin wall in 1989. Since the work process of building conservation has a variable result more dependent of the time when being realised than anything else, the evaluation method applied was inspired by M. Scriven 1972[5] model of *Goal-Free-Evaluation*. The method implies the use of both qualitative and quantitative analyse methods and enables the evaluator to maintain objectivity. This approach is signified by the data gathered directly on the process effects, and its effectiveness, without focusing on stated goals for the actual process. In the licentiate study the qualitative facts about the process were obtained through interviews with a defined group of people active in the projects, eight per project to ensure the validity, in all 113 respondents. The answers represented by the majority opinion, were finally transformed into more comprehensible graphical diagrams and became quantitative figures on a table were structural patterns of the intrinsic factors; *object value, team, legislation* and *finance* could be traced and analysed. The study showed, for example, that object value had the most influence over the conservation process and objects with high legislative protection frequently were conserved through more drastic and modern methods and the listing actually had a negative effect. Spirit of time and conservation tradition was much more decisive for the treatments chosen than the actual maintenance requirement of the building. The factor Finance was signified by three distinct sources; public-, private/public- and private means but only two effects could be traced in the conservation processes. For public funding the object were manor houses, restoration teams; experts, the financial flow; uneven with interruptions and the project time; 12 years in average. Significant for project funded by private means (or public in combination with private funding) the objects could be all three categories, restoration team; no experts, the financial flow; uneven with interruptions but also even/more intense and the project time; 6 years in average.

2.2 Survey II; 2000-2004

The results achieved in the first survey were transformed in the follow-up research project focusing on the finance factor alone that holds a unique position in the work process. Unlike the other three factors finance is independent of nationalistic and political boundaries. This contributes to make finance studies general and relevant for any country. In this second phase a more detailed study was intended of what effect and impact different financial sources, public and private, might have on building conservation by studying how the roles of the actors and their involvement might be affected. By selecting conservation projects from Denmark, Germany, Great Britain representing private financial tradition for conservation, equivalent projects were selected from Norway, Finland and Sweden all exemplifying public funding of building conservation.

The research design was a redevelopment of the methods already used in the licentiate study. The qualitative facts from interviews were again transformed into quantitative and objective feasible circle diagrams to reduce the interpreters subjective influence on the results, all concealed in the six segments of the circle, equivalent to the number of answers available per question for the respondent. Each segment was given a number, from one to six, in clockwise order that represented the answers or categories to facilitate the interpretation. Through the questions the "cast list" of following five actors involvement; donor, driver, recipient, distributor and controller could be measured; The initial respondents interviewed in the study from the countries were employees at the national board of antiquities in the countries and they also made suggestions of conservation projects suitable for the study. Two renovating projects were selected per country; one represented the highest financed conservation project and the other one the lowest financed, all in progress during 2000-2004. To maintain the validity on descriptions of the building processes, the questions were to be answered by three different persons each representing one defined role. The three interview parties were *State authority* (SA), *Private financier* (PF) and *Recipient/ owner* (RO). Six interviews were held per country and it added up to a total of 36 interviews carried out during 2004.

One of the most obvious effects from the survey was the distinction of building categories chosen in the two groups were manor houses, churches and vernacular architecture were representative for financed by private means. Projects with public means were more limited signified primarily by early industrial building such as mills, power- and radio stations and cellars. This effect could be a result of a deliberate choice from the financiers and relate to the dominating public funding of castle in the previous study. A limitation of financial source might reduce the multitude of heritage. Finally the cast list (donor, driver, recipient, distributor and controller) for private funded project showed that four out of five roles were casted by different private groups and by the public funded the limitation of involvement was distinct, were four out of five roles were casted by state or authorities.

2.3 Survey III; 2008

The sequential study of private and public financial support and methods were compiled by facts and figures retried from publication, interviews and the Webb.

2.4 Survey IV; 2008

An investigation of alternative fiscal institutions is primarily a litterateur study of relevant research papers from the filed of economy, literature but also interviews with established NPO ´s.

3. Results

The preliminary results show that to succeed in retrieving sufficient means for the increasing need, the legacy has to be marketed for the prospective financier in accordance to antiques or visual arts. By promoting the built heritage as an investment, future function and historical monuments this activates new individuals and financial pluralism to prevail over single minded decisions. Insufficient public means works most efficient for administration costs and tax-exemption already proved in the UK.

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A DIFFERENT APPROACH TO STUDY MICROBIAL COLONIZED ASSETS AND ENVIRONMENTS

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Biodeterioration of works of art is a complex process involving a high number of microbial species in both inorganic and organic materials. Particularly, fungi and bacteria, widespread in biosphere environments, are the main microorganisms related to the deterioration of cultural assets[1,2] but, moreover, complex microbial communities may emit mixed aerosols into indoor air.[3] In order to identify the components of microbial populations in biofilm on works of art and dispersed in the aerosol, we carried out the investigation by microscopic and molecular biology analyses. Combining the results, we were able to describe an almost complete composition of microbial consortium, present in the biofilms and bioaerosol analysed. The sampling was performed by non-destructive procedures for works of art surfaces and by the gelatin membrane filter method, for bioaerosol. Actually we are developing in collaboration with BioNat – Italia (Palermo-SME) specific protocols for the extraction of genomic microbial DNA, directly sampled onto different surfaces and from gelatine membrane. Since microscopic analyses were consistent with molecular results, we conclude that the combination of these approaches improving our understanding of microbial communities thriving on cultural assets.

Depending on surface or aerosol, samples were collected by different strategies: (i) from surfaces, we performed sampling of biofilm by removing very small fragments or by Hybond-N positive charges membrane (Amersham), (ii) from aerosol, by Gelatin Membrane Filter (Sartorius). The microbial consortium was analysed by optical, SEM and CLS microscopy and the identification of microbial components was performed by molecular biology techniques.[4-6] We tested the efficiency of different protocols (our laboratory protocol and commercial kits) specific for total DNA extraction from biological samples and, in collaboration with BioNat-Italia, we set up a rapid and reliable method to extract microbial DNA from small aliquots (about 100 mg of sample) operating, in the preliminary phase, *in situ*.

Moreover, we extracted microbial DNA, directly, from the gelatine membrane filter, in order to analyse the presence of fungi and bacteria in the bioaerosol. The identification was performed by PCR amplification of target sequences, specific for fungi or bacteria, such as the ITS (Internal Transcribed Spacer) sequences of ribosomal genes.

The analysis of the nucleotide sequence of PCR amplification products and the comparison with the corresponding parts of microbial genomes, available in the EMBL-Germany and NIH-USA database, have allowed us to identify the main part of microbial species.

In the same case, samples carried out on surfaces by Hybond-N membrane (positive charged), were utilised to inoculate agar medium (Nutrient agar, Difco), for *in vitro* culture.

The characterization of microbial consortium and the related metabolic activities are essential for understanding if the conservation procedure is convenient, outlining the possible risk for both works of arts and operators/visitors. Finally, this work is included in a technology transfer program, from the Molecular Biology Laboratory of Department of Botanical Sciences and BioNat Italia.

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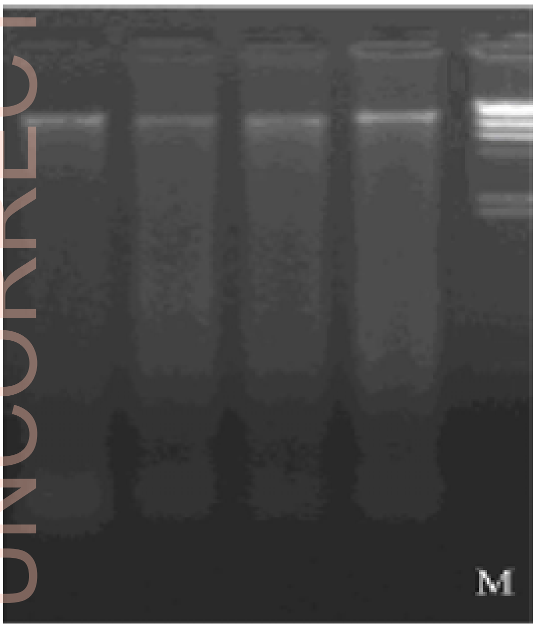

Figure 1: Microbial genomic DNA extracted by M.B.L.-BioNat protocol, from 100 mg of biofilm. M= molecular DNA marker.

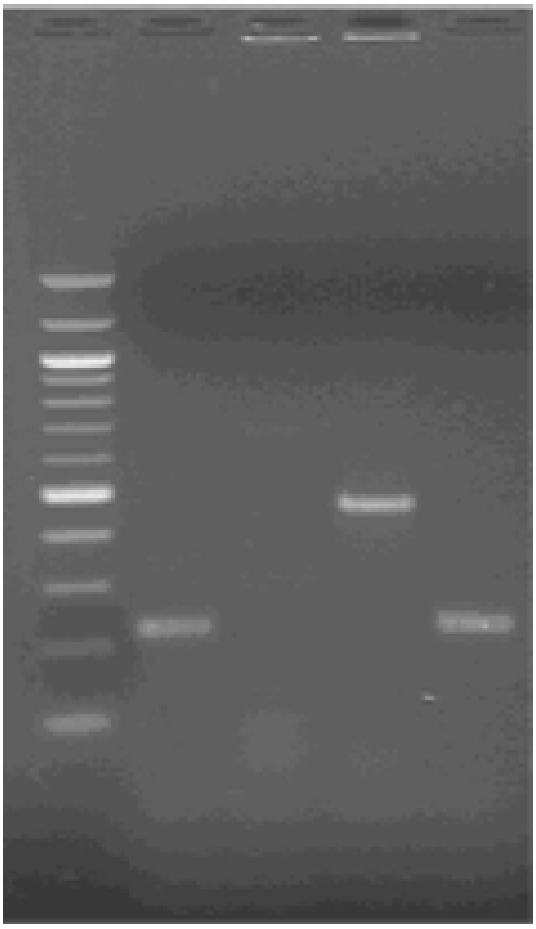

Figure 2: Aerosol analysis; ITS-PCR reactions, using as template microbial genomic DNA extracted from gelatine membrane. DNA fragments were resolved on 2% agarose gel.

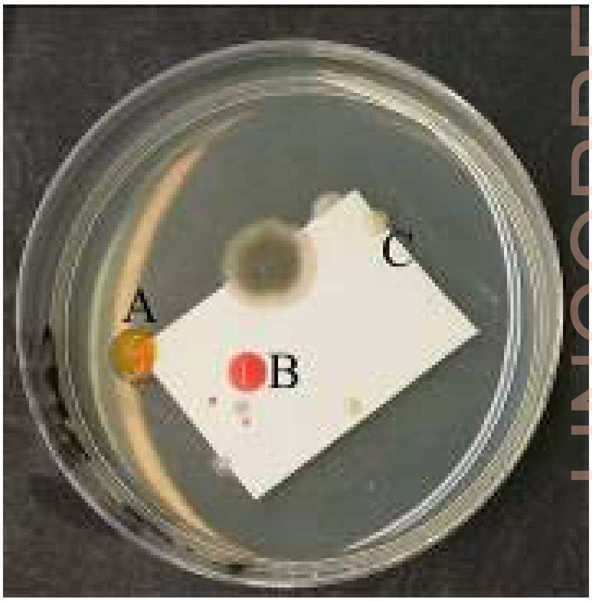

Figure 3: Microbial colonies grow on Nylon membrane fragments, in nutrient agar.

IS PROTECTION OF ARCHAEOLOGICAL HERITAGE - AS SEEN IN THE DISCOURSE OF MODERN MUSEOLOGY - IN CONFLICT WITH CONTEMPORARY ARCHAEOLOGICAL THEORY AND ETHICS?

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In the last decade, Slovenian archaeology achieved a great success at discovering and researching archaeological sites. During highway construction, a special strategic study was put forward regarding the prospectus and systematic archaeological research, which became an inseparable part of highway planning. The number of excavated sites increased enormously. But the number of professional publications remained insufficient and above all too slow – the reason may be in disproportionately developed digging strategy and technology.

The sites presented publicly and in situ are only a few. In most cases, after the digging procedures the material is taken from the sites to central depositories, and only after long years of scientific research it is ready for museum exhibitions.

The majority of Slovenian museums is following traditional museology within the scientific domain. Due to the absence of interpretation they remain disconnected from the public. The contact with the archaeological site is effaced, and its architectural remains are usually protected by the law of protection of archaeological heritage.

Because of the fast industrial development and countryside urbanization on one side, and because of the growth of legally protected archaeological sites on the other, we are faced with extensive monument demolitions and apparent legal inefficiency in heritage protection.

The lack of interest in archaeological research and our past ages cannot be the reason for great damage, which is testified by nearly all field archaeologists; after many years of museum practice I dare claim that public interest for our own past is ascending. Public claims for including the processes of heritage presentation into the environmental context have become increasingly louder, although they met no response from archaeological authorities. The locals are also not included in the processes of presentation and communication regarding moveable and immoveable archaeological heritage. No site is known to be interpreted by both – the research team and the local community. Very rarely, monument heritage services consider the wishes of local inhabitants when including the protected monument in the cultural context of the environment.

Local communities of touristically undeveloped countryside, wish their archaeological heritage to be kept in the regional centres. If the presentation in situ is not possible, they mostly like to keep the collection or a part of discovered objects to show them to the visitors.

As experienced in the western countries, cultural heritage can not be successfully protected only by the law. The legislative principles more or less reflect the rigid doctrine of Slovenian archaeological science towards the public, which has been structurally altered during transitional processes. Its needs and claims have altered as well, and cannot be fulfilled by old fashioned, strongly authoritative attitudes. Archaeology, by definition a researching science, interprets and protects the remains of the past ages and is exposed to modern social (scientific) streams – therefore it represents one of the important governmental means. It is by scientific interpretation of the past that the contemporary society can understand the role of a single nation. The way of governing of a certain nation had always been strongly depending on our knowledge of the past, i.e. the archaeological finds. It defines the present relation to the society or to the individual social groups, the level of democracy and the basic relation of the society towards the environment. Thus it defines the relation of the society to the remains of the past.

In theory, the principle of the cultural (archaeological) protection must be on three bases; on the balanced research and interpretative work of archaeological authorities, on collaboration of professionals with local inhabitants, and on team work of monumental services and museums. The active principles of including the locals into research processes, interpretation and presentation of archaeological heritage are of primary importance for understanding and experiencing material remains of the past as a part of contemporary cultural countryside. (It must be clear that we are speaking about the interpretation of archaeological processes and about cultural installation of material culture and the site). Only on this level of monument protection well conceptive legislation can be helpful.

Unfortunately, the unsuccessful model of protection by law associated with the Slovenian traditional model, oriented in science and in museum collections' protection. Our museums with their old-fashioned museological approach could not meet the needs of contemporary public claims. Their traditional scheme, based on protection and scientific approach of the preserved material, implicitly neglects communication and interpretation fields. So the museums are stepping aside from the active model, from the total protection of cultural heritage in the primary cultural contexts, including the protection of in situ presented site remains, and from local presentations of material culture. The traditional concept obstructs processes of interpretation and communication regarding the contents of archaeological heritage, and most importantly, prevents the population from experiencing the past ages as their own historical and cultural identity. Therefore, it prevents the past from being incorporated in the image of their cultural and economic environment and properly protected.

Contemporary museology is ready to answer the public claims by means of changed concepts in museum activities; although together with the eco-museum model it awakes strong resistance among the archaeologists and museum workers.

The aim of the article is to answer the often discussed questions about the protection of archaeological heritage in discourse of contemporary museology, corresponding to comprehension of modern archaeological theory and to demands of professional ethics.

STORAGE OF CULTURAL HERITAGE IN THE RUSSIAN STATE LIBRARY: OUR EXPERIENCE

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1. Introduction

One of the basic functions of libraries is storage of documents in its funds. The safety of funds is a complex problem which includes the creation and maintenance of suitable conditions, including physical safety of the documents and well-equipped storage areas.

Physical safety of the documents includes creation of optimum storage conditions, sanitary and hygienic control, regular routine inspections, regular hygienic clearing, restoration, education of readers how to care for the books, development of activities guaranteeing the safety of valuable and rare editions.

Good storage is about maintenance of funds in specially equipped rooms with the necessary levels of light, temperature, humidity, and creation of optimum physical - chemical and biological conditions.

On the other hand library buildings are also the cultural heritage of the country: the so called "Pashkov Dom" – an 18th century building where the first public library of Moscow was opened - is an unfading symbol of our capital alongside with the Kremlin and the Red Square. The Center of Oriental Literature is a 19th-century building, the former estate of the dukes Shahovskiys, the main building and storage are architectural monuments from the first half the 20th century. The conservators from Research Center for the Conservation of Documents of the Russian State Library try to do their best to store cultural heritage of the Russian people, both books and buildings. The first two buildings were adapted to store the documents and sometimes it is difficult to create favorable conditions for the safety of library funds and the building simultaneously. As times goes by there are significant changes in the design of the buildings. Conservators demand to create modern climate systems according to the IFLA recommendations and the National Standard.[1,2] So the reconstruction of storage areas and restoration of the building have been carried out at the same time.

In relation to this, the specialists of the Research Center for the Conservation of Documents of the Russian State Library had to watch not only the conditions of safety of funds, but also the safety of library buildings - monuments of architecture. For each of them, optimum climate parameters were chosen, both to store library documents and to store the buildings themselves.

We believe it is necessary to participate in all the processes of reconstruction and restoration of these buildings to take into account all possible factors promoting the optimum safety of materials and objects. We participated at different stages of the reconstruction.

2. Results and discussion

The group of specialists participating in this work consisted of biologists, climatologists and chemists. This group reviewed the buildings from the outside and the inside, researched the climate in it (temperature, humidity, light levels), carried out biological and chemical analyses. e.g., during the reconstruction of "Pashkov Dom" we were faced with a problem – leaking walls. To solve it, we communicated with the library administration and builders who reconstructed it. We made chemical and biological experiments, administration and builders were informed about their results.

When examining the outside of the reconstructed building we paid attention to cracks in walls, water stains, plaster descaling, windows, presence of nitrate. According to our remarks, the design and the arrangement of drainpipes and flutes for water drainage were changed. External defects of the building were also paid much attention to while examining the storage areas. When inspecting the inside of the storage areas, we looked at:
- At windows - inefficient closing of windows, presence of dust between frames, deformation of shutters, traces of water on window sills, cracks
- At walls and ceilings - cracks, plaster delamination, traces of water
- At floors – cracks.

We had to examine rooms adjacent to storage areas and the corridors used for transportation of documents. If necessary, photos of problem areas were taken. During the whole period of inspection, climate parameters were measured by thermo-hygrometers "IVA - 6A", "TKA", light-meter "Argus" and pH-meters.

Another example of participation of the conservators in the development of mutually acceptable decisions, both for the safety of funds and for the safety of buildings, is the optimization of humidity in the "Basic storage". As a result of reconstruction of this storage, natural air exchange in it was discontinued due to installation of new windows and creation of an artificial climate in the storage according to National Standards (humidity must be ca. 55%). After these actions the condensed water began accumulating between windows and in side-walls of the building as there was a lot of dead-air space. This phenomenon was also promoted by severe winter conditions. Taking into account the whole situation, the conservators decided to reduce the relative humidity of air to 40% without damage to the funds, which allowed stabilization of the situation.

Through the teamwork of builders, keepers and conservators, positive results were obtained, which positively affect the service conditions of historical buildings and safety of library funds.

We think the conservators should control all stages of reconstruction, since the drawing up of the project, to putting the object into commission.

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DEAD SEA SCROLLS: MATERIALS CHARACTERISATION BY MEANS OF IR-ERS, SYNCHROTRON BASED μ-FTIR SPECTROSCOPY, μ-XRF AND SEM

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The Dead Sea Scrolls (DSS) were discovered between 1947 and 1956 in the caves along the northwest coast of the Dead Sea[1]. The texts, of great historical significance, have experienced complicated and seldom accurately documented post discovery treatment. For their long-term preservation and provenance study the reconstruction of the post-discovery events including recognition of the treatment materials is of primary importance. Furthermore, presence of foreign organic material influences the reliability of radiocarbon dating. Thus, it would be highly desirable to devise an easy non-invasive method for identification of various contaminations present in the scrolls. The present study is focused on the physical and chemical characterisation of parchment surface by means of infra-red external reflection spectroscopy (IR-ERS) and synchrotron-based Fourier transformed infra-red microscopy (Synchrotron-μ-FTIR).

The available documentation on the scrolls has been collected into a data base that allows quick reference to the known treatment materials, photographs, experimental results and archaeological data. In short, the majority of the scrolls have been treated either for contrast enhancement or for conservation purposes[2]. In the former case castor oil and glycerine was usually applied. In the latter, PMMA adhesive and British Museum leather dressing have been used. To evaluate our ability of detecting these materials on the scrolls by means of non-invasive IR-ERS we conducted experiments on several modern parchment samples (MOD), each treated with one of the materials mentioned above. Using the Kramers-Kröning transformation (KKT) to simulate the reflectance in case of negligible roughness, and the Kubelka-Munk function to include the effect of surface roughness we obtained the pseudo-absorbance spectra needed to assign the spectral bands to specific functional groups or collective vibrations of the analysed material[3]. The spectra were then compared with those collected by conventional techniques such as FTIR in transmission and ATR-IR. In addition, we also used radiation in the Far-IR range (wavelengths from 14 to 200 microns), so called "Terahertz" range. In this range, most molecules display specific signatures, just like in the mid-IR, but the scattering effects are less important due to the longer wavelengths used. The results have shown that the complex optical reflectance spectra of parchment surface bear information on the presence of foreign compounds (waxes, polymers, oils, etc.), despite overlapping of their bands with those characteristic of collagen.

Another question of importance is presented by the fact that a large portion of the fragments has no secure documented archaeological provenance. Characterization of the surface might bear indication of the true place of the recovery. The Sy-μ-FT-IR measurements on fragments of the Dead Sea Scrolls allowed identification of collagen as well as foreign materials located on the surface (carbonates, silicates, oxalates etc.). Vibration analysis is complemented by x-ray fluorescence measurements with a mobile micro-XRF device and environmental scanning electron microscopy (ESEM).

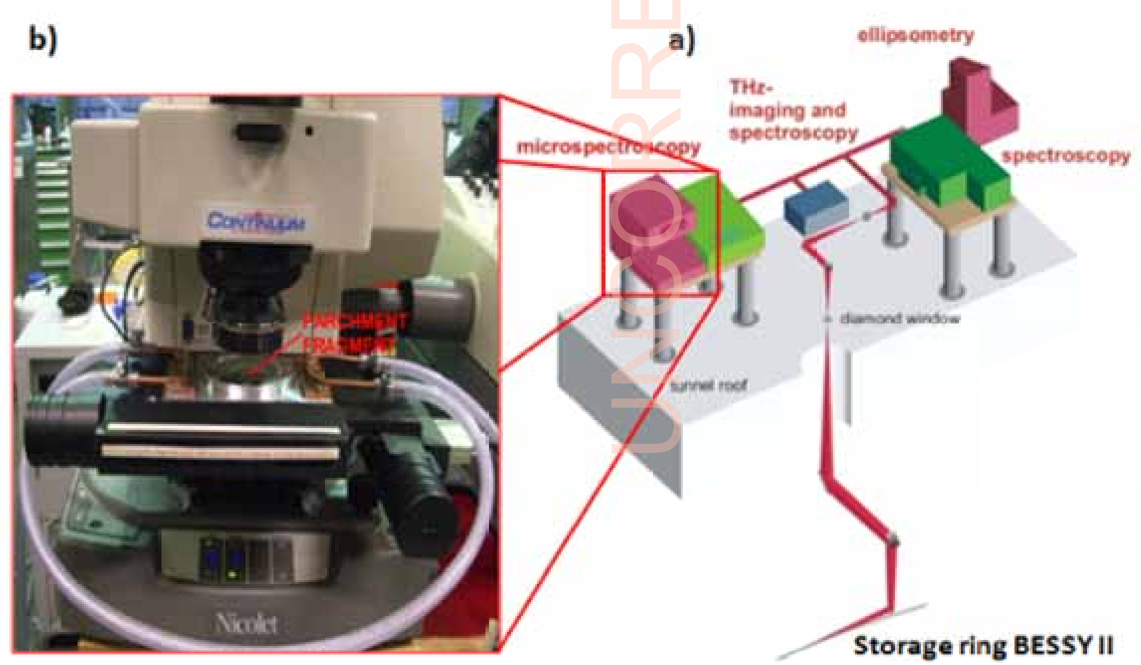

Figure 1: Experimental set-up used for Sy-μ-FT-IR measurements. Synchrotron radiation from a storage ring is convoluted to the micro spectroscopy part of the beam line (a). The sample is located in the specially designed environmentally controlled holder stage of the microscope (b).

Fig. 2: Dead Sea Scroll sample from the Cave 4. In the scanning electron micrograph (on the right) the black arrow indicates the centre of 5 x 5 micrometer area covered by the measurements. EDX spectrum (upper left) and mid μ-FTIR absorbance spectra (lower left) detect mineral deposits in addition to the lines characteristic for collagen. Beside a Reststrahlen band observed at about 1400 cm^{-1} associated with calcite ($CaCO_3$) the FTIR spectrum is characterised by bands that can be assigned to C=O stretching (1741 cm^{-1}), Amide I (1661 cm^{-1}), Amide II (~1550 cm^{-1}), oxalates (1328 cm^{-1}), silicates (1184 cm^{-1}, 1141 cm^{-1}, 1095 cm^{-1}) and calcite (875 cm^{-1})[4].

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RISK ASSESSMENT OF OPEN AIR ETHNOGRAPHIC MUSEUM FROM BUCHAREST USING PHOTONICS

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This paper presents a long term research project that aims at the evaluation of risk factors in an open air museum and at establishing a preventive conservation strategy. Heritage (buildings and moveable heritage) and the environment will be evaluated according to known parameters and this will represent a starting point of tremendous importance in prediction of the evolution of conservation status and also in the creation of risk factor distribution map over the open air museum area. The instruments used in the examination and investigation of heritage objects are portable, do not require sampling, and assume the use of non-destructive, non-contact, non-invasive techniques. Quantitative data obtained include structural characterization of the studied heritage object surfaces, which is of great importance in the identification and evaluation of risk factors and their impact over the different surface and material types.

Within the open air museums, an important factor in the conservation strategy is the fact that there are always new acquisitions of edifices. It is very important that they should regain their initial shape, which is difficult to achieve even with precise photographic documentation. Using tri-dimensional laser scanning, we can provide a detailed representation not only of the architecture but also of the cultural object's positioning within it, keeping alive the old traditional environment. The digitally reconstructed model could be used in future virtual ethnographic exhibitions.

Additional data are acquired using laser induced fluorescence techniques, which allows identifying bio-deterioration, various pigment contours, salt fluorescence, deteriorated reinforcements etc.

Conservators from the National Village Museum "Dimitrie Gusti" from Bucharest were interested to find out more about the conservation status of several replaced old buildings and about the stability of their new positions. In this respect the basements of buildings and their surroundings were controlled using the ground penetrating radar (GPR) technique.

Ground penetrating radar is a non-destructive geophysical method that produces a continuous cross-sectional profile, without drilling, probing, or digging. Ground penetrating radar profiles are used for evaluating the location and depth of buried objects and to investigate the presence and continuity of natural subsurface conditions and features. It can offer early information about the continuous and good shape of an old building groundwork. Ground penetrating radar operates by transmitting pulses of high frequency radio waves (microwave electromagnetic energy) down into the ground by an antenna. The transmitted energy is reflected from various buried objects or distinct contacts between different earth materials. The antenna is then set to receive the reflected waves and send them for storage, analysis and display to a digital control unit. The used scanning system was Mala GS, RAMAC X3M with 250, 500, and 800 MHz antennas.

GPR scanning investigations have been done inside and outside of Sârbova House and acquisition parameters are presented in Table 1.

Figure 1: Sarbova House from "D.Gusti" Museum - entrance side.

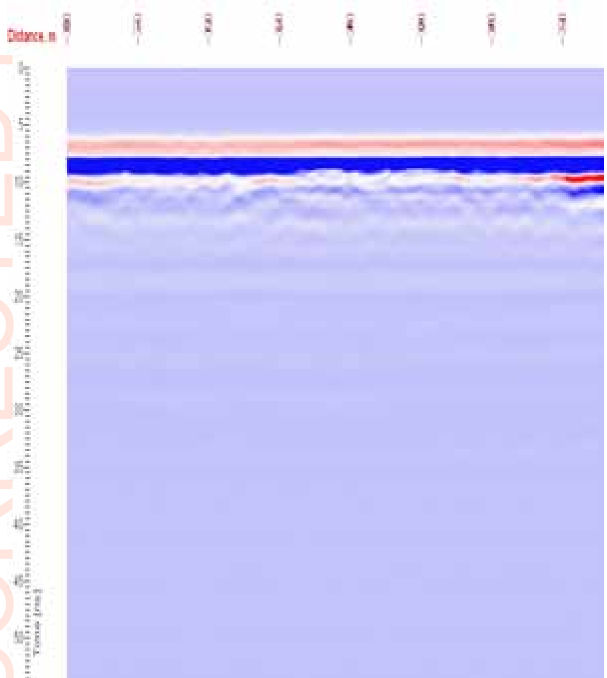

Figure 2: GPR inspection: radar scan along the entrance wall permit to investigate soil layers homogeneity and distribution (by scanning with 500 MHz antenna).

The temporal window for back room scanning was a long one (176 ns) that allowed groundwork identification. Time-deepness conversion was done by time multiplying t_i to speed radiation speed into the ground v, d = $t_i \cdot v$. The speed was established as ratio between the light speed in air ($c = 3\cdot10^8$ m/s), and electrical constant of soil 9 F/m (known as 1 to 5 F/m for concrete, and ~ 8-10 F/m for soil).

For the visible part of the building the accurate model is based on a 3D laser scanning model that could be associated with thermal distribution and microclimate dynamics. The same building benefits by a complete measurement, and especially the façade was carefully reconstructed in digital space. The façade scan was done at an angular resolution of 100 line per degree, with 5 m between the scanner and the building, which resulted in a spatial resolution of 1 mm. Only one scan was made, because a second scan would have generated a detail overlay error of 0.8 mm, close to the scan resolution, which could affect the quality of results. The wide angle at this distance was 70˚, and the scan time was of 40 min.

The surface digitization is based on the laser beam scan and on the transformation of façade details into geometrical coordinates of high precision. The scanner used was the Surphaser 25HS, with a radiation wavelength of 690 nm and 15 mW power. The distance between the object and the scanner can be located between 1.5 m and 22.5 m, the profile recording principle is similar with the fly time. The representation method is the form of pixel clouds, several tens of millions of pixels, with the possibility of transformation of the pixel coordinates data base, through a pixel polygonalisation phenomenon.

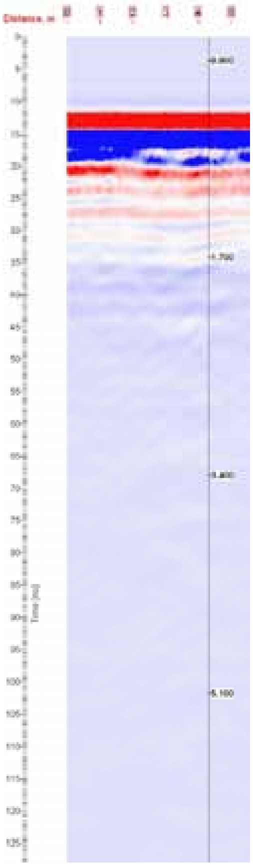

Figure 3: Groundwork thickness of aprox. 0,8 m. The vertical scale is replaced because of direct wave effect.

Figure 4: Sărbova House façade.

Usually, for big objects such as buildings or façades, which demand more than one scan (scans that are aligned afterwards on the same coordinate set), it is preferred that for the pixel cloud presentation the model resolution is 1.5 - 2 mm. This resolution allows the object visualization as well as identification of identification of details. If the object displays inscriptions which are difficult to identify and have lost their readability, a more detailed scan can be performed, with a maximum resolution of 150 µm.

The 3D model obtained offers the possibility of studying the building at different levels of complexity, e.g. a detailed examination from different perspectives, as if recorded by a video camera, but with more information about details and their relative positions; metric images can be relevant either to the precise location of different painted features, architectonic elements or surface damage (delaminations, sketches, incisions etc.), degraded or lost architectural elements can be replaced or consolidated in right position.

Figure 5: Polygonal or continuum surface representation.

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Figure 6: Pixel clouds representation.

Figure 7: Detail of a polygonal surface representation

RECOMMENDATIONS FOR DIFFERENT APPROACHES IN NDE ASSESMENT OF WOODEN CULTURAL HERITAGE STRUCTURES OR HOW TO AVOID POTENTIAL ERRORS

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The paper presents experiences based on research projects related to application of various non-destructive evaluation methods suitable for inspection of heritage wood structures and their elements. The term non-destructive evaluation (NDE) encompasses a much broader range of activities in comparison to non-destructive testing (NDT) itself. The question is how to choose the most effective NDE method? One of the possibilities is to compare and select the NDE techniques according to their accuracy of predicting the level of wood structure decay and damage. NDE of heritage wood structural components in-situ is most important in view of the degree of degradation. Such evaluation is needed for quantification of the remaining strength of the components and for assessment of the reliability, safety and residual life of the entire structure. There are several difficulties related to in-situ investigation: inaccessibility of the critically deteriorated structural components, variable moisture distribution depending on the location of structural member, seasonal temperature changes, interference caused by the neighbouring structural components, localized discontinuities caused by decay, insect cavities or mechanical damage, eroded surface that makes it difficult to securely attach NDE sensors but there are many others. The author has been involved in several NDE projects, national and bilateral, such as "Expert systems in wood structures design", "Studies of reliability and bearing capacity of wooden structures", "Characteristics of wood-lightweight concrete structures", "Modern methods of testing structural material" mostly related to examination of mechanical properties of wood structures. Therefore, several methods and case studies will be presented in this paper in order to discuss the NDE success, usefulness and applicability.

1. Stress wave-based non-destructive evaluation

Non-destructive testing techniques for wood differ greatly from those for homogeneous, isotropic materials such as metals, plastics, and ceramics. In non-wood-based materials of which the mechanical properties are known and tightly controlled in the manufacturing processes, NDT techniques are used only to detect the presence of discontinuities, voids, or inclusions. However, in wood, these irregularities occur naturally and may be further induced by degrading agents in the environment. Therefore, NDT techniques for wood are used to measure how natural and environmentally induced irregularities interact in a wooden component to determine its mechanical properties. Clearly, wood is a composite material composed of many tube-like cells cemented together. At the microscopic level, energy storage properties are controlled by orientation of the cells and structural composition, factors that contribute to static elasticity and strength. Such properties are observable in the frequency of vibration or speed-of-sound transmission. Conversely, energy dissipation properties are controlled by inertial friction characteristics, to which the bonding behaviour between components significantly contributes. The rate of decay of free vibration or acoustic wave attenuation measurements are frequently used to observe energy dissipation properties in wood and other material. Several techniques that utilize stress wave propagation have been researched for use as NDT tools.

1.1 Systems induced by transient impact excitation

During testing, wood samples were simply observed on a table so that the boundary condition was friction between the table and the sample. The same results were obtained when the sample was supported at two nodal points or when it was hung on a very thin thread. It can be concluded that in this way of excitation, the boundary conditions do not have much influence.

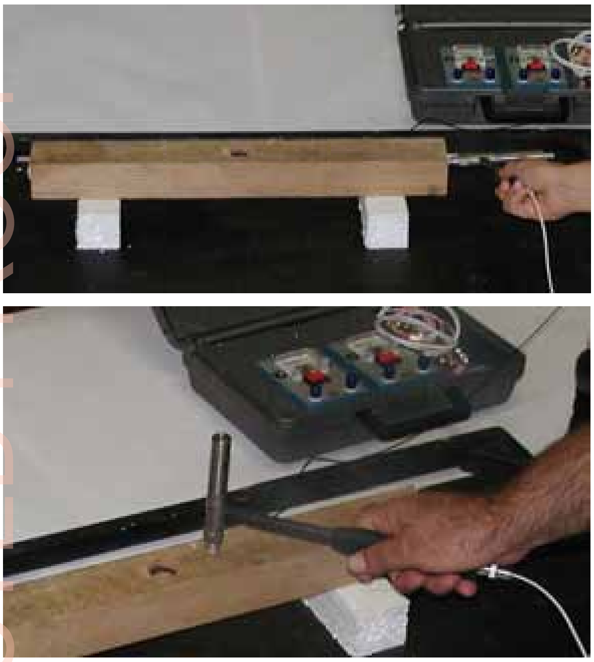

Figure 1: Testing of an oak sample by transient impact excitation (top) and by transversal impact excitation (bottom) in laboratory conditions.

Wood samples are induced artificially using transient impact excitation by hammer (Figure 1, top). To know the function of the impulse, the impulse hammer ICP type 086C03 was used with the hardest impulse cap (made of steel). Thus, the impulse was of a very short duration and high frequency. The signals are typically of a very low voltage and often need to be amplified above the threshold of the electronic recording equipment (spectrum analyzer HP). The dynamic modulus of elasticity can be calculated from the corresponding equation which is related to the first resonant frequency and test sample span (Figure 2). The result shows very good accuracy in comparison to results obtained using static techniques for determination of modulus of elasticity. This research also provided conclusions about the influence of sample dimension, moisture content and defects (such as voids and decay) on the sample response.

1.2 System induced by transversal impact excitation

For this type of excitation, boundary conditions are very important. As shown on Figure 1, samples are treated as simply supported beams. Samples are induced to vibration by transverse impact. From the frequency response, the peak resonant frequency is determined (Figure 2). By solving the equation of motion of a cantilever beam, we obtain the dynamic modulus of elasticity (MOE). This method shows very non-accurate results and the conclusion is that it should not be used at all.

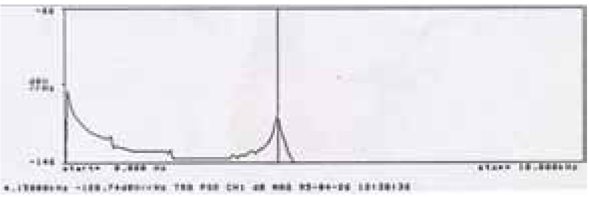

Figure 2: Response following a transient impact in the frequency domain.

1.3 Static techniques for determination of mechanical properties

Measuring the MOE of a component by static bending techniques is fundamental to Machine Stress Grading of timber which is equal to visual grading. This simple measurement involves the use of the load-deflection relationship of a simply supported beam loaded at its midspan. MOE can be computed directly by using equations derived from fundamental mechanics of materials.

2. Ultrasound devices

Many devices for non-destructive testing of structural materials are based on ultrasound. Ultrasound is propagated through materials in a range of frequencies from 20 kHz to 250 kHz. The frequency of ultrasound propagation is $f = c/\lambda$. It depends on the velocity of wave propagation (c) and wave length (λ). In hard media, sound propagates with a speed of 1,500 to 5,000 m/s. The use of ultrasound in assessment of mechanical properties of wood is very well presented by Fortunko et al..

In Figure 3 we show the equipment “Sylvatest Duo” which is usually used in the author's team. It makes use of the software Sylvius which enables the analysis of results and their graphical or numeric presentation. This equipment is usually used to easily obtain MOE, and class of the wood according to EN 338. The measurement is performed by placing the probes at a chosen distance. One probe is the ultrasound generator and the other one is the receiver. The generator induces mechanical impulses which are transferred through the wood to the receiver where they are transformed into electric impulses. With this instrument, mechanical properties in the parallel and in the perpendicular direction to the grain can be obtained with an acceptable accuracy. Before the assessment, the parameters which depend on the wood species need to be set up.

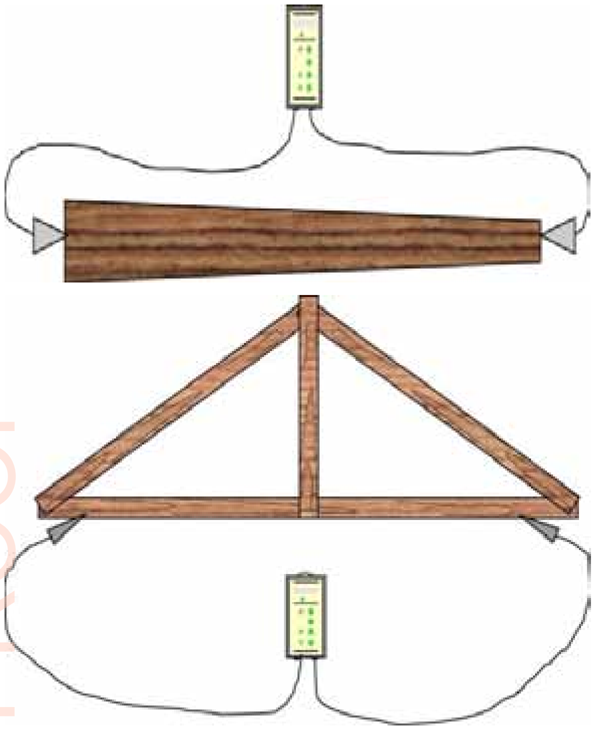

Figure 3: The instrument, probes, computer and software Sylvius and examples of examinations.

3. Smart image sensor

The smart image sensor led to several improvements in defect detection with respect to machine strength grading. A smart image sensor consists of a control for addressing and exposure time, a photo diode array, an A/D converter and a processor. Upon irradiation of a wooden surface with light most of the light is reflected and some of it is scattered within the wood. The scattering is influenced by material density. Light scatters more in clear wood than it does in a knot due to its higher density. This method was used successfully in a few projects for detecting knots and decay in structural elements.

4. Drill resistance device

Drill resistance devices operate under the premise that resistance to penetration is correlated with material density. Drill resistance is determined by measuring the power required to cut through the material. Plotting drill resistance versus drill tip depth results in a drill-resistance profile that can be used to evaluate the internal condition of a tree or timber member and identify locations of various stages of decay. Due to the invasive nature of the drill resistance technique, and the fact that it provides a very localized measure of density, we used this technique in conjunction with NDE methods that provide qualitative condition assessment (e.g. visual inspection) or regional condition assessment (e.g. stress wave or ultrasonic inspection). Drill resistance measurements could then be taken at the limited number of key locations. During our measurements, we used RESISTOGRAPH® device with a very high accuracy.

5. Conclusion

In this abstract, an overview of NDE of wood is given and their characteristics and accuracy are discussed.

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ON THE AUTHENTICATION AND TRACEABILITY OF PARCHMENTS

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1. Introduction

Parchments are amongst the most powerful physical manifestations of culture, thought and human relations left to us from the past. Many parchments constitute cultural heritage flagships, like e.g. the Dead Sea Scrolls, Magna Carta Libertatum, and the Doomsday Book. However, less important parchments are also decisive for the detailed definition of European history. The authentication and traceability of parchments are therefore important, also because parchments are particularly sensitive to frauds, copies, and thefts. This presentation gives an outline of present and possible future means of analyses that will help to authenticate parchments and to trace their provenance. In particular two types of analyses will be described in the presentation.

The first relates to the authentication of parchments by radiocarbon dating. The major problem is that of de-contamination of conservational fluids prior to radiocarbon dating.
The decontamination of castor oil from the Dead Sea Scrolls is such an example.[1,2] In terms of authentication it is, however, not only the radiocarbon date that is of value. The occurrence of specific compounds extracted - as contamination - prior to radiocarbon dating also constitutes an important and so far unused source of establishing authentication and traceability.

The other type of analysis relates solely to the traceability of parchments. We suggest that due to their fluffy surface structure, parchments can act as passive samplers of chemical compounds and dust grains. The analysis of such compounds and dust grains – we predict - will allow us to trace *where* a particular parchment has been kept through time, i.e. its provenance. The method relies on two prerequisites: 1) the parchments ability to catch and hold on to micro particles, and 2) that site specific chemical or isotopic differences of the dust particle inventory can be used to distinguish between the different storage sites of the parchment.

The first question to be raised is if particles really are caught on the surfaces of parchments. Figure 1a shows a SEM micrograph of an un-inscribed part of a medieval French monastic parchment from ca. AD 1280. The arrow indicates a spherical particle with a diameter of ca. 10 μm. Figure 1b shows the same parchment area with a mapping of Si (red) and Fe (green) by the SEM-EDX. It is clearly seen that the particle is rich in iron and therefore not part of the document.

Bringing this method of provenancing to work properly, we should obviously look for much smaller particles, perhaps 0.1 to 1 μm, depending on the capability of the analytical beam techniques available.

In another case study, a small sample of an un-inscribed Dead Sea Scroll has been subjected to SEM analysis. An area of several hundred square microns of a sample of un-inscribed Dead Sea Scroll has been subject to EDX analysis. Figure 2 shows the resulting spectrum. The occurrence of Al, Si, and Fe in these amounts indicates that silicate rich dust particles are adhered to the surface of the parchment.

We therefore believe that there is a basis for suggesting that dust particles are indeed present on the surfaces of untreated parchments, i.e. parchments that have not been subjected to a severe rinsing in the conservational laboratory. Several analytical techniques can be suggested for the analyses of these particles: SEM-EDX, ion probe or other beam based techniques for the characterisation of single particles, and INAA, ICP-MS, and other highly sensitive techniques for bulk analyses. It remains to be seen which analytical techniques are the best to distinguish between dust particle sources and in this way reveal the places the parchment has been stored.

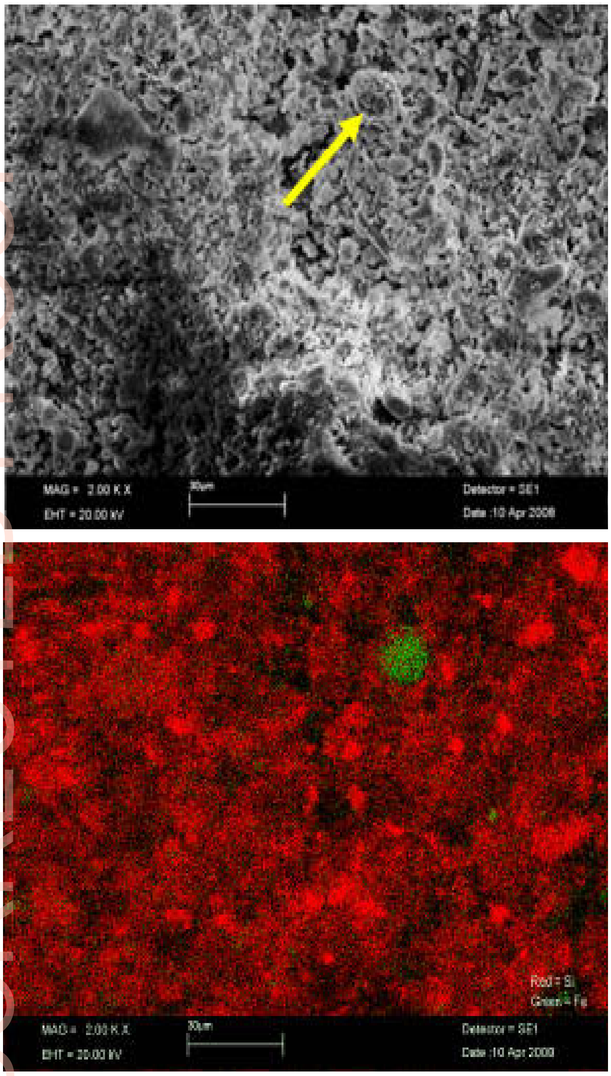

Figure 1: a) above - SEM micrograph. The arrow points to a spherical particle ca. 10 μm in diameter. b) below - The same area of the sample in the K-alpha X-ray line of Si (red) and Fe (green).

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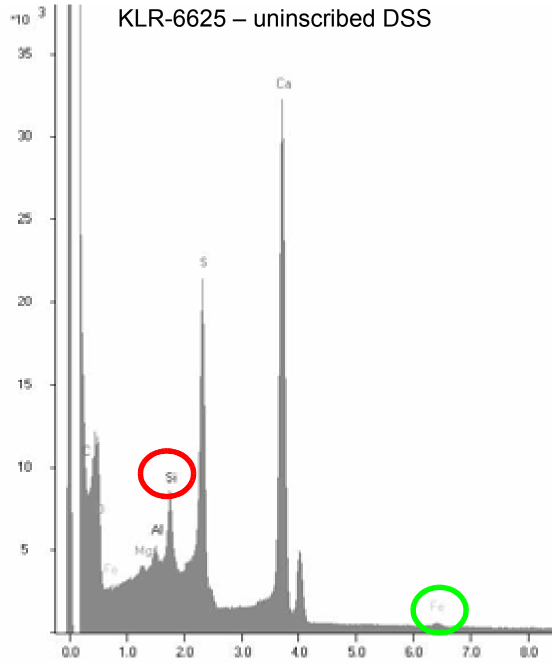

Figure 2: An SEM-EDX X-ray spectrum of a small sample of un-inscribed Dead Sea Scroll. The data is acquired over an area several hundred square μm large. Note that Si, and Fe are detected in appreciable amounts.

U-ITR: A 3D LASER SCANNER PROTOTYPE AIMED AT UNDERWATER ARCHAEOLOGY APPLICATIONS

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The U-ITR (Underwater Imaging Topological Radar) is a 3D laser scanner prototype currently under development at the ENEA Artificial Vision Laboratory (Frascati, Rome), designed to operate directly in underwater environments. The system is based on the amplitude modulation range finding technique, which enables to acquire both range (distance) and reflectivity (imaging) information in a single scan. First results are reported showing how the use of a blue (405 nm) CW laser probe amplitude-modulated at sufficiently high frequencies makes it possible to significantly reduce the optical noise produced by the back-scattering of light off water, resulting in higher contrast, reduced blur and more accurate distance determination. Additional improvements can possibly be obtained by using conveniently arranged polarising filters - yet at the cost of reduced sensitivity (shorter operational range). The final U-ITR prototype will be mounted on board of a ROV for marine archaeology surveys in relatively clean sea coastal waters.

1. Introduction

The development of laser scanning systems for underwater 3D imaging has been gaining considerable interest recently, in view of potential applications in fields ranging from submarine archaeology to inspection of submerged structures for industrial or scientific purposes. The task is particularly challenging because of the substantial absorption and scattering rates of light in natural waters, which produce a significant degradation of image quality. The effects of light absorption can in principle be reduced by selecting the laser wavelength which maximizes the water transmission spectrum. Nonetheless, the variation of seawater composition, strongly affecting light absorption, makes it unfeasible to univocally determine an optimal wavelength. Most current underwater laser imagers use radiation sources in the green region of the spectrum (~532 nm), corresponding to minimum absorption in turbid seawater with a relatively abundant chlorophyll concentration. As long as the minimization of the detrimental effects on undersea laser imaging of light scattered off water is concerned, several experimental setups have been proposed in recent years, such as the use of pulsed lasers which enable temporal discrimination of scattered light and time-of flight-measurements of target range[1,2].

The amplitude modulation (AM) range finding technique, very successfully utilized so far for 3D digitization in air, has recently been proposed for 3D imaging of targets immersed in water[3,4]. A unique, quite attracting feature of continuous wave (CW) AM laser imaging radars is the intrinsic capacity to measure in a single scan both the intensity and the phase shift of the fraction of an AM laser beam reflected by the target, which enables to produce self-registered photorealistic 3D models. In an underwater environment, though, the performances of AM laser radars are strongly dependent on the optical properties of natural waters, in turn heavily influenced by the types and concentrations of hydrosols and suspended particulate. In particular, signal to optical noise ratio *S/N* - i.e., indirectly, phase measurement accuracy - and contrast *C* can be strongly degraded because of radiation scattered off water and falling into the instantaneous field of view of the receiver, what can seriously compromise the quality of resulting 3D models. It is common practice to limit the overlapping of transmitter and receiver field of view by adopting a bistatic optical layout, which enables to reduce the stray light associated to backscattering in water[5].

The potentialities of AM range finding for underwater imaging were explored for the first time by L. Mullen et al.[3] in turbid water (beam attenuation coefficient >$1 m^{-1}$), at short ranges (~3 m) with an electro-optically modulated Nd:YAG laser in bistatic configuration. It is worth remarking, though, that seawater turbidity and chlorophyll concentrations are only significant in the proximity of coasts, getting close to clean water conditions in open sea, with a consequent considerable reduction of light backscattering and a blue shift of the absorption minimum. It turns out that, for an AM laser 3D imager designed to operate in relatively clean seawater, the bistatic geometry condition can in principle be weakened without severely compromising the device performances. In addition, the recent availability of a compact diode laser operating at 405 nm and suitable of digital radiofrequency modulation enables to better match the absorption minimum of clean seawater in the blue region of the visible spectrum.

These considerations led the ENEA Artificial Vision Lab (Frascati, Rome, Italy) to initiate the design and development of the U-ITR (Underwater Imaging Topological Radar), in the framework of the Italian national project "BLU-Archeosys" - Diagnostica per l'archeologia subacquea" (Diagnostics for underwater archaeology). The U-ITR is a compact, quasi-monostatic AM laser scanner for medium range (~10 m) quantitative imaging in relatively clean seawater. Although at the moment of writing the system is still under development - the first prototype will be operative by end 2009 - a vast number of preliminary laboratory tests have already been completed, whose results are reported in the present paper.

2. Preliminary experimental results

A first series of laboratory experiments were aimed at assessing the possibility to increase measurement accuracy by adopting a polarimetric technique based on the use of polarized laser radiation and a polarization selective detection scheme[6]. The method takes advantage of the different polarization properties of laser radiation backscattered by water as compared with the Lambertian component diffusively reflected by the target. Measurements were performed by adopting both co-polarized and cross-polarized detection with linearly and circularly polarized laser radiation. Various degrees of turbidity were realized by adding skim milk or Maalox® to water in order to mimic realistic natural water scattering conditions. The effects of the transition from Rayleigh to Mie scattering regime on phase accuracy determination were investigated together with the role played by high order scatterings as the medium approaches the optical thickness condition.

A second series of measures were aimed at verifying the possibility to improve signal to optical noise ratio *S/N* and contrast *C* by increasing the modulation frequency of the laser source, as firstly suggested by Mullen et al.[3]. In underwater CW AM laser scanner operation, an interferentiallike overlapping of water backscattered radiation with the target signal can be observed, which produces an oscillating behaviour of *S/N* and C versus the modulation frequency f_m. These quantities present maxima and minima in correspondence of precise values of f_m, depending on the water extinction coefficient k and on the target-receiver separation. Laboratory tests were carried out in purposely realized tanks, one 1.5 m long and the other

25 m long, with a capacity of about 6 m^3. This enabled us to directly measure the water backscattered radiation and experimentally demonstrate the interference-like effect[7]. In addition, the data processing method used to this aim enables to remove the contribution of water backscattering from detected signal and drastically reduce signal fluctuations due to the medium.

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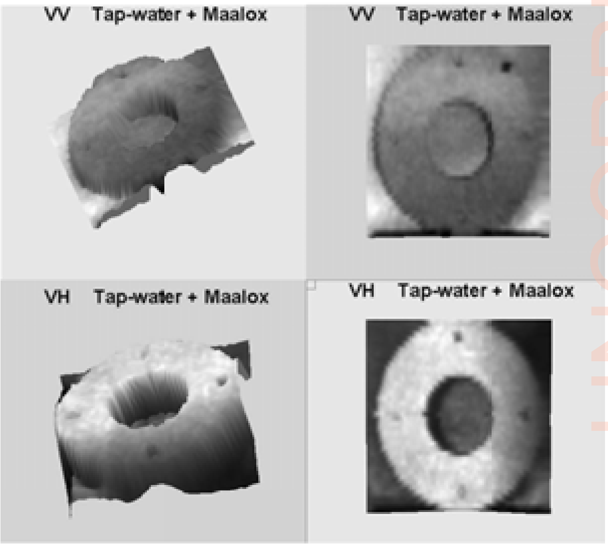

Napaka: vira sklicevanja ni mogoče najtiFigure 1: 3D images of a white painted metallic target with slightly curvature and some holes, immersed in turbid water (27 L of tap-water + 0.1 mL of Maalox®, range = 1.5 m, f_m=39 MHz) equipped with the polarization control on both the transmitter and receiver stages by means of co-polarized (VV, on the top) and cross-polarized (VH, on the bottom) working schemes.

MONITORING OF INDOOR ENVIRONMENTS IN MUSEUMS AND COLLECTIONS: CURRENT PRACTICE AND FUTURE PROSPECTS

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1. Introduction

Museums, collections and archives hold a large part of our cultural heritage and try to protect it against adverse external influences, such as mechanical damage, excessive light exposure, extreme temperatures or humidity, dust and soiling, and degradation by gaseous chemical pollutants. Very often, artworks are kept in showcases which act as additional physical and chemical 'filters' against potential adverse effects of museum indoor environments by creating individual microclimatic conditions.[1] To ensure that museum indoor environments, as well as showcase microenvironments satisfy the delicate requirements of the exposed pieces of art, the atmospheres must be monitored. In this context, only monitoring and analysis of chemical parameters shall be considered. Among these, formic and acidic acid, aldehydes, general volatile organic compounds (VOCs), and the inorganic trace gases (nitrous oxides, sulphur dioxide, hydrogen sulphide and ozone) are the most important ones.

2. Classification of measuring systems

A classification of the repertoire of analytical methodologies for the measurement of indoor air pollutants is given in Figure 1. A number of criteria must be considered in the selection of the most suitable analytical technique, including required measurement range, sensitivity of the method, time resolution, invasiveness, practicality and finally also cost. Off-line methods are nowadays very well established. They involve the sampling of a defined gas volume which is passed over a solid adsorbent bed (e.g. active charcoal for VOCs or dinitrophenylhydrazine- (DNPH)-impregnated silica for aldehydes) to collect the analyte(s), or through a scrubber solution (e.g. an aqueous solution containing tetrachloromercurate for SO_2 sampling). While the scrubber solution can be processed directly, the analytes have to be desorbed thermally or by a suitable solvent from the solid bed onto which they have been collected either before they are analysed by (gas or liquid) chromatography or by spectrophotometry. The advantage of these methods is that, in principle, their sensitivity increases proportional to the sampled air volume, and that selective sampling chemistries can be applied, such as the DNPH derivatisation for aldehydes. The disadvantages are the requirement for pumped sampling, the limited time resolution, and that the result is only available after analysis in the laboratory. The first of these drawbacks can be circumvented by passive sampling. In this case, the air sample is not drawn through the ad- or absorbent, but sampling of the analytes is based on their diffusion to the collecting medium according to the concentration gradient. Passive sampling can be tuned in sensitivity by appropriate design of the dimensions of the sampler, in particular the diffusion pathlength. Due to the fact that passive sampling is diffusion-controlled, the sampling rate is limited and practically always lower than with active sampling. Moreover, sampling conditions are not as stringently defined as in active sampling, so that precision and accuracy of these measurements are generally lower than with active sampling. Moreover, sampling times are significantly longer than with active sampling (typically days to weeks) so that time resolution is essentially lost, while providing a relative good estimate of the time-weighted long-term average concentration. The significant advantage of such passive sampling devices is that they are typically small, inexpensive and can be deployed without requiring any infrastructure or attention during the time of sampling. Passive samplers are to be removed after the exposure period and sent back to the laboratory where analysis is performed. In contrast to the actual passive samplers, there are also passive sampling devices (PSDs) which can be read out directly, as the exposure leads to a specific change in properties, e.g. the change of colour or reflectivity. These PSDs should more correctly be termed dosimeters, since the reading does not represent a concentration, but rather the dose (= exposure time × concentration). Dosimeters are frequently used for inorganic trace gases (SO_2, NO_x, H_2S, acidic gases) where useful colour reactions exist for indication. Although their advantage in use is most obvious when exposure leads to a colour change directly perceptible with the eye, instrumental techniques may be necessary to increase sensitivity of detection, or to detect the reaction products if not leading to a visible change in colour or hue. Examples of such dosimeters have been developed in the EU-project MASTER (EVK4-CT-2002-00093)[2] to measure individual or combined effects of environmental parameters. The two dosimeter systems are a generic early warning dosimeter for organic objects (EWO-G) and a specific (EWO-S), responding selectively to SO_2, NO_2 or O_3. The change in optical properties of the dosimeters is measured photometrically by a dedicated portable instrument. The generic dosimeter is particularly interesting in that it does not respond to an individual substance, but rather to the combined effect of trace gases, humidity and temperature which is modelled by an empirical function. While it is practically impossible to extract information on the individual contributions from the cumulative response, the response is highly relevant, as it represents the potential damage to an object in the given micro-environmental situation. This dosimeter follows the line of development started earlier by the Fraunhofer Institute für Silikatforschung with an environmental impact (glass) sensor according to the German technical guideline VDI 3955/2: 'Assessment of the corrosive effects of environmental conditions at materials: exposure of glass sensors'. In this case, however, the duration of exposure is 3-12 months, and the changes of the glass substrates need to be evaluated by IR spectroscopy, or alternatively by light and electron microscopy. The above mentioned devices are examples of so-called impact sensors which measure the effect of the chemical environment, rather than the concentration or dose of a chemical in the atmosphere. Provided that the material and the chemistry working in these devices is representative for a given range of objects, these sensors hold great potential in predicting whether a certain atmosphere leads to deterioration of the objects or not. Evidently, the sensor materials must be designed in a way that their degradation is well reflecting the threat to the art objects, but does so on a much shorter timescale in order to allow preventive action to be taken before the object is actually damaged. These sensors can thus be considered modern realisations of the corrosion coupons initially developed by Oddy[3] to screen the suitability of materials for use in museum showcase construction which were visually inspected after exposure to the atmosphere for a pre-defined period.

Even if often termed so, the above devices do not actually comply with the definition of a chemical sensor which requires that the analytical information be available on line. There are, however, sensors for indoor air monitoring based on different principles: In the frame of the EU Project 'Corrlog',[4] an electrical sensor was developed in which the electrical resistance of a very thin metal layer is continuously monitored. With corrosion taking place, the cross-section of the metallic track decreases and electrical resistance increases correspondingly. Different sensing metals (Zn, Fe, Ni, Cu) can provide different selectivity, or allow matching with the actual art objects to be monitored.

Optical sensors also hold great potential for on-line monitoring of chemical parameters: Similarly to dosimeters, they require a colour-forming reaction or otherwise detectable response to the analyte, such as change in reflectivity, refractive index, polarisation, or fluorescence. An example is the sol-gel-encapsulation of two indicators which respond to relative humidity and acidic gases.[5] The sensor is fully reversible, and has a short response time (ca. 10 min). Acidic trace gases (e.g. SO2) can be determined on the base of the induced pH-change down to ca. 10 ppm.

Quartz-microbalances (QMB) offer another possibility of chemical sensing: They are based on chemically modified quartz crystals in a resonator that, due to their mass, resonate at a specific frequency. When a change of mass occurs due to a specific reaction of the chemical modification (e.g. a metal or polymer film), then the resonance frequency also changes. Due to the fact that frequencies can be measured very precisely, these sensors are able to detect very low gas phase concentrations (~ppb) of the analyte, provided a suitable reaction is available for sensing. Depending on the nature of the sensing reaction, sensor response may be reversible or not. This principle is employed in the commercial Purafil OnGuard® system6 which is based on metal-coated quartz microbalances that are capable of registering on-line minor changes in weight of the metal coating caused by corrosion, thus allowing quantitative assessment of the corrosiveness of the tested atmosphere.

'Electronic noses', consisting of arrays of electrochemical or mass-sensitive sensors whose response is evaluated chemometrically, are popular in the detection of volatile compounds particularly in the field of food and flavour analysis.[7] They have not yet been used for the monitoring of museum indoor atmospheres, but appear to hold great potential for this task, particularly as they could be modified to provide some degree of chemical selectivity.

3. Conclusion

From the above said, it appears evident that smart sensors will become increasingly important in the monitoring of museum indoor environments. Since the sensor systems so far provide a global, rather than a specific response, they primary use will be as an 'early warning system' to identify with short response time environmental situations which represent a threat to sensitive objects. As such potential threats are detected, one of the more conventional analysis techniques (based on sampling and off-line analysis) will have to be applied to actually identify the compound of concern, and to quantitatively determine its concentration.

This two-step strategy will provide a fast and economic possibility of monitoring the quality of environmental conditions in museums, archives and galleries, and to take precautionary steps for the protection of cultural heritage objects. It requires, however, continuous improvement of existing and development of new sensor systems and principles, in order to cover all relevant chemical threats with sufficient sensitivity.

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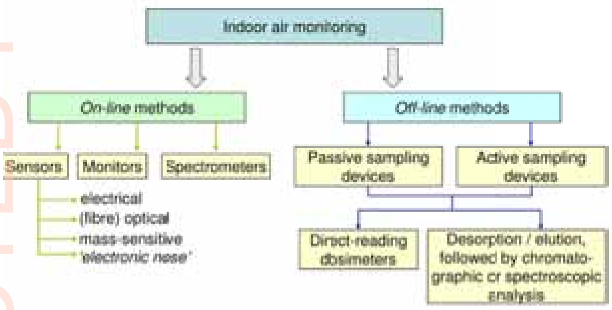

Figure 1: Classification of analytical techniques for museum indoor air measurements.

OPERHA PROJECT: APPROACH TO THE STRENGTHENING OF HERITAGE BUILDINGS BY LOW-IMPACT AND INNOVATIVE TECHNOLOGIES

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Abstract

The OPERHA project aims at the design, development, testing and validation of an adaptable and reversible restoration solution for strengthening historical structures in Europe and the Mediterranean (Med) Area. As such, the OPERHA consortium, coordinated by Labein-Tecnalia in the name of Dr. J. Tomás San-José, is composed by experienced professionals in architecture, engineering, training, archaeology and history, in the field of the building Heritage restoration all over Europe and the Mediterranean Area.

The scientific and technological testing and validation was done at lab scale, and the validation of final solution in pilot proofs on properly monuments. These trials have been made at different real Heritage sites all around the Med countries. More specifically, the purpose of this paper is to present the state of an investigation aimed at improving the knowledge about multi-leaf stone masonry walls behaviour. In addition, two strengthening solutions, based on advanced composite materials are proposed to be applied in these structures: surface treatment with Textile Reinforced Mortars (TRM) and transversal sewing with Fibre Reinforced Polymer (FRP) bars.

1. Introduction

Walls are fundamental structural elements in stone masonry buildings. They can be understood mainly as compressive elements providing the appropriate support to roofs, vaults, domes and arches, but also, when correctly constructed and connected, as structural elements able to face in-plane and out-of-plane loads from horizontal actions. The huge number of possible combinations generated by the geometry, nature and arrangement of units as well as the characteristics of mortars raises a high diversity of stone masonry walls typologies.

In the spite of having a long-live expectancy in general, a large part of walls are affected by structural problems, being the most common causes the environmental degradation of their natural materials, displacements of foundations where they are supported and overloading or different use which they were conceived. Multi-leaf stone masonry structures are prone to failure by buckling and disconnection of the leaves. In addition, as masonry has generally a negligible tensile strength, horizontal loads and displacements of foundations may develop cracks, even with low tensile stresses.

In the last two decades, advanced composites (fibre-reinforced polymer or FRP) have gained considerable worldwide interest and growing acceptance in the construction industry. The preservation of concrete structures the most appealing applications of FRP composites in the construction field. They use possesses some advantages compared to traditional retrofitting methods, per example, low installation cost, increase of the reinforced member capacity with minimal addition of dead load to the structure, easiness to transport and handle, applying technique relatively quick, corrosion resistance and durability.[1]

However, its application on masonry structures presents some critical issues still not sufficiently investigated: compatibility of the FRP system with the parent material (chemical and physical compatibility, flexibility to allow building deformations and water vapour permeability), long-term durability of FRP-repaired structures and minimal invasiveness. In this situation a certain level of reversibility of the upgrade and optimal material selection is required. Furthermore, social, cultural and aesthetical requirements must been taken into account.

The application of general solutions, currently designed and used for civil works, in Heritage buildings requires further development and research as per the following aspects have not been solved until now:

- Organic resins, used as matrix to encapsulate and bind the fibres and to bond the FRP laminates to ancient substrates, are incompatible with these existing heritage materials. They are also vulnerable to humidity and high temperatures.
- The fixing and anchorage systems are of a very limited efficacy, as they are designed basically for concrete substrates, thus compromising the reliability of these systems applied to decayed substrates of heritage structures. The actual anchorage systems in civil works imply high visual impacts by using bolted metallic plates, steel profiles around the edges, high anchorage lengths affecting annexed elements, etc.

Consequently, new ideas have to be established for the heritage structures by combining advanced composites and light additional fixing systems to the substrates, such as simple bolting, FRP mats, inorganic mortars, etc.[2] One possible solution could be the substitution of the organic binder (polymer) by an inorganic mortar, lime or cement based, compatible with the specific materials used in each structure. Another issue is that with mortar as a matrix of the composite strengthening system, the fibres should be in a textile format instead of fabric. The properties, the amount and the arrangement of the used fibre materials have a great influence to the characteristics of the composite. Requirements on the fibres are: high fibre tenacity, a modulus of elasticity much higher than that of the mortar matrix, small relaxation under permanent load, a good and constant adhesion between reinforcement and mortar, low cost and the possibility of processing them easily on textile machinery. Alkali-resistant man-made glass fibres (AR-glass), carbon and aramid essentially meet these requirements for the design and fabrication of textile reinforcements.

This new structural material, namely Textile Reinforced Mortar (TRM), was developed for precasted elements, as an evolution of short-fibres reinforced concrete, in order to obtain very thin-structured concrete elements with a high strength in compression as well as tension. The results obtained from preliminary studies on the use of TRM as a strengthening solution of unreinforced masonry walls[3] can be extended to heritage masonries where the use of epoxy resins is prohibited. For these masonry elements, a lower strength TRM system than for reinforced concrete structures will be suitable. Hence the use of lower properties fibres than carbon, for example AR-glass or basalt fibres can be adopted.[4]

The expected results of this strengthening system are: an increase in ductility and tension / shear resistance, a decrease of cracks by located tensile loads and an improvement in the general behaviour, especially at the failure moment.

The need of a low cost TRM system is obvious, since there are many thousands of heritage buildings around the Mediterranean and many of them in countries where the cost is of major importance for the governments to fund a heritage monuments strengthening project. In a TRM system, mortar's cost is low compared to textile cost. Hence the cost of textile is predominant. For this reason the carbon and aramid high cost fibres are not suitable.

Related to the TRM application as strengthening system on historical masonry structures, nowadays, there are in course multi-year development efforts regarding its ability to retrofit un-reinforced masonry walls. The objective is to establish the adaptability of a full-compatible and highly durable structural strengthening system based in TRM, including:

- The strengthening core: a technical fibre textile, adaptable to strengthen different structural elements (vaults, aches, walls) and substrates (masonry, adobe bricks and timber).
- Fixing system: based on mortars or/and in anchorage devices, in case of need.
- Conditioning and finishing mortars: based on modified or lime-cement mortars, such as a compatible interface between the substrate and the TRM and improving its aesthetic integration. The effectiveness of any externally applied reinforcement is highly dependant on the bond between the composite and the substrate, therefore the interface behaviour is one of the key issues in the structural analysis.
- Connection elements: transversal sewing with stainless and FRP bars to improve the connection between leaves and among other structural members.

In the scope of the OPERHA project, the validation of the strengthening system is carried out by a lab test campaign, regarding characterization of the materials (stone, mortar, masonry and TRM), the design of suitable anchorage system and the construction, strengthening and testing (under static loads) of nine real stone walls made at 1/3 scale.

These structural tests were defined from the knowledge of this type of masonry (typology, materials, etc…) and the structural behaviour connected to the specific deficiency to eliminate[5]. Therefore, a particular attention was taken in choosing the geometrical and the morphological characteristics and the constituent materials of the walls to test, to make them as much as possible representative of the Spanish Romanesque real typology, available in situ.

2. Experimental

Two types of stone were used to build nine multi-leaf masonry wall specimens. Ashlar masonry leaves were made with Sandstone 1, a uniform fine grain sandstone rock. It was received in big blocks, and afterwards, it was cut in a cutting machine of samples with a diamond disc. For the rubble masonry leaves, Sandstone 2, a darker rock, was used. It was received as irregular blocks and they were broken manually by the bricklayers. Cores of Ø50 mm were taken from these stones and tested, obtaining the mechanical properties included in Table 1. The mortar used in the joints and in the inner core was designed on the basis of the low compressive strength (< 0.5 MPa) of mortar found in some ancient decayed walls, aiming to obtain a similar behaviour. Dosage of this mortar was 0.5-1.5-19 (white cement – lime – sand).

In spite of the available equations to obtain the compressive strength of the stone masonry from its typology, geometry and mechanical properties of units and mortar, prism testing is still necessary to obtain real values. Several stone blocks, whose dimensions are 50 cm wide, 40 cm high and 30 cm thick, were constructed, stored at room conditions and tested at the age of 150 days, with load velocity control under uniaxial compression load (Figure 1). This is an essential approach to know the behaviour of the entire walls under compression load.

Table 1: Mechanical properties of masonry wall materials.

Material	Sand-stone1	Sand-stone2	Inner mortar
Density (kg/m^3)	2,090	2,066	2,011
Compressive Strength (MPa)	36.20	64.60	0.2692
Tensile Strength (MPa)	6.28	5.14	0.139
Elasticity Modulus *E* (MPa)	10,468	10,620	4,866
Shear Modulus *G* (MPa)	4,046	4,635	1,75
Poisson Ratio	0.3	0.15	0.38

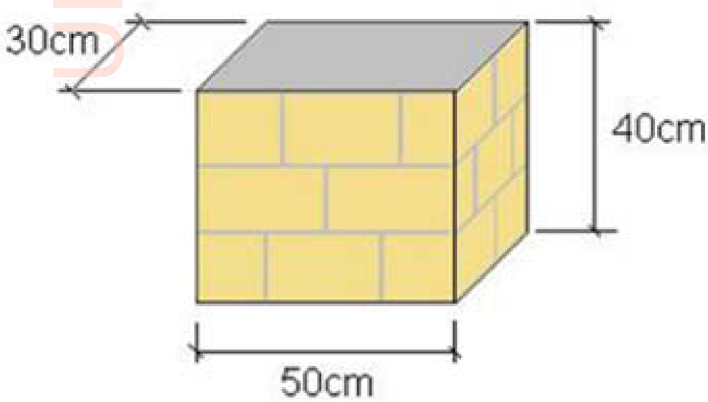

Figure 1: Masonry prism: test setup (left) and size (right).

From the experimental results, the following conclusions may be drawn:

- Dry-ashlar masonry has the highest deformability modulus and a greater load capacity than the other combinations under compression load.
- The quality of the mortar and workmanship affects the masonry strength. The values fail to comply with current standards, as an extremely poor mortar was used to simulate ancient degraded mortar.
- Both ashlar (with bed-mortar joints) and rubble masonry exhibit uniform behaviour, with a strain-stress slope that is practically constant.
- The deformability modulus is greatly influenced by the previous load history.
- In general, the values specified in the standards are very conservative and imply high safety factors.
- The results for the ashlar masonry prisms show greater variation. Further tests are needed for them to be developed in the future; nevertheless, the tendencies are sufficiently well defined to be able to compare the load bearing capacities of three leaf walls (ashlar blocks / inner core / rubble masonry).

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Then, a set of nine walls was built with low strength lime-cement mortar and sandstone units, representing Spanish Romanesque walls and similar to walls often found in historical urban centres, with two external leaves and an internal core of rubble material. They have an inner core made of low quality mortar and rough-cut sandstone pieces (remains from rough-shaping of the stones), poured between the two external layers, like real three-leaf stone masonry walls, erected by expert masons in Heritage interventions, with a similar configuration than historic original ones.

The wall specimens were deflected, a common structural problem in these elements, having the following nominal dimensions: 2 m wide, 2 m high, 0.3 m thick and a 50 mm of deflection, from the half height to the top.

The shape of the cross section was obtained with auxiliary guides. This way, all the walls have similar external geometry. The first meter is perpendicular to the ground. From that point, the wall begins a curve, reaching a horizontal deflection of 5 cm at the top.

Connection between external leaves is obtained through the mortar internal core and some key stones. These are ashlar units placed tangentially to the plane of the wall, without appearing on the irregular masonry leaf . The last 4 walls have a narrower layer of inner filling mortar and more stones keys than the other 5.

After five months of the building date, a finishing mortar layer, jointly with two different strengthening solutions, was applied to the walls:

- Transversal sewing with FRP bars. The main scope of this technique is the improvement of the connection between the leaves and the consequent reduction of the transversal deformations. A first low impact intervention consist of six low modulus CFRP (∅7.5 mm) bars (1.5 bars per m^2), inserted into holes (∅12 mm) drilled approximately at 1/3 of the height from the bottom and the top, and at 1/4 of the width from the left and the right sides of the wall. The holes were executed through corresponding irregular masonry mortar joints, without crossing completely the ashlar masonry in order to not affect the external appearance. A second intervention, with a moderate impact, consist of five AFRP (∅8mm) bars, inserted into holes (∅16) in the top part of the wall, crossing completely the corresponding ashlar units.
- Surface treatment with TRM on one side. In some cases, the render mortar layer at the irregular masonry face has been reinforced in one or two layers with the technical basalt textile. Furthermore, the TRM is anchored to the wall by means of fibre anchor devices (around 10 per m2). The thickness of the strengthening layer is less than 2 cm. In case of application on an even surface, TRM thickness could be just a few millimetres[6].

A summary of the interventions is presented in Table 3.

Table 3: Structural testing program.

		Strengthening system	
		TRM	FRP
Wall specimens	Keystones per wall	surface treatment	transversal sewing
Wall 1		-	-
Wall 2		1	MI
Wall 3	6	2	MI
Wall 4		1	LI+DI
Wall 5		2	LI
Wall 6		-	-
Wall 7	15	1	MI
Wall 8		2	MI
Wall 9		1	LI

Figure 2: Masonry wall specimens.

The nine wall structures were tested under vertical compression load, by means of two hydraulic jacks and a metallic frame, under static conditions. The frame was composed of two metallic groups of welded steel profiles, under and below the wall. The first group was positioned over the two jacks and it was rigidly connected, by means of four steel rods, to the second group at the foundation of the wall. There were additional steel profiles between the jacks and the top part of the wall. The load was transmitted through a 2 cm mortar layer to avoid stress concentrations.

The specimens were instrumented with 8 horizontal and 8 vertical inductive displacement transducers and various strain gauges placed on the reinforced mortar and the visible face of some ashlar units. Two load cells measured the applied load. A data logger was used to register the data of the referred sensors and the time. In addition, the crack pattern was noted manually for each load level and a video camera registered the deformations in the cross section of the wall.

The compression was applied by successive load steps. The time between two steps was around 5 minutes. During this period, the deformations and cracks were examined and registered. In this way, the complete test took from 90 to 120 min. Due to the size of the specimens, high load values and the brittleness of the masonry, careful safety measures were adopted. Therefore, the tests were performed by placing a scaffold box around the test frame.

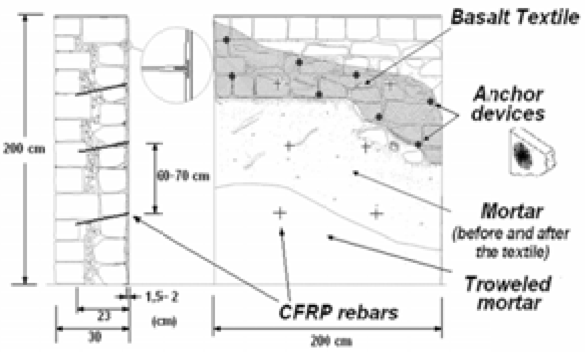

Figure 3: Scheme of the strengthening solution proposed.

3. Results

The ultimate load is related with the failure mode. With this test configuration it was difficult to generate a local crushing zone because punctual loads were not applied. The failure was due to swell up of the ashlar leaf due to the poor connection and the low strength of the inner filling mortar. From the experimental results, the following conclusions may be drawn:

- Walls with higher number of keystones have an average maximum load 15% more than the first group of specimens.
- Sewing with FRP bars, when properly executed, improves the connection between leaves and has shown a rise of 30% in the maximum load in lab structures. However, it is difficult to obtain a perfect bond between the wall and the rebar. A compatible mortar, instead of epoxy resin, must be selected according to the local materials.
- TRM gets a more ductile failure of the nearness leaf. Because of the aesthetical requirements, only the rubble masonry leaf was covered with TRM. Since the failure happens in the ashlar leaf, the TRM has no effect in the load or the displacement, under this test configuration.
- Strain gauges placed on the face covered with mortar have revealed positive deformations in certain zones of the wall. The presence of tensile tensions is not easy to locate by conventional methods when the structure is damaged or there are structural deformations that affect geometry. These tensile loads could be partially assumed by the textile of the TRM when the leaves have a well connected. As it is showed in Fig 5, TRM remains intact after the wall collapse.

4. Conclusions

The FRP, in its different formats (strips, rods, sheets), has proven to be a reasonable solution for the reinforcement of masonry structures. However, actual trends for Heritage structures are focused on a more compatible technique (TRM). Materials cost of the intervention with TRM is significantly reduced. Lime-cement matrix is between 6 and 10 times cheaper than epoxy resins. Other researches on regular masonry have demonstrated a certain improvement of the mechanical properties, even with low cost fibre textiles. However, time and labour required for positioning the anchor devices may increase the total cost of the intervention. In order to design the anchorage solution, it is necessary to consider the substrate material nature, its conservation status, the load history, the aesthetic requirements and the reversibility.

By the application of the FRP sewing bars, reinforced elements can be obtained without modifying significantly the original appearance. The strengthening intervention could be done while the structure is in service, increasing until a 30%, the ultimate load, in walls with a higher number of key stones (cross linking effect between leafs).

5. Acknowledgements

This research is being financed by EU Commission through the OPERHA (FP6-2003-INCO-MPC-2-517765) and the Basque Government through the TEXMOR project (SAI-OTEK 2007-2008).

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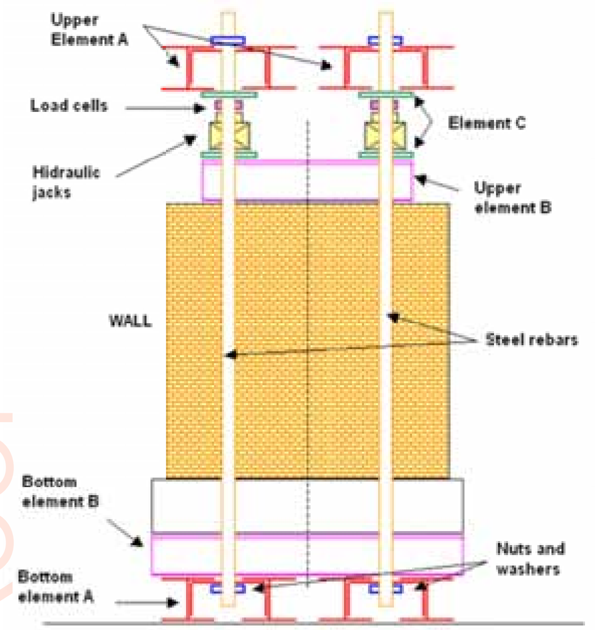

Figure 4: Test Setup.

Figure 5: Crack pattern on the cross section of one wall specimen.

REHABLITATION OF THE OLD BRIDGE IN MOSTAR - A QUALITY CONTROL STORY

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The Old Bridge ("Stari most") in Mostar, built in 1566, destroyed in the 1990 conflict, was rebuilt in 2004. According to UNESCO, "the Old Bridge area, with its pre-Ottoman, eastern Ottoman, Mediterranean and western European architectural features, is an outstanding example of a multicultural urban settlement". The reconstructed Old Bridge and Old City of Mostar is a symbol of reconciliation, international co-operation and of the coexistence of diverse cultural, ethnic and religious communities".

A rehabilitation project of the Old Bridge and surrounding structures was initiated in 1999, began in 2001 and was completed on July 23th 2004. It was one of the most prestigious and ambitious UNESCO-Projects: to copy a historic masterpiece by using adequate materials and forgotten technologies, to build a replica of a lost heritage, is a success. The Old Bridge was reconstructed with local stones and mortars. From July 15th 2005 Mostar is among cultural cities inscribed on UNESCO's World Heritage List.

Quality control has entrusted to "IGH-MOSTAR" d.o.o. Mostar in cooperation with the it's prime company Civil Engineering Institute of Croatia "IGH" d.d. Zagreb.

In the first part of this paper, results of testing of the local Neocene age limestone "tenelija" for masonry on the Old Bridge (from Mukoša quarry 5 km south of Mostar) and local Eocene age fine-graded limestone (from locality Opine, 2 km south of Mostar) used for the Old Bridge's pavement are presented.

Within reconstruction of the Old Bridge in 2003-2004 detail physical-mechanical characteristics of tenelija from the Old Bridge's remnants were made, as well as for tenelija extracted from quarry. Tenelija is stone of yellowish colour at the moment of extraction from the quarry and it has light brown colour in moist state. With drying it gains the whitish colour and with time and aging the light grey and grey colour. Its texture is homogenous and of high porosity. Densely packed ooides can be seen under the microscope of uniform grain sizes, with the average diameter of 300 µm. Ooides are somewhere dense, and on some places with the air space between them.

In accordance to categorisation of architectural-structural stones, tenelija belong to the group of stones with very low strengths (25 to 45 MPa), week resistance to wear (resistance by Böhme – app. 48 cm3/50 cm2), middle class heaviness, extreme porosity and great water permeability (app. 10-6 to 10-5 m/s). Variations in strength and porosity are very high depending of the sample origin, due to what the special attention is paid to selection of stone in relation to its visual variations in structure, porosity and colour.

The most of earlier tenelija analyses had been done on stones built inside the Old Bridge, where it was noticed that tenelija gained strength increase during time. Due to high porosity, tenelija contains large amount of quarry moist, which can contain dissolved salts, when first extracted from the quarry. In stone drying process, salts migrate together with the moist towards the stone surface where they become crystallized creating the patina. Also, due to the high porosity with connected porous space, the water penetrates the stone structure easily. Together with the carbon dioxide, water soluble calcium bicarbonate is formed from the calcite, which migrates towards the surface during drying, forming a firmer crust, thus improving mechanical properties of the surface.

The best information on durability of tenelija is obtained from the stones in the structures of closer and more distant past. While unfavourable results on durability were obtained for freshly extracted samples of rock mass, the Old Bridge has resisted the atmospheric influences and earthquakes for almost five centuries, confirming its durability.

Limestones of Eocene age distinguish themselves with fossils of alveolina and nummulites. These fossils, like white brindles, decorate polished stone surfaces and give them unique appearance. This particular appearance of limestone from locality Opine has symbolised, for instance, the pavement of the Old Bridge, where they were they were emphasized by the polish, induced by the passenger's footsteps.

In the second part of this paper preliminary and control testings of the mortars (mortars for the arch masonry and wall filling, mortar below pavement - "Dark Red mortar" and mortar inside pavement joints - "Pink mortar") and their components used in rehabilitation of the Old Bridge are presented.

Dark red mortar (or Turkish insulation) is located immediately below the stone elements of pavement and above the release cavities stone slabs and above the stone elements of the arch. The task of this layer was to transfer the load of the pavement and the pedestrian traffic upon it and to prevent the breakthrough of water inside the bridge's elements. Such kind of a "mortar" is a compressed structure in multiple layers of red soil and crushed rock with lime as a bonding material. To avoid greater deformations of mortar (shrinking, swelling, creep) crushed rock aggregate of grain size 0-8 mm was used, and at the lower layers on the bridge the larger grains could have been used. At the time of construction it was prepared by adding the quick (not slaked) lime in the red soil and slaking (adding the water) at the building point. Appropriate kind of mortar used for the bridge's reconstruction was produced as chemical (with lime) and mechanical (by compressing) stabilised layer of different thickness (by the bridge's ends up to 120 cm and at the crown approximately 25 cm). Characteristics of such layer (strength, water permeability, stability) are directly related to compression, so this parameter was especially emphasized. When material contains too much water, it cannot be compressed because the incompressible water is preventing it. Dry material is hard to compress due to increased shear between the particles. Proctor's analysis had provided us with optimal humidity of material for easiest compressing, i.e. smallest content of pores. Special attention should be paid to care of freshly compressed layers (protection from rapid drying and extreme temperatures).

The bridge's pavement was made in Pink mortar, which fills up completely the joints between the stone elements. Its purpose is to stiffen the pavement and to prevent the water penetration. Originaly, mortar was prepared with the filling of terra rossa or bauxite and bond – quick lime slaked inside the fill. In trial mixtures of new suitable mortars same materials were used with addition of stone powder to achieve desired shade, and tryouts with powdered brick were also made. Instead of quick lime, the lime paste was used.

Taking into account that we have dealt with the exact replica of the Old Bridge the Investor has demanded the use of traditional component materials, and the special accent was pointed to the mortar appearances, i.e. the colour, which had to be as similar as possible to the colour of "original" mortars.

Basic principle for preliminary testing was the following:
- selection of mortar components (part of the components was previously selected);
- tests of basic component characteristic;
- preparation of trial mortar mixtures by varying the components and their interrelations;
- tests of basic characteristics for all trial mixtures in fresh and strengthened state;
- selection based on key characteristics of mortar (compressive strength, appearance…);
- tests of specific characteristics of selected mortars;
- final selection of mortars;
- display of selected mortars on models;
- approval of selected mortars for the bridge.

Component material used for various mortars during preliminary testings:
- traditionally produced lime paste [$Ca(OH)2 \times nH2O$] from Sukošan near Zadar, Croatia;
- natural sand from Neretva river (0-4 mm, while for the wall filling it was 0-16 mm);
- various kinds of powdered brick: "Jedinstvo" Crvenka, Serbia, «Radnik» Križevci, Croatia, and "IGM" Visoko, B&H;
- Red soil (Terra rossa) from the origin Gradnići near Mostar;
- bauxite from Žovnica near Mostar;
- stone powder of manufacturer «IGM» Posušje, B&H;
- crushed limestone of manufacturer «IN KA», Ljubuški, B&H (fractions 0-4 mm and 4-8 mm were used in ratio 1:1).

Mortar components were dosed by volume, considering the simplicity of site procedures and traditional way of mortar preparation. Mistakes of such dosing in laboratory are small since the uniform material is used.

During preliminary testing the following characteristics were tested on fresh masonry mortars: consistency, capability to retain water, porosity, workability and volume mass. The fresh pavement mortar was tested for consistency, volume mass by Proctor, optimal content of water by Proctor (for mechanically stabilised mortar layers below the pavement) and resistance to penetration on Proctor's needle. Important characteristics of mortar were tested too: bending and compressive strength, water resistance, capillary and hydrostatical water-permeability, adhesion to stone - Pull off test, stability on frost, volume deformations – shrinking and swelling, therefore, in accordance to this the appropriate kinds of tests were conducted.

Based on testing results of prepared mixtures in fresh and strengthened state and the colour of mortar, the UNESCO's expert group has decided on compositions of mortars:
- Arch masonry: lime paste : sand : powdered brick = 33% : 34% : 33% (by volume);
- Mortar bellow pavement (Red mortar): lime : terra rossa : filling = 20% : 50 - 40% : 30 - 40%;
- Mortar inside the joint (pink mortar): lime : brick : stone powder : aggregate fill = 20% : 30% : 20% : 30%.

It should be taken into account that in the actual conditions of multi-axial loading on mortar inside the joint; such mortar achieved several times higher strengths at control masonry model tests designed in Zagreb upon suggestions of the UNESCO's expert group.

At the site, special attention was paid to storing of the materials (the sand, terra rossa and powdered brick had to be protected from moist because with the change of humidity, their volumes change). Site quality control of the arch masonry mortar involved also control of mortar preparation (check of dosing accuracy, corrections of working receipt), consistency tests, i.e. workability of mortar and if necessary tests of mixing ability. Mortar samples were taken from the site on a daily basis to test the compressive strengths in age of 28, 60 and 90 days. Within the internal quality control, the component materials of mortar were tested too: consistency of lime paste, grain-size composition and content of fine sand particles, grain-size composition of powdered brick.

THE OLD TOWN OF LJUBUŠKI – CONDITION AND TAKEN RESEARCHES DESCRIPTION

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The construction of The Old Town of Ljubuški as a building ensemble had been undertaken in the 14th and 15th centuries under the reign of herceg Stjepan Vukčić Kosača. The century old ruins have a romantic dimension making it a unique monument integrated in its surroundings.
Three years ago it was declared to be a national monument and classified as endangered.

During 2007, certain reconstructions were under way without engaging experts in traditional techniques and materials.

To introduce this cultural inheritance and the problems of its condition and protection, to the public, the Commission for protection of national monuments is working on updating the collection of all materials related to this monument.

The protection of historic ensembles and buildings is a matter of old meeting the new.

Medieval towns and fortresses were fortification structures with a defensive purpose, but the feudal centres were located there too. Thus, the fortification structures were representative of the economic and cultural centres of the region. This is why special attention was paid to the choice of the position fortification. Places, which were inaccessible at least from one side, were selected. Walls were positioned on cliffs or other natural terrain where only small modifications made the fortifications inaccessible.

The old town of Ljubuški is situated just outside the town of Ljubuški on the eastern outermost crest of the hill Buturovice on a dominating position (349 m above sea level). It is possible to reach it from two sides: from the south using a footpath and the north using a gravel road from 1994.

The foundation has a form of an irregular polygon. It extends to 93 m from east to west and its average width is 50 m in the direction north – south. Its area is 3,350 m^2.

In the neighbouring regions, most old towns – fortresses are made of stone, which is the reason why they have been preserved until today. However, the lack of care in the past resulted in the need to urgently renovate this building. The structures are in different stages of preservation (Figures 1 and 2).

The defence walls, towers and a large complex of structures which make part of this Old Town are in ruins. This is not due to the quality of stone but because of the foundations and the mortar, as well as due to ill maintenance. The quality of stone is good, but the mortar has already been removed by the ravages of time.

The massive walls surrounding the fortification are the basic elements. They are of a large width varying from 0.90 m to over 3 m. They have two faces and they are built of irregular pieces of crushed stone and infilling of fine-crushed stone called "trpanac". Symmetrical forms of stone blocks are used only in corners.

Such walls cannot appear as walls of uniform quality. Between the two wall faces, built from bigger stone blocks and the fine-crushed stone, there is no safe joint ensuring uniformity of the wall.

Bearing capacity of this wall depends on the bonding and compacting function of infills.

Figure 1: The Old Town of Ljubuški.

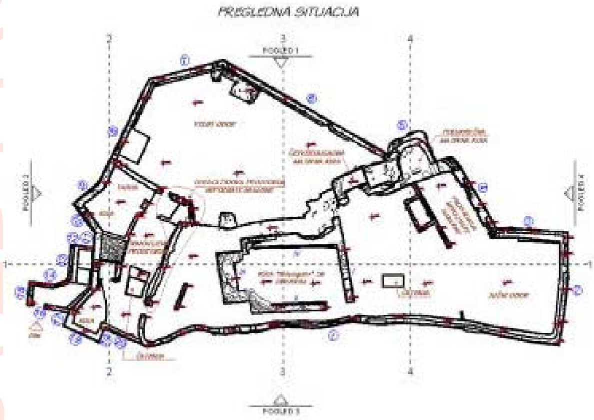

Figure 2: The Old Town of Ljubuški – plan.

The towers of old towns had a protective function, as it was possible to attack the enemy from the side, and not only frontally.

The brickwork of towers was better maintained. The height of towers is different, adapted to the configuration of the terrain, and depending on the position and defence function. The towers have levels with flooring, which is evidenced by the positions of wooden beams used for floor construction.

The main damage to the Old Town of Ljubuški can be described as:

Parts of the foundation show extensive weathering due to atmospheric impacts, which led to the removal of fine particles on parts of foundations made of scree mixed with clay. On certain parts the bonding was completely washed away and walls like look dry stone walls.

There are large unconnected parts of walls – a consequence of seismic forces (1961 earthquake) led to destruction of large parts of walls and other parts are in an unstable state.

Despite their mass, these walls are vertical consoles, very sensitive to any horizontal forces in the cross direction.

Various conditions of foundations and fissures in walls were registered during the investigations. Walls are partly founded on rock and partly on scree mixed with clay. Thus, different conditions of the foundations and bearing capacity resulted in a large number of fissures in walls, especially following the earthquake.

The corners of walls are usually connected by large blocks of cut stone, but only externally. Generally, connections between walls are frequently weak connections.

Tops of walls are degraded and have been laser-scanned, as well as photographically recorded, and visually assessed. Unfavourable natural impacts include: plants, freeze/thaw cycling, microclimate conditions and wind erosion. On a large part of the defensive walls, degradation is so extensive that all traces of loop holes were lost.

Inclined walls and especially high walls without bracing are bulging and unstable.

The defence walls and towers have holes in which wooden beams were placed. The beams were mainly set horizontally, although on some places (Figure 3, walls 1, 2, 5-9) we can see vertical holes. Thanks to the mechanical properties of wood, the role of wooden beams was similar to the role of reinforced beams in modern constructions. Wooden beams enable faster bricking, uniform distribution of the load of wall mass on the base and connections between walls in complex constructions. However, wood is sensitive to moisture and subject to biodegradation and their main limitation is in their durability.

The lime mortar is of different age and different composition, which depended on the period in which it had been repaired and the masonry practice.

In order to use the authentic original building technique during reconstructions, it is necessary to perform detailed investigations on all materials used on the old town. This is the topic of our future research.

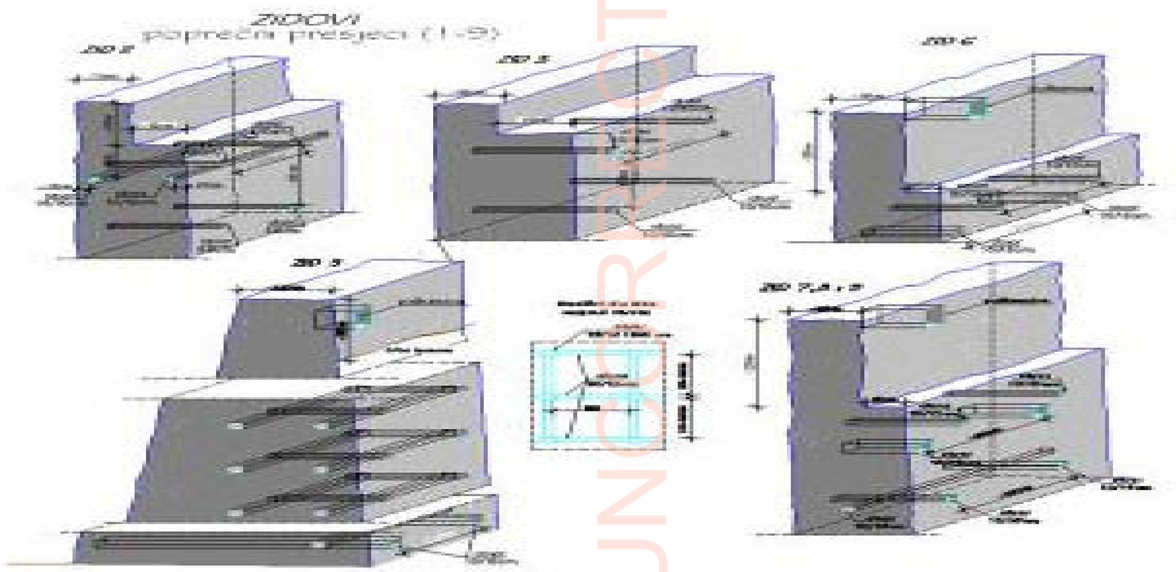

Figure 3: Old Town of Ljubuški – wall cross sections.

INVESTIGATIONS ON THE POSSIBILITIES OF IDENTIFICATION OF VARIOUS TYPES OF SOILING AND PAPER COMPOUNDS USING NIR SPECTROSCOPY

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Abstract
This work is a part of a research project aiming to investigate possibilities of application of the near infrared spectroscopy for identification of different types of soiling and fillers or other substances introduced to the paper works of art. The NIR spectra were recorded in the range of 1300 – 2500 nm in the diffuse reflectance mode. The spectra measured for various art media: e.g. additives, adhesives, finishes as well as substances recognized as staining factors, were chosen as the components of the NIR spectral data library. Several materials included in the library were chosen and introduced into the different types of model modern paper samples to verify the identifying possibilities of NIR spectroscopy. The multivariate analysis applied for spectra of paper-based samples with some soiling substances introduced into paper structure, indicates paper characteristics as dominating factors discriminating the spectra. Analysis of the paper-subtracted spectra allows the classification of samples according to chemical composition of the substance introduced into paper. For samples of different soiling concentration, the library matching procedures were applied to examine the conditions for identification of the soiling substances applied to the paper samples.

1. Introduction

In analysis of cultural heritage material, due to the sampling restrictions the non-destructive techniques are preferred. The near infrared (NIR) spectroscopy is a non-destructive technique widely used for qualitative and quantitative material analysis in many areas of science.[1-3] In analysis of paper artefacts NIR spectroscopy has been increasingly applied as a tool for providing data of the utmost importance required for the effective and safe conservation practice as well as for the purposes of studies of degradation processes.[4,5] The possibilities of non-destructive, in situ examination allow NIR technique to be especially useful during recovering and preservation works carried on the ancient paper artefacts. Unlike the mid-IR spectroscopy, the NIR spectra are characterized by low structural selectivity and are dominated by absorbances of overtones and combination of fundamental vibrations related to functional groups, such as N-H, C-H, and O-H. In order to reveal specific and useful information from NIR spectra the use of chemometric methods is necessary.

Paper is a complex material consisting usually of cellulosic materials and various extenders and additives added during the production process. It is known that the composition of paper, as well as the substances introduced to paper throughout its lifespan are the main factors influencing paper artefacts durability and must therefore be carefully studied.

In this work, we have investigated conditions for identifying the substances that can be considered as staining factors on paper samples.

2. Experimental

Several types of modern paper and a variety of substances that can be considered as responsible for the detectable stains on paper objects were chosen for the analysis. NIR spectra of the investigated samples were collected in the diffuse reflectance mode using a custom-built scanning spectrometer equipped with a broadband radiation source (quartz tungsten bulb, 3000 K) and PbS detector. Samples were scanned in the wavelength range between 1300 and 2500 nm with spectral sampling interval of 2 nm. Reference spectra were recorded before each sample measurement by scanning the Spectralon reflectance sample. Spectra collected on each sample were converted to absorbance units (log(1/R)). In order to minimize the influence of the radiation scattering due to the paper surface inhomogeneities, five independent spectra were measured at different locations across the surface of the paper sample and the results were averaged.

The NIR spectra collected for 70 pure substances that are known in paper making, conservation and art techniques on paper or those commonly recognized as staining factors are selected as primary compounds of the spectral library.[1] The selected substances represent different chemical groups including proteins, lipids, carbohydrates, polymers etc. The spectral search by comparing the library spectra with those of a tested sample by applying different matching algorithms is considered as an important step in a procedure of identification of unknown soiling substances introduced to the paper objects.

In order to determine conditions for paper soiling identification, the measurements of spectral characteristics were carried out for three types of the modern paper samples – treated with the solution of the selected substances of controlled concentration. Data concerning the paper samples and types of substances chosen for the analysis are given in Table 1.

The samples for analysis were prepared by immersion of the pure paper samples in water solution of examined substances of controlled concentration. Then, the samples were dried at room temperature for 48 hours. The relative concentration of the substance applied to the paper was estimated by comparing the sample weight before and after introducing the substance to the paper, measured under the same laboratory conditions. The respective spectra were recorded for 30 different values of relative concentrations in the range from 0.45 to 0.05. The influence of the humidity fluctuations on the variations of water content in the investigated samples was minimized by taking measurements under controlled humidity level of 50 - 53% RH and temperature of 23 °C.

Table 1: Paper samples and substances chosen for the analysis.

Type of paper	Substances
Paper_A – Whatman filter paper: cotton linters; 98% α- cellulose content Paper_B – bleached sulphite softwood and groundwood cellulose pulp : 69% birch, 31% pine content, Paper_C – 87% chemicothermomechanical pulp, 8% sulphite groundwood (pine), 5% sulphite softwood cellulose pulp	Sub_1 –synthetic polymer adhesive: dispersion of polyvinyl acetate and polyvinyl chloride (Vinavil) Sub_2 – vegetable gum: saccharides and glycoproteins (gum arabic) Sub_3 – animal glue: partly hydrolyzed collagen (gelatin)

3. Results and Discussion

The NIR spectra recorded for selected model papers are given in Fig. 1a. The differences in properties of the examined paper samples related to their chemical and physical structure are demonstrated by noticeable differences in the examined spectra. Their large spectral differences are observed in the region characteristic for the water absorbance bands 1400 – 1520 nm and 1860 – 2020 nm as well as in the range of 2100 2200 nm assigned to cellulose band.

Spectra of substances chosen for analysis are presented in Fig1b. Despite the differences in the chemical composition of the substances signed as Sub_2 and Sub_3 (Table 1) their spectral characteristics, including the position and relative intensity of the main absorption bands, are very similar. Sub_1 has its spectrum completely different – a high intensity band in the region of 2200-2500 nm is very characteristic for this substance. Sub_1 - the synthetic polymer adhesive (Vinavil) has a hydrocarbon backbone chain that makes it so much different from the typical cellulose paper material. The other two media (Sub_2 and Sub_3) are natural polymers consisting of polysaccharides and glucoproteins or proteins and therefore they are much more related to the natural polymer: cellulose, polysaccharide that consist of various number of D-glucose units.[6] The fact of presence same analogical side groups like: hydroxide, aldehydic or ketonic and carboxylic as well as cyclic chemical constitution of the polysaccharide units results in the effect of resemblance of their NIR spectra with overlapping the main bands that make them difficult to distinguish.

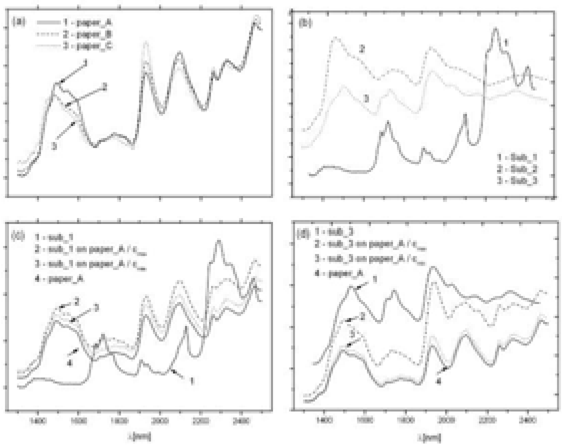

Figure 1: Characteristic absorption spectra of (a) - model papers, (b) - substances selected for analysis and spectra recorded for complex samples characterised by minimal and maximal concentration of substances (c) - Sub_1 and (d) - Sub_3.

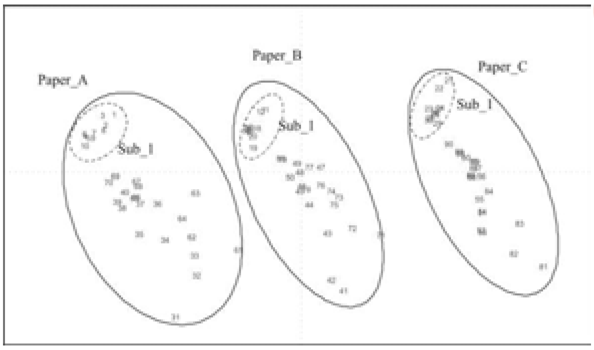

Figure 2: The first two principal components calculated for spectra of 90 samples (three papers contaminated with three substances and ten levels of concentration).

The spectral examination of the paper samples treated with the solution of the soiling substances shows only slight changes in the visual appearance of the spectra. Spectra measured for two extreme concentrations (C_{min} and C_{max}) of the substances of Sub_1 and Sub_3 type applied to the A-paper are given in Fig. 1b and Fig. 1c with those of the pure paper samples and of the respective pure substances. Changes in the applied substance concentration are displayed as changes in the intensity of the main absorption bands in the paper samples treated with the solution of the soiling substances. For high values of concentration, some slight distortions in the examined spectra are visible in the regions corresponding to the characteristic bands in the spectra of applied substances, e.g. in the range of 1600-1900 nm and 2200-2400 nm for Sub_1 and 1600-1800 nm and 2000-2200 nm for Sub_3. These regions are recognized as the most highly correlated to concentration of the soiling substances introduced to the paper sample.

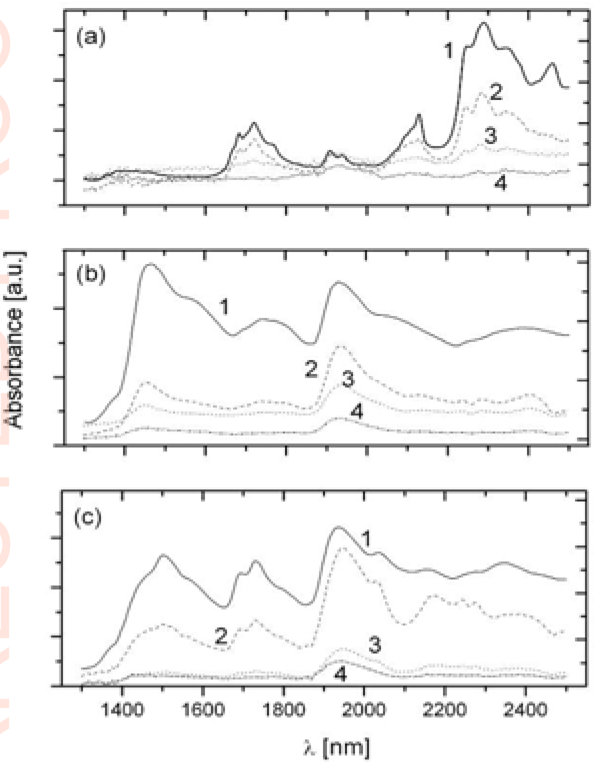

Figure 3: Characteristic absorption spectra (1) measured for pure substances: (a) - Sub_1, (b) - Sub_2 and (c) - Sub_3, compared to the paper-subtracted spectra measured for samples of different concentrations: (2) – 0.4, (3) – 0.15 and (3) – 0.08.

Visual inspection of spectral features of the investigated samples leads to the conclusion that in the considered range of variations in the soiling substances concentration, the spectral properties of the paper are the dominant factors determining the spectral characteristics of the compound samples despite the evident differences in the chemical composition of the substances introduced to the paper.

This conclusion is confirmed by a principal-component analysis used to observe any clustering and separation in the sample sets.[7] The PCA was applied to standardized (MC and SNV) spectral data concerning the samples of A, B, C paper contaminated with substances (Sub_1, Sub_2 and Sub_3) of ten levels of relative concentration (from 0.05 to 0.4) – Fig. 2. The samples of Sub_1 on paper A, B, C are marked by numbers from 1 - 10, 11-20 and 21-30, respectively. Samples of Sub_2 on respective papers are numbered as 31-40, 41-50 and 51-60. Samples of Sub_3 are marked as 61 - 70 for A-paper, 71-80 for B-paper and 81 to 90 for C-paper.

The PCA separates the spectra of samples into three distinct groups. These groups are composed by spectra of different substances applied to the paper of the same type. Within each group, samples are distributed according to the soiling substance concentration. Strong clustering observed for samples with Sub_1 confirms the distinct spectral properties of this substance compared to Sub_2 and Sub_3. Detailed analysis of the PCA results proves that conditions for identification of the substances applied to the paper depend on the substance type, its concentration and the paper properties.

In order to eliminate the influence of the paper properties in the identification procedure the analysis of the paper-subtracted spectra was carried out. The spectra of pure paper samples were subtracted from the spectra of the soiled paper by applying autosubtract procedure supplied by the Grams software.[8] This procedure is based on an iterative algorithm, which determines the subtraction factor by minimizing the derivative of the resulting residual spectrum.[9]

The paper-subtracted spectra, given in Fig. 3, reveal the bands corresponding to the spectral characteristics of the examined pure chemical substances. While the position of these bands does not change, the relative intensities in the paper-subtracted spectra vary according to the relative changes in the substance concentration and the type of paper. For high concentration, the paper-subtracted spectra reproduce the spectra of the pure substances with a good accuracy while for low relative concentrations only strongest absorption bands are recognized.

The PCA performed on the paper-subtracted spectra discriminate three main groups of samples according to the type of substance applied to the paper – Fig. 4. Results presented in Fig.4 confirm that the influence of the paper has been reduced significantly in the paper-subtracted spectra. However, detailed analysis of PCA plot reveals that inside the main groups, some subgroups of samples related to the type of the subtracted paper can be identified. Samples 1-8 and 11-20 are assigned to Subs_1 on the papers -A and -B, respectively. Samples 41-50 in the group of Sub_2 are identified as samples of paper B while samples of 81-90 in the group of Sub_3 can be easily recognized as samples obtained for the paper C. It means that the paper influence has not been fully eliminated from the paper-subtracted spectra and in consequence some samples are not assigned to the proper group of substances and thus their correct identification is impossible (e.g. samples 70 and 78 of Sub_3 could be identified as samples of Sub_2 and similarly samples 56 and 58 of Sub_2 can be found in the group of Sub_1).

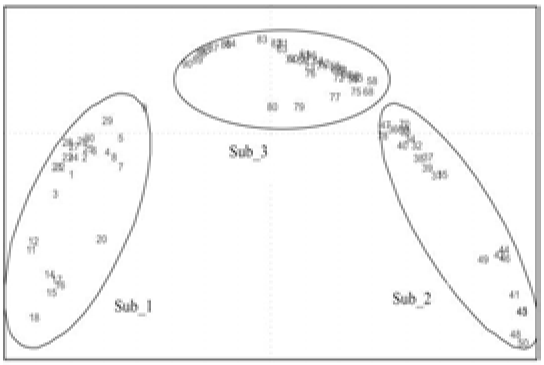

Figure 4: The first two principal components calculated for paper-subtracted spectra measured for 90 samples (three papers contaminated with three substances and ten levels of concentration).

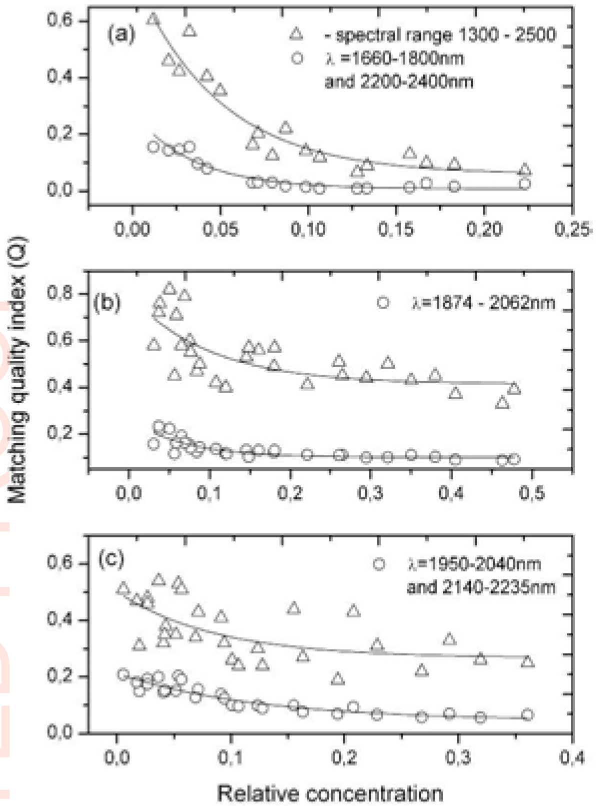

Figure 5: Matching quality index (Q) versus sample concentration calculated for full spectral range and for selected spectral bends; (a) - Sub_1, (b) - Sub_2, (c) - Sub_3.

Tests for identification of materials applied to the paper samples were performed by comparing the paper-subtracted spectra with those available in the prepared library by using the library search program of the Grams. The spectra to be identified are compared against spectra in the library by using vector correlation method and a list of the closest matches is identified by ranking the library spectra by a calculated matching quality index *Q* with values from 0 to 1. The better match between the examined and the library spectra the lower value of *Q*- index is found (the spectra are considered to be identical for matching index of 0).

Fig.5 shows the values of the matching index calculated for paper-subtracted spectra calculated for different values of the substance concentration in the paper samples. Results obtained for a full considered spectral region of 1300-2500 nm are compared with those calculated for selected bands that correspond to the characteristic bands of the examined soiling substance and show the highest correlation of the spectral response to the substance concentration.

A decrease in the substance concentration is accompanied by an increase of the matching quality index value. It confirms the earlier conclusion concerning the paper-subtracted spectra (Fig. 3) that their identification is more and more difficult with a decreasing of the soiling substance concentration. The analysis shows that only for a Sub_1 (Fig. 5a) of the relative concentration higher than 0.1, the matching indexes are found to have relatively low values (< 0.1) and the unambiguous identification of this substance is possible. For Sub_2 and Sub_3, considerably higher values of *Q*- index are calculated and then it is only possible to distinguish a group of substances characterized by the spectral patterns that are the most similar to the examined one.

The characteristic band selection (Fig. 5) results in a significant reduction of the matching index values and an acceptance threshold for *Q*- index (<0.1) is moving toward lower values of concentration.

The detailed analysis of the quality of match between the examined paper-subtracted spectra and the respective pure substances spectra in the library reveals that matching quality index depends not only on the spectral properties of the substance and its relative concentration on a paper sample but also on the type of a paper. It means that paper-subtracted spectra still contain some 'information' concerning the paper type. This effect is not very pronounced for the soiling substances with spectra characterized by narrow and well defined bands as it e.g. in the case of Sub_1 but for Sub_2 and Sub_3 *Q*-index behaviour reveals distinct dependence on the paper type for which the subtracted spectra were found.

The effect of paper marks in the paper-subtracted spectra, recognized by both applied methods (the PCA analysis and the library spectra search technique), can result from two reasons: 1 – the subtraction factor is not optimal, 2 –the paper-substance chemical interaction result in changes of the spectral properties of the paper and its spectrum cannot be removed by simple subtraction from the soiled sample spectrum. The experiments, carried out for different combination of papers and soiling substances proved that the properties of paper-subtracted spectra depend strongly on the spectral range that must be chosen for calculating the subtraction factor. It is not obvious how to specify such a range especially in the case when the spectral properties of a substance that must be identified by the paper-subtracted spectrum is not known and thus the question how to remove correctly (and fully) the paper spectra from those of the soiled paper samples regardless the type of paper, the substance as well as its concentration still remains open and the alternative methods of spectral subtraction need to be developed.

4. Conclusions

The analysis of spectra measured for complex samples confirms that the paper properties are always a dominating factor that classifies the set of investigated samples. For the proper identification of substance introduced to the paper, the paper-subtracted spectra need to be analyzed.

The observed dependence of the sample identification condition on the type of paper and the type of contaminating substance as well as its concentration confirms the influence of the paper-substance interactions on spectral characteristics. It can be concluded from the results presented in the paper that effectiveness of library search and thus effectiveness of the identification procedure for examined soiling substances can be improved by selecting spectral regions where characteristic absorption bands can be expected. In order to retrieve the soling substance from the paper sample the algorithm for subtraction NIR spectra of samples with specific properties must be optimized.

5. Acknowledgements

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MARBLE AS BUILDING VENEER: CASE STUDIES ON ITS BOWING POTENTIAL

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1. Introduction

When slabs of a marble façade deform after few years of exposure, the owner of the building or the responsible person will have to decide, how long the slabs can stay on the façade without jeopardizing by-passers (Figure. 1a, b, c). Usually, there are two contradictory interests. On one hand, stability of the marble slabs must be guaranteed even with a strong wind load. On the other hand, the owner would like to save money and therefore tries to initiate the required measures as late as possible but as early as necessary. That is why long-term prognoses are valuable information for the owner of the building.

In the following it is discussed, with the SUB (State and University Library Göttingen) building as an example, what the results acquired can tell us about the long-term stability of a marble façade. The comparison between the bowing of the years 2000 and 2003 definitely proves that the weathering process combined with an irreversible deformation (expansion, bowing), disaggregation of structures and loosening, proceeds continually. Therefore it has to be decided, at what time the stone is not strong enough any longer and the structural safety of the marble slabs cannot be guaranteed any more.

A very important indicator is the mapping of the building, which is an essential part of the anamnesis of the damage observed. The relative occurrence of visible damage can also be used as an indicator for the intensity of the damage. With the SUB building it could be observed that the percentage of the slabs suffering from cracks or breakout increases with the degree of bowing. Petrophysical investigations of slightly and strongly deformed façade slabs or slabs, coming directly from the quarry, found that the bowing tensile strength and the breakout strength at the anchor mandrel is reduced all the more the stronger the bowing, e.g. for the SUB resulted that the flexural strength of slightly or not deformed slabs is reduced from approx. 12 MPa to less than 4 MPa with strongly deformed slabs. That means, that e.g. at the SUB building every forth slab (26%) with a bowing of >11 mm/m has cracks or breakouts. In the year 2003, however, this was not yet dramatic as only 3.1% belonged to the highest bowing class. Limiting parameters were calculated for the most common slab format 104 x 74 x 4 cm combined with the static calculation of the wind load. In order to calculate the back pressure which is included in the calculation, a height of 8-20 m on the building was assumed according to the German Industrial Standard DIN 1055. Accordingly, the bowing load to be expected is 0.8 MPa and the critical anchor breakout load 0.31 kN. The observations of the Carrara marble made at the Finlandia hall in Helsinki by Mustonen et al.[1] provided a basis. According to these observations, a reference specimen form 1970, directly from the quarry had a flexural strength of 50 MPa. In 1984, the decrease of flexural strength observed of 26 MPa corresponded to a bowing of 6 mm/m. In 1991, bowing was already at approx. 10 mm/m with a flexural strength of less than 10 MPa. Actually, this value may differ with other types of marble, as shown by Siegesmund et al.[2,3]

Obviously, the decisive problem is the change in the stone structure and thus the loss of solidity occurring together with the deformation of the slabs. The detected ageing process has not been provided for in the current standards. The petrophysical tests are clearly determined and demand checks according to EN 1469: petrographical description (EN 12407), optical appearance (visual check), flexural strength (EN 12371 or EN 13161), breakout load at the anchor mandrel (EN 13364), apparent density and open porosity (EN 1936) as well as frost resistance (EN 12371). The example of the presented marble façade s show, that the demanded tests are not sufficient to consider all the complex factors (this may be true for other types of natural stone as well).

Although the same mechanisms might be valid for all types of natural stone, deformations, i.e. bowing, occur a lot more often with marble. The most important difference to other types of natural stone is based on the extreme thermal characteristics of its main minerals, calcite and dolomite, having a high anisotropy of the thermal expansion compared to other rock-building materials, causing high internal tensions inside the marble depending on the weather and favouring a de-cohesion of the grain structures. Thermal and later thermal-hygric weathering processes play the most important role, at least at the beginning. According to the published investigations frost resistance seems to be another problem. There is still a lack of further detailed analyses, though. Generally it must be assumed that the discussed deformation processes generate a network of microcracks along the mechanically weaker zones of the stone such as grain edges, crystal-internal surfaces as well as discontinuities comprising several grains. The more cracks causing porosity occur, the more weathering mechanisms based on the influence of water, such as solution processes or frost blasting inside the stone, come along. When the pore volume increases, the marble expands inevitably. If the degree of expansion is unevenly distributed in a marble slab, it will bow. That means, bowing can be primarily considered as a special form of expansion caused by microcracks. Moreover, constraints and crystal plastic deformations may be another cause for bowing, suggesting the slab bowing is an indicator for residual expansion and thus for the disaggregation of the grain structure by thermal and hygrically induced mircrocracks.

Therefore, it is influenced by the same structure parameters, which play a role in the expansion behaviour. That means, their anisotropy is influenced by the texture as well as the orientation of the grain edges.

Figure 1: (a) Finlandia City Hall in Helsinki with deformed panels made from marbles, (b) Details of strongly deformed Façade cladding made of Carrara marble from Finlandia Hall in Helsinki.

Bowing (in the laboratory as well as on the building) is a function of the slab thickness. There is no doubt that bowing and thus the disaggregation of the structure and the residual expansion is a lot more distinct with thicker slabs than with thinner ones. There are extremely bowed slabs with a thickness of approx. 7-8 cm on the Munich cemetery Südfriedhof.

Summarizing the results presented by us, we would like to advise to carry out adequate investigations in advance in order to check e.g. whether a certain selected type of marble is suitable as façade cladding. This can be done by means of the investigation of the thermal-hygric characteristics and by the analysis of the bowing potentials. This analysis has already proven itself for the assessment of the structural safety of façade s which have already been damaged, as due to this kind of experimental assessment the bowing progress can be determined. Based on this information, damaged slabs can be checked regarding their mechanical properties and they can be used for long-term monitoring in connection with static evaluations.

Finally it can be stated that façade slabs made of natural stone are no safety hazard. However, an adequate assessment of natural stone and a qualified analysis are essential. The results presented here within show that natural should by no means be selected only according to its colour and pattern.

Figure 2: Lower Saxony State and University Library (SUB) showing a pronounced bowing of marble panels.

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ASSESSMENT OF THERMAL RESPONSE AS TOOL FOR SUSTAINABLE MANAGEMENT OF HERITAGE BUILDINGS

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1. Introduction

Considerable scientific effort and financial resources are involved in conserving historic buildings and in creating appropriate indoor climate conditions and thermal comfort for users, visitors, exhibited objects, restoration works and the building itself. In order to investigate the impact of different heating strategies and to adjust the indoor climate conditions to actual needs the analysis of thermal behaviour of building is necessary.

Analyses are based on a computer simulation such as the advanced PHYSIBEL[1] simulation tool that enables combined analysis of determination of the temperatures in the building substance and determination of the resulting indoor air temperature and energy demand.

2. Simulation of thermal response in Brežice Castle during occupancy

In the renaissance Brežice Castle (16th century, SE Slovenia) occasional surface condensation on cold walls was assumed to be one of the most important reasons for deterioration of the 18th century wall paintings on the walls and ceilings.

There was a lot of interest in giving concerts and short – term exhibitions in the Knight's Hall, but the microclimate measurements in the Knight's Hall demonstrated the risk of cold wall condensation during events. Therefore in Brežice Castle, wall tempering[2] was considered in the arms exhibition room, to reduce relative humidity, and in the Knight's Hall, to prevent surface condensation risk and its impact on fresco deterioration. To guaranty the expected impact of the wall tempering a temperature distribution in the building was simulated.

2.1 Temperature field in Tower

The simulation of temperature profiles in the walls and in the indoor spaces of the tower was based on assuming radial symmetry of the auditorium. In the vertical cross-section, the unheated cellar, wall-tempered room in the first floor and unheated exhibition room in the second floor were modelled. Steady-state conditions were assumed for the simulation due to the size limitation of the calculation model. The boundary conditions used for simulation correspond to the measured temperatures.

One of the important factors for the accuracy of the simulation is the indoor air exchange rate. The better the insulation of the envelope, the bigger the impact of ventilation losses and vice versa. In Brežice Castle the air exchange rate has not yet been monitored.

Taking into account the average air tightness for new windows and the measured air exchange rate for similar heritage buildings, an air exchange rate of 0.9 h^{-1} was assumed for the simulation.

Simulated surface temperatures were in general lower than the measured values. Simulated indoor air temperatures are very sensitive to the indoor air exchange rate, which has already been indicated to be a critical datum. In the simulated case, the calculated indoor air temperature was 16 °C. This temperature is much lower than that measured 19.6 °C, so the assumed air exchange rate may be too high.

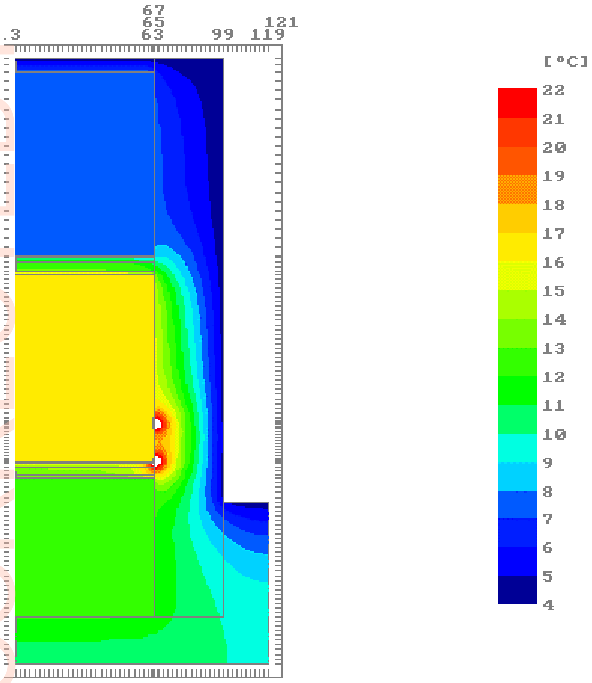

Figure 1: Simulation of the temperature field in Tower 1. Boundary conditions: *T* outdoor air 4.2 °C, ground temperature 10 °C, temperature of water in pipes 40 °C, distance between pipes 80 cm, simulated using PHYSIBEL – RADCON.

Most likely, however, there is additional reason for the difference between the simulated and measured indoor air temperatures. In spite of relatively firm arguments for a steady-state simulation, in reality there are inevitably moderate daily temperature oscillation and passive solar gain. These dynamic processes were excluded in the above case, although one could integrate them into the model in a simplified way if measured climate data were available. Thus, a basic requirement for future simulations is reliable data for the air exchange rate.

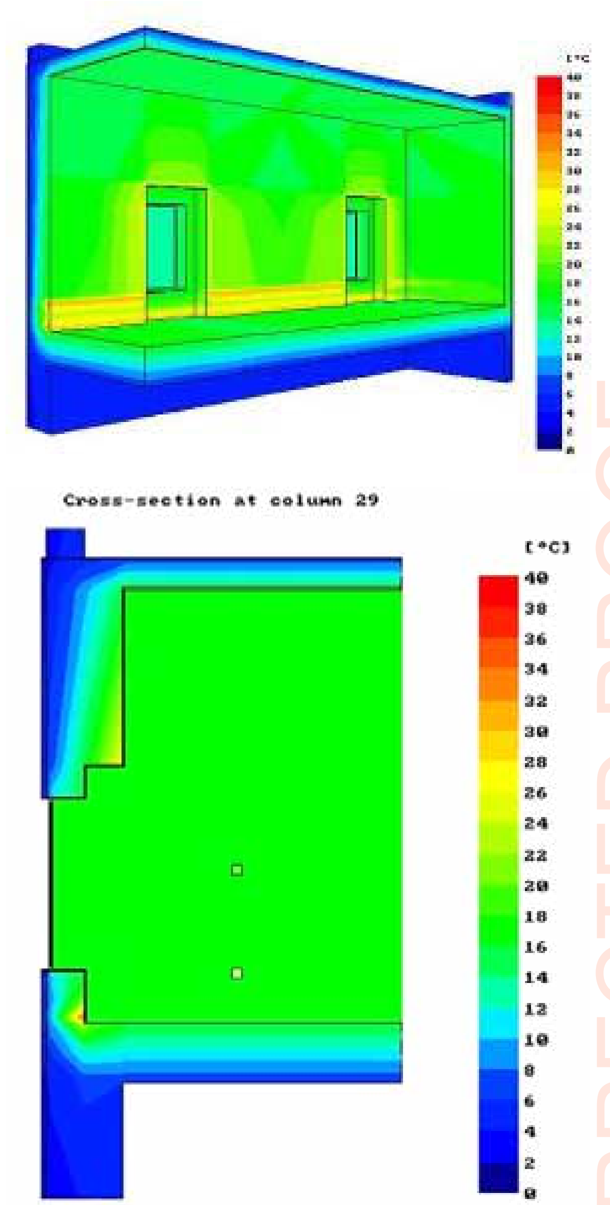

Figure 2: Vertical cross-section of the 3-dimensional simulation model of Knight Hall (above), temperature field with position of two nodes for simulation of effective temperature (below).

2.2 Temperature field in Knight Hall

The large Knight's Hall stretches over the first and second floors of the east wing of the castle. The ground floor under the Knight's Hall is used as a wine cellar. The castle walls are massive stone masonry. The roof and ceiling structures above the Knight's Hall are made of timber beams which are covered with wooden boards thatched with reeds, which are in turn covered with multi-layer plaster.

The wall tempering system was designed in order to provide basic thermal comfort for visitors of occasional cultural events in the cold period of the year and to prevent cold wall surface condensation due to relative humidity raise caused by generated moisture. The boundary conditions assumed temperature conditions in the winter period. As already described, the ventilation heat losses were simulated by iteration, dependent on the difference between indoor and outdoor air temperature. With respect to the condition of windows and in absence of air exchange rate measurements the air exchange rate of 0.1 h^{-1} was assumed.

The results showed the equilibrium indoor air temperature of 16.1 °C. In order to finally show the desired influence of the warm surrounding walls, the effective temperature in certain nodes, 1.8 m from to the wall ware simulated. In the nodes of consideration, the black globe thermometer characteristics were modelled so that the simulated temperatures in those nodes represent the effective temperature which is an indicator of thermal comfort showing positive influence of warmer areas of surrounding walls, felt by a person in a room.

In the simulated winter conditions it was shown that the effective temperature is between 2.1 °C (lower layer) and 0.8 °C (upper layer) higher than the surrounding air temperature.

3. Thermal response of St. Nicholas cathedral during restoration works

Restoration techniques and materials used are subject to specific temperature conditions required for optimal results. On the other hand restoration works are often executed in the cold period of the year. In such conditions the restorers have to consider various strategies to assure appropriate thermal conditions for undisturbed completion of chemical processes and better thermal comfort for the workers.

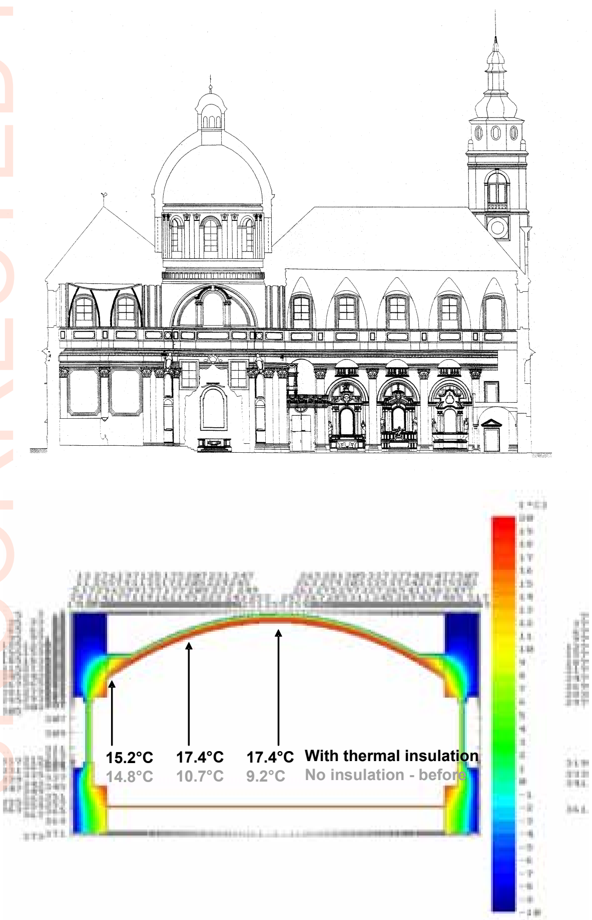

Figure 3: Cathedral St. Nicholas in Ljubljana, north view (Plans: ZVKDS, RC),[3] under the arched ceiling the separated restoration area (simulated) is indicated, Model of restoration area and temperature distribution in the arched ceiling with thermal insulation in the attics compared with no insulation case.

In 2002, the Slovenian institute for protection of cultural heritage - Restoration centre started extensive restoration (cleaning, preventive strengthening of colour layers, injection of cracks, chemical cleaning, retouch of paintings) of Gulio Quaglio paintings in the arched ceiling of Cathedral St. Nicholas in Ljubljana, a baroque church from early 18th century.[4]

Due to the functional reasons the temporary ceiling (5 cm boards) was installed to separate the restoration area from the main nave bellow. The ceiling acts also as a thermal barrier between the restoration area and the rest of the church. The following issues were seriously considered and supported by computer simulation of thermal conditions in the church: what is the relevance of additional insulation layer on the top of arched ceiling if the surface temperature of fresco paintings during restoration should be at least 16 °C (T_{min} =15 °C and T_{opt} = 18 °C for the applied chemical process); what kind of additional heat source is needed, if any; what will be the impact on summer conditions?

Assuming the outdoor air temperature -10 °C, indoor air temperature 18 °C, 12 °C in the nave below the restoration area and air exchange rate 0.5 h^{-1} with outside air and 0.6 h^{-1} with air in the nave bellow (after tuning the model with measured parameters), the surface temperatures in the arched ceiling were simulated as well as the need for insulation during restoration was justified.

Without additional heating the indoor air temperature can not exceed 9.2 °C, even if heat gains from lighting and convection heat gains from the heated nave are taken into account. An additional heat flux of 17 kW needed for maintaining the above indoor temperature of 18 °C in the restoration area was also estimated. In the summer conditions ($T_{out\text{-}air}$ = 26 °C, $T_{nave\text{-}air}$ = 20 °C, $T_{attics\text{-}air}$ = 30 °C, heat gains from lighting) the simulation showed the equilibrium indoor air temperature 24.9 °C, what was considered as acceptable for restoration works.

4. Conclusion

The accuracy of thermal simulations is subject to many data, which are often lacking in the real life of heritage buildings. Nevertheless, the case studies showed that simulation of thermal conditions in heritage building can be a reliable tool for supporting the decisions of building heritage management as well as of restoration and conservation experts. Using these results the heritage buildings management can make decisions for adequate preventive restoration strategies.

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POSITIVE FINDINGS IN LASER RESTORATION OF COLLAGENOUS STRUCTURES: LEATHER AND PARCHMENT

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1. Context

This paper is part of a broader study of the effect that laser cleaning has on collagenous composites, such as leather and parchment. Cleaning procedures applied to organic substrates of artefacts can be challenging due to their high sensitivity to external factors, their fragile nature demanding a high precision and accurate monitoring of the cleaning process.[1] Although laser cleaning applications for organic materials are quite circumvent, reported results show that the innovative technique has potential of contactless, chemical-free cleaning of historically important objects, providing an overall high accuracy and successful cleaning. The effect of laser light on this type of organic materials is still poorly understood, as is the effect of the wavelength or the energy density (fluence). This study was focussed on two lines of investigation of laser cleaning effects:

From the visual assessment and aesthetical point of view:
- *Colourimetry* - the CIE L*a*b* colour parameters and spectral characteristics allow us to monitor the surface chromatic differences working with the spectral signature of reflected light from the surface.
- *Microscopic* investigations in order to explore the characteristics of the samples surface structure - before and after laser cleaning, revealing any deterioration of the surface morphology that may be induced.

Probability of causing induced ageing:
- *Shrinkage temperature* – The micro hot table method[2] (MHT) utilizes the measurement of hydrothermal shrinkage observed when a sample is subjected to a controlled temperature dynamics.
- *NIR – Near-infrared spectroscopy* based on molecular overtone and combination vibrations.

2. Experimental aspects

All the samples were prepared in the same manner, artificially soiled with candle smoke in order to simulate the impurities that can be accumulated on historical and religious documents kept in various religious locations. The laser cleaning was made using a Q-switched Nd:YAG laser, that emits at the fundamental wavelength of 1064 nm and its three harmonics: 532 nm, 355 nm and 266 nm.

The *leather* samples comprised in this study – 3 cattle and 2 calf - were crafted using old traditional methods on the basis on different tanning components (Mimosa, Chromitan, Quebracho). In Figures 1 and 3 we present extracts of the investigation charts.[3]

In the case of *parchment* we worked with 4 samples (lamb, goat and calf), subjected to the same investigations as the leather ones.

3. Conclusions

The paper reports a synthesis of a large study regarding the behaviour of the leather and parchment samples after laser cleaning protocol of restoration-conservation. Several cases have been validated based on morphological evaluation of old leather, mainly from libraries or book – restoration workshops. For the first time an advanced study is done on a large series of fresh samples crafted following traditional guidelines.

After macroscopic control and aesthetical evaluation of samples with efficient cleaning (with over 75% efficiency), they have been tested in view of induced ageing effects. The results prove that with a proper selection of the laser regime the fibril structure is preserved and no laser-induced ageing is present. Also, positive results were obtained by NIR that shows no modification of collagen catena.[3]

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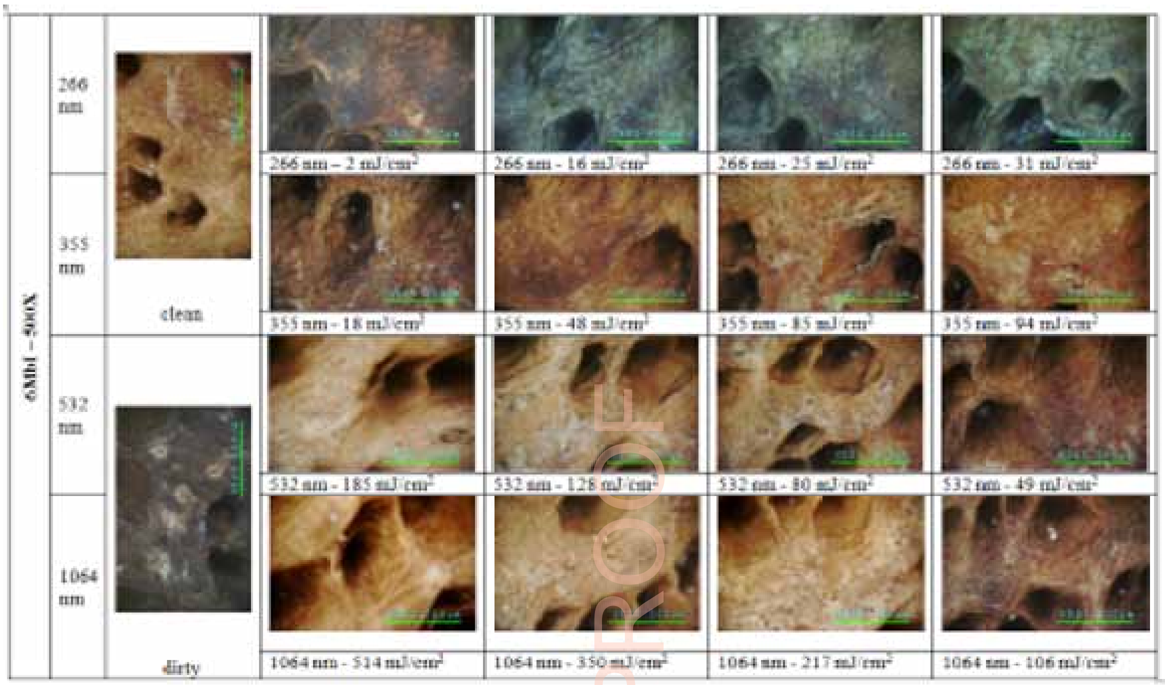

Figure 1: Optical microscopy images of sample 6MbI - cattle, combined tanning: 4% Chromitan (mineral tanning) [1% Cr_2O_3] + 15% Mimosa (vegetable condensed tanning).

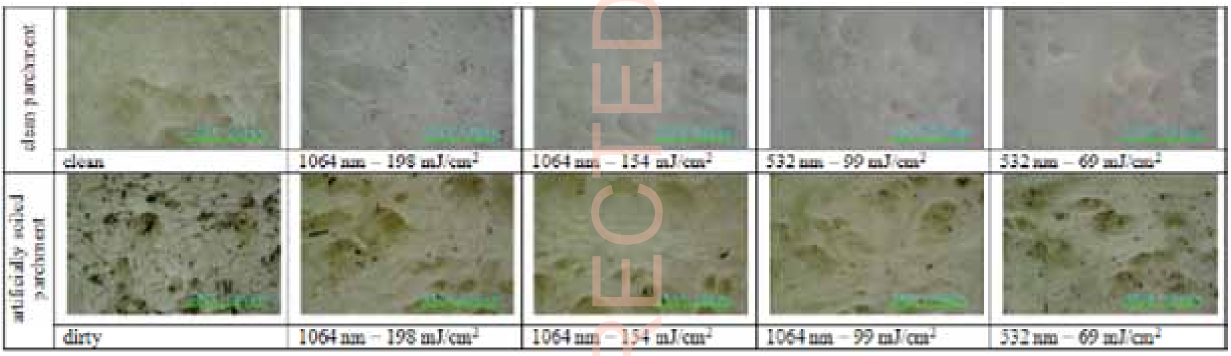

Figure 2: Optical microscopy images of parchment sample 1.

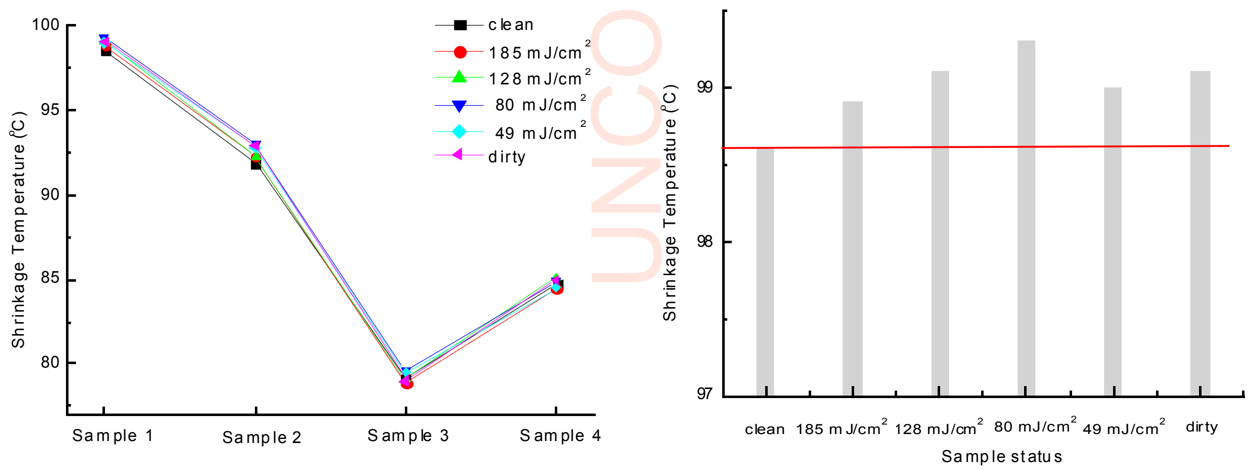

Figure 3: Shrinkage temperature characteristics corresponding to laser cleaning regime that used the 532 nm wavelength (left)- for all samples irradiated at 532 nm, (rifght) - for sample 1.

STUDY OF THE SOLUBILITY AND MIGRATION OF INKS IN MANUSCRIPTS WITH ICP-MS AND ADDITIONAL DATA FROM FTIR

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1. Introduction

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1. Introduction

Black and brown inks used to write manuscripts are frequently iron gall inks. These inks were mostly prepared with extract from tannins and with iron(II) sulphate, which can also contain some cooper and zinc depending on quality and source.[1] Agglutinant is always gum Arabic, because the protein flocculates with tannins. Gum Arabic is of vegetable origin. It maintains and thickens the suspension of ink. Potassium can also in the ink as an additional ion, introduced mainly by gum Arabic. The acidity and the presence of catalytic transition metal ions lead to enhanced degradation of the ink and the paper support.[2-3] A thorough understanding of the composition of the ink, and the degradation processes it induces still present a challenge.[4-6] Because of the complexity of factors that contribute to degradation, it is not easy to obtain data from inks and its corrosion process without destroying or damaging the original samples.[7-9] We have opted for Laser Induced Coupled Plasma Mass Spectrometry (LA-ICP/MS), because it gives us an insight into the elements present in the ink and paper with minimum degradation of the originals. We have focused on the evaluation of solubility and migration of Fe, and Cu ions from the ink, when paper is immersed into water or 20% v/v aqueous solution of alcohol. The initial composition of the inks was characterised using Fourier Transform Infrared (FTIR) technique. Spectrum of the ink together with pH and other physical parameters like thickness, g/m^2, sizing and fibrous composition of paper permits to characterize the sample before the treatment.

2. Experimental

a) Sample from original manuscript: designation A, (M-98); 19th century; pH 5.46; 65 g/m^2; thickness 120 □m; fibre composition: linen 60%, hemp 40%; similar to sulphite treatment; sizing 20% gelatine.

b) Treatment: The sample was soaked in deionised water (Millipore) or in aqueous alcohol solution (20% v/v). Process with bath was applied by using large excess of solvent during five minutes and was followed by short drying under light weight (0.8g/cm^2) for 10 seconds, with the samples placed between reemay folded with blotting paper. After this, the samples were air dried.

c) Techniques:
- Before treatment, inks were characterised with FTIR (Figure1). (Bomen MB-120, Spectratech Plan Microscope with MCT detector) Diamond cell and microscope were used to characterise a small particle of ink.
- Before and after the treatment, the samples were studied using LA-ICP/MS. Energy of each laser pulse was around 1 mJ and the diameter of irradiated area was 100 µm (laser: Nd:YAG 266 nm, Bio Laser, GERM, Gaussian Mode, 20 Hz; ICP: Perkin Elmer ELAN 6000).

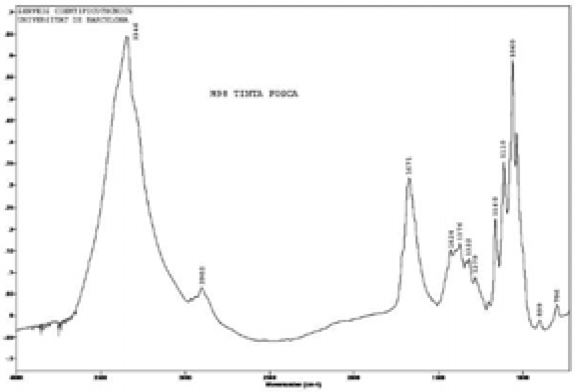

Figure 1. FTIR spectrum of ink **A**

3. Results and discussion

With FTIR spectrum of sample before treatment we identified cellulose, but some bands could be assigned to iron potassium oxalate, iron oxalate, and calcium oxalate.

Normally, 3-5 lines, perpendicular to the ink were analysed using LA_ICP/MS (Figure.2). The technique permits to identify inorganic elements in the ink (mostly Fe, Cu, Zn, K) and in paper (mostly Ca, Mg, Al), their distribution, consequently, their migration as a consequence of a treatment (Figure.3). In this study, more than 50 lines have been analysed for each stage of the treatment (before bath, after water bath and after water and alcohol bath).

Focusing the discussion on the manuscripts, the results obtained show that sample A (M98) includes iron and, in a minor proportion, cooper. The distribution of these elements decreases drastically with the distance from the line. The analyses also show the presence of calcium and magnesium in the paper. It is interesting to remark that for these elements, the signals are more intense when the analysis is located on the ink line. It is also interesting to point out that whereas calcium signal decreases with as we move away from the ink, as is the case iron and copper, magnesium signal is strong also far away from the ink.

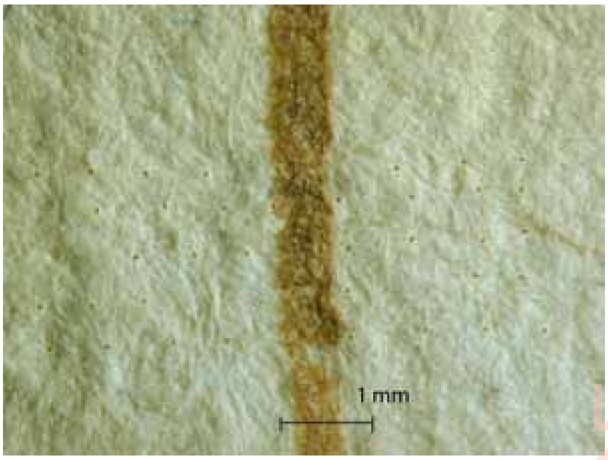

Figure 2. Lines of spots with LA-ICP/MS. 20X

In general, it has been observed that the signals for iron and copper in the ink line decrease after the bath for about one order of magnitude and no changes appear in the distribution of the signals outside the line. Similar results are obtained for magnesium, which maintains an important signal far from the ink line. However, after the bath, the signal of Ca is undetectable on the ink or away from it.

Low repeatability of measured data between replicates probably due to the low concentration of the different elements in the ink and in the paper, and also to the heterogeneous distribution of the elements in the ink and paper. This distribution together with size of the spot of the laser (100 µm diameter) led to fact that the signals obtained in each determination depend on the number of particles, if any, which are included in the ablated area. Heterogeneity is a constant in artworks composition and the analytical methods must take into account this fact. Conditions of analysis must be specifically defined for each type of artwork and in this case, series of analysis are necessary to obtain representative results. An alternative would be to increase the area of the ablated spot.

Finally, it is interesting to stress that the application of a bath to the manuscript produces a huge decrease in the signal obtained for the different elements related to the ink and the paper. This is especially important for calcium.

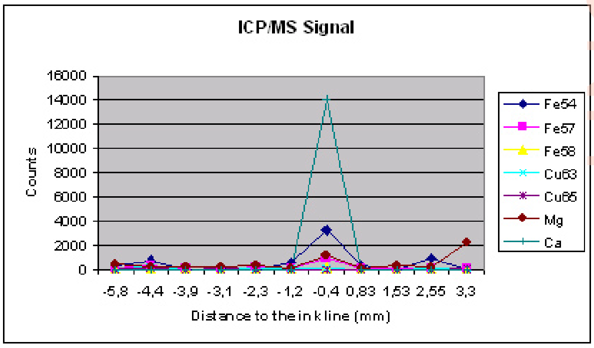

Figure 3. Signal distribution of elements before bath in sample **A.**

4. Conclusions

1. LA-ICP/MS is a good technique to be used for identifying inorganic elements in manuscripts. It is possible to get a map the distribution of Fe and Cu in the ink line and in the zone of migration.

2. The technique permits to test the distribution of elements after using generous bath with solvents with different polarity, and to distinguish between dissolution and migration of the dissolved components of the ink.

3. Facilitates the study of interaction between components of the ink and solvents with different polarity.

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THE EFFECT OF AIRBORNE AMMONIA ON THE DETERIORATION OF MURALS

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1. Introduction

During the last 60 years a number of Danish farms have greatly expanded their production of livestock and for this reason the concentration of airborne ammonia in many Danish rural areas has increased significantly. The Danish National Environmental Research Institute (NERI) has measured an increase in ammonium concentrations in the atmosphere and precipitation of 250% over the past 110 years, and the increase in ammonia concentrations is a bit more than that.[1]

In the same 60 years, many murals in Danish medieval churches indeed over all of Europe have undergone appreciable deterioration.[2] This deterioration is originating from mechanical stress, as parts of the murals crumble or flake off of the surface on which they are painted (Figure 1). Mechanical stress may be introduced to the walls in several ways, where one is unfriendly heating resulting in cycles of swelling and shrinking of the plaster due to water movement and evaporation to dryness. The presence of salts is also prone to cause stress, as cycles of crystallization and dissolution may cause chemical alterations in the bonds between the whitewash and the paint layer. These are well known factors and builders are advised not to whitewash surfaces that contain high amounts of salts, ammonia residues, or are very humid.[3] We, however, investigate whether or not a correlation between the increased ammonia concentration and the deterioration can be demonstrated.

Figure 1: Murals from Gjøl Church, Denmark. The murals in the arch to the right have deteriorated completely leaving only blank whitewash to the spectator.

The main hypothesis under investigation at the moment is that it could be expected that increased airborne ammonia concentrations would lead to increased production of micro organisms such as fungi and bacteria in the walls and the murals, and thus leading to increased deterioration. Micro organisms have been found in many churches, mural and other historical buildings, and it is to be expected that they have a certain influence on the degree of deterioration. Just by respiration the organisms will excrete carbon dioxide that converts to carbonic acid when resolved in pore water. The binding of whitewash and pigments to the surface rely on a high pH value, and excretion of acid could undermine the binding making the plaster flake or crumble. Micro organisms that can utilise ammonia as a nutrient include the nitrifying bacteria. These bacteria convert ammonia and ammonium to nitrous and nitric acid, thus adding even more acid to the basic environment. Furthermore they thrive at high pH values[4] and are very abundant. Doichinov and Khadzhivulcheva found nitrifying bacteria in 70% of their samples of a mural,[5] and Bock et al. found that these bacteria make up the largest group of micro organisms in the Schlaitdorfer sandstone in the Kölner Dom accounting for up to 80% of a population and reaching at least 5 cm into the stone.[2] If there is just as many in the Danish churches they could pose a serious threat to the murals and an estimation of the nutrient level is called for. Presently we are measuring airborne ammonia, temperature and RH inside and outside ten churches in Denmark. The ammonia is collected by passive diffusion samplers (ALPHA) and analyzed by ICP. The lives of micro organisms are dependent on the temperature and RH of the environment and by measuring this we can estimate how well they might live in the churches of interest. Micro organisms will thrive at a RH greater than 65%, and that condition matches half the churches in this investigation. An average RH lower than 40% does not occur in any of the churches.

For churches near pig farms it was expected that the outdoor concentration values would be much higher than the indoor values. However, our preliminary measurements show quite the opposite: higher concentrations indoor than outdoor. The churches appear to have a higher base line indoor than outdoor but fluctuations in the concentration seem to be coinciding. Some of the excess ammonia is speculated to originate from cleaning agents. One of our measurements clearly shows the polishing of the chandeliers inside Nr. Broby church with Brasso®, a cleaning agent with a high content of ammonia. Some future work will include the comparison of the passive sampling with an active sampling form. Statistical work involving the measurements, number of church goers, airing of the churches and more is planned along with the determination of micro organisms living in the churches of interest.

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INTEGRATED NON-INVASIVE ARCHAEOLOGICAL RESEARCH: FROM BASIC RESEARCH TO CULTURAL HERITAGE MANAGEMENT

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1. Introduction

Within the field of archaeology, conceptual innovations and new goals set, most explicitly since the 70s of the 20th century, have engendered a wide array of new tools capable of capturing and processing information on the site and regional levels[1]. These developments were triggered also by the new technologies at hand for the detection of surface and sub-surface archaeological features, and have been greatly facilitated by the breakthroughs in information technology, both in field data collection and recording, and in data retrieval, analysis and visualization[2]. While academic institutions, often and increasingly in synergy with small and medium enterprises, are to be credited for the core of these innovations, introduced as they were and tested as part of their basic research in field projects across Europe and the Mediterranean, they are clearly of great consequence for the management of archaeological heritage. The potential of the new tools has now been recognized by the bodies entrusted with heritage management: non-invasive approach to archaeological research is privileged and recommended by European charters, which tend to limit excavation to unavoidable cases of imminent destruction in face of urban development and infrastructural projects[3]: on the other hand, Archaeological services are increasingly recurring to remote sensing, both airborne and ground based, and to systematic surface survey such as developed within field projects since the end of the 70s, mainly as part of preliminary assessments in areas to be developed and invasively investigated before construction. More holistic and integrated approaches are rare within the heritage community, and not uniformly present in European countries[4]. While generally, such trends are undoubtedly positive, future policies should to our opinion both establish the capabilities within the Heritage services to apply non-invasive techniques to goals beyond those currently prevailing, and honour the importance of basic research within academia to further develop the concepts and tools necessary.

2. Research

Since the 80s, the Ljubljana University Department of Archaeology has been testing non-invasive research on sites and landscapes in a number of projects, in Slovenia[5], Croatia[6] and Greece[7]. Building upon the experience accumulated in bibliographic survey such as organized by the Slovenian Academy of Arts and Sciences in the 70s, and following current trends in the world, also by establishing joint research with foreign colleagues, we developed necessary competences in the field. The common thread of this research has been to integrate data layers acquired by various techniques so as to be able to analyze them jointly and build new knowledge at the interface between sets of archaeological data, and against environmental data. Since all projects were low budget, the development was slow, there were many discontinuities, and new institutional focuses of research emerged along the way, independent of the Department. The success of the endeavour very much depended upon the energy and quality of the students and young researchers involved.

The tools permitting integration and analysis of data layers were thus of special interest within our scheme. A first GIS based study was conceived in 1989 within the joint Split / Ljubljana / Bradford research on the island of Hvar by Zoran Stančič and Vincent Gaffney as part of their PhD study, supervised in part by Kenneth Kwamme, then of Arizona University[8]. The study of the archaeology of the Karst region in Slovenia by Predrag Novaković followed since 1993, building upon earlier settlement studies by Božidar Slapšak there[9]. GIS is now taught as part of the undergraduate curriculum and employed regularly by our students.

Besides systematic surface (ceramics) survey, fully acquired through synergy with John Bintliff, then of Bradford University[10], structural survey was developed to document landscape features such as on the island of Hvar[11] (Figure 1), and urban structures such as in Tanagra[12]. Both have permitted analyses of modular composition and metrology of the structures involved. Qualitative architectural studies and special surveys such as architectural fragments survey have also been deployed to complement structural survey.

A first differential GPS survey was also done within the Hvar project, in 1995 by Jure Mlinar, supervised by Andrej Bilc of the Ljubljana based Geoinformatics co., and permitted to reconstruct the surveying procedure used by the Greeks in laying down the regular grid of the land division in the chora of the early 4th c. BC Pharos colony[13]. Differential GPS is now regularly used wherever precision control must be established in surveying over extensive areas, such as ancient cities and landscapes.

Surface morphology study was developed in 1993 in difficult woodland environment at the site of Rodik, with excellent results, permitting as it does to read clearly the urban organization of the Late Roman settlement there[14] (Figure 2). Andrej Bilc has applied also lidar scanning of the prehistoric landscape of the Ljubljana Marshes, with Mihael Budja and Dimitrij Mlekuž[15].

Ground based remote sensing was first experimented with at the Department in the late 80s in collaboration with the Bradford team, with Chris Gaffney, Vincent Gaffney and Andy Waters. Since 1990, the Department has developed its own capabilities and Branko Mušič successfully applied geophysical prospections using a number of techniques both in contract work and within research projects, with some spectacular results such as in the ancient city of Tanagra[16] (Figure 3). Younger colleagues have now taken over within our Greek research.

Airborne remote sensing is developed at the Department by Darja Grosman, active member of the Aerial Archaeology working group of the Europae Archaeologiae Consilium[17]. Aerial reconnaissance and vertical photogrammetry applied in Greece are giving excellent results, including a surprisingly informative first map of the lower city of Haliartos (Figure 4).

3. From research to heritage management

Such research experience and the methodological expertise developed and formulated as part of the undergraduate curriculum by Darja Grosman, opened way to involving the Department of Archaeology in conceptualizing archaeological research within the major infrastructural project of the 90s, the motorways in Slovenia. Bojan Djurić was nominated head of the project body (SAAS), and Darja Grosman and Predrag Novaković were entrusted with developing the methodology for preliminary assessment of archaeological potential[18]. The methodology proved highly successful and permitted timely detection and identification of virtually all sites along the motorway corridors, thus enabling the investors and the Heritage service to avoid many conflict situations, make changes where necessary, and minimize the cost of rescue operations. In 2006, the authors were then charged by the Ministry of Culture to formulate minimum standards regarding all rescue operations in Slovenia, this time jointly with Matjaž Novšak and Rene Masaryk of the Arhej contract archaeology group - a typical development reflecting the methodological and operational competence built up in the meantime within the newly established independent rescue archaeology enterprises. Bojan Djurić is also involved in the establishment of the Center for non-invasive research at the Institute for the protection of cultural heritage.

Another case worth mentioning is the listing of the regular land division in the chora of the Greek colony of Pharos on the island of Hvar among Unesco World Heritage Sites in 2008. Initiative of the Croatian Ministry of Culture[19], this listing was to our understanding facilitated by the body of knowledge accumulated by the research project in which the Department has been involved, together with the Croatian and other colleagues, and by the tools developed, permitting as they do easy control of relevant data and visualization of the heritage area, and therewith its appropriate management.

4. Conclusions

Evidence from non-invasive research is by now admitted by the Archaeological services as documentation upon which legal protection of archaeological heritage can be established. Heritage services are increasingly recurring to such research to acquire the data necessary to assess the archaeological potential of the areas under threat: extensive use of geophysical prospections in on-site situations is a typical case in point. There is more to non-invasive research though, and on the other hand, the role of the Heritage service does not end at the edge of the land plot under development. Building up capabilities within the Archaeological service to carry out non-invasive research should open way, through systematic recording of archeological features within their area, on both the site and the landscape levels, for comprehensive understanding and control of the overall archaeological heritage there, and therewith enhance their active role in urban and regional planning and in developing strategies of heritage management.

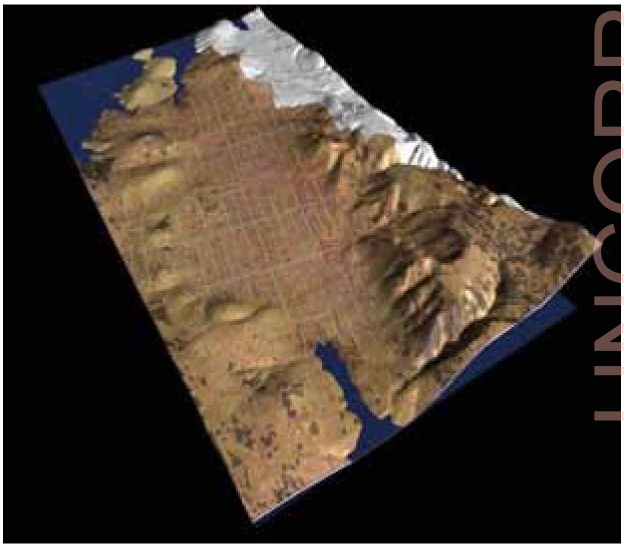

Figure 1: The regular land division in the chora of the 4th c. BC Greek colony of Pharos, Island of Hvar, Croatia regular grid and archaeological sites against 19th c. cadastral map on DTM (visualization: M. Erič)

Parallel to that, the role of basic research within academia must be fully acknowledged. At one hand, basic research projects are typically the space of experimentation and methodological innovation, by definition too risky for user dependent applicative research. On the other, the body of archaeological knowledge needed to meaningfully develop strategies of archaeological heritage management, is typically developed within academia. For both reasons, European research policies regarding archaeology need to be revised, so as to support knowledge-oriented field projects. Methodological awareness is a criterion of good scholarship, and will engender innovation even if the applicability of the tools deployed beyond the goals set for the project is not expressly stated. Heritage is by default the medium of archaeological research: its protection and management would profit by such policy shift greatly.

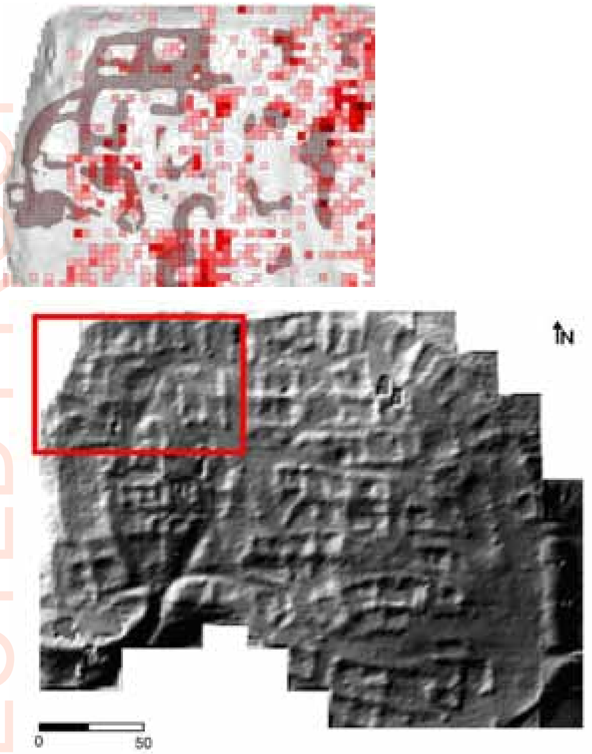

Figure 2: Surface morphology of the Late Roman settlement on Ajdovščina above Rodik, Slovenia; above, surface architectural features and ceramics distribution overlay in the NW part of the site

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Figure 3: Magnetometry map of the ancient city of Tanagra, Greece, against aerial photo (geophysics: B. Mušič)

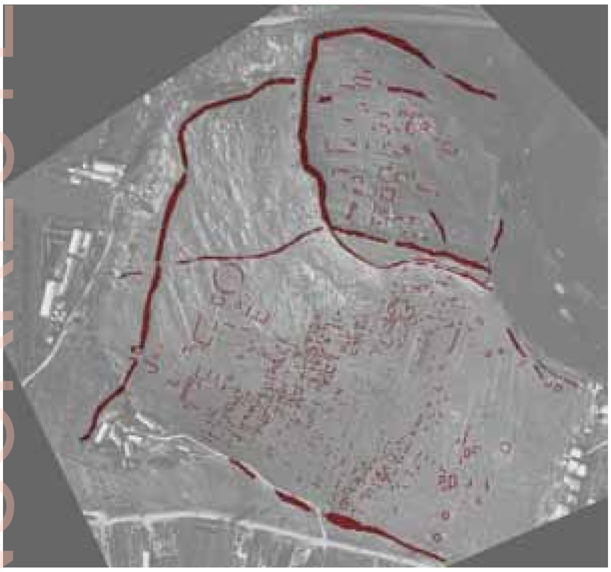

Figure 4: Urban structure of the ancient city of Haliartos, Greece, from aerial photography (D. Grosman)

RED PIGMENT'S DIAGNOSTIC BY LIBS AND LIF TECHNIQUES AND DETERMINATION OF INFLUENCE OF LASER RADIATION @1064NM ON THEM

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Laser cleaning of the artworks have proved many advantages over the classical cleaning techniques.[1] Using this technique there is no alteration or modification suffered by the objects' surface structure, the cleaning efficiency is much improved and final result is the esthetical aspect of the subject. This can be obtained only if using the optimal laser radiation parameters for each given situation. For example, it has been observed that several sorts of red pigments are highly sensitive to specific laser wavelengths.

In this paper, it is studied the characterization of the red pigments using the LIBS (Laser Induced Breakdown Spectroscopy) and the LIF (Laser Induced Fluorescence) technique.[2] The resulted information contains data on the pigments' chemical structure, using 355 nm laser radiation, and their fluorescence spectrum, obtained after 266 nm laser irradiation, both of them in Q-switched regime. These inter-complementary data will make possible a diagnostic of the pigments from in-situ objects cleaned using the laser technique. The identification of these pigments would allow us to take a better decision regarding the viewpoint of laser cleaning for the inquired objects or some of their areas, as well as regarding the optimal laser working parameters for the cleaning.

This way, the use of lasers in the artwork restoration will experience a great improvement.

1. Results

1.1 LIF spectra of red pigments

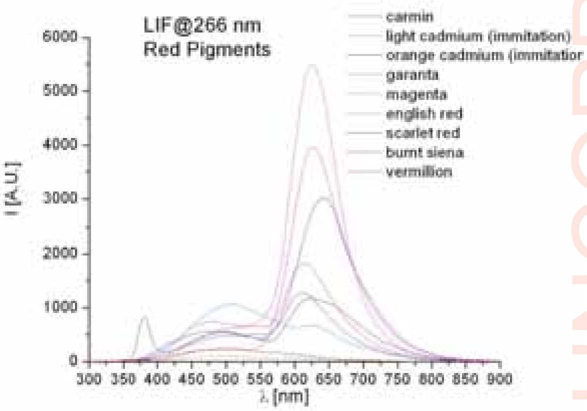

Figure 1: LIF spectra of red pigments

Table 1: The LIF picks.

	380 nm	420 nm	475 nm-510 nm	550 nm	600 nm – 640 nm
Carmin	x		x		X
Light Cadmium			x		X
Orange Cadmium			x	x	X
Garanta			x		X
Magenta		x			X
English Red			x		X
Scarlet Red			x		X
Burnt Siena			x		X
Vermillion			x		X

1.2 LIBS results

1.2.1 English Red Pigment FeO

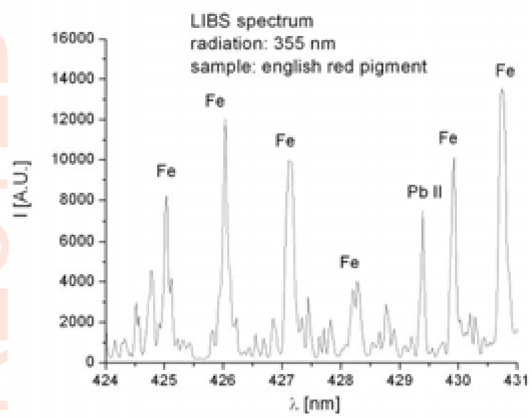

Figure 2: LIBS spectra of English Red Pigment FeO

Chemical elements found: Fe, Ba, Co, Cr, Mg. Mn and Ti.

Except for the constitutive Fe element, the Ba element is often used in pigment composition, and the other elements are probably from the deposition layers.

1.2.2 Burnt Siena pigment – FeO

Chemical elements found: Fe, Ca, Co, Cr, Mg, Mn, Ni, Ti, Zn

Except for Fe as a main element, there were also found some other Sienna Earth elements, which consists this type of pigment.

1.3 Pigments' irradiation tests

There was made an irradiation test on these pigments with the paintings' laser cleaning regime, at 1064 nm with a fluency of about 0.3-0.4 J/cm^2. The non-organic pigments are clearly altered; the irradiated area is getting darker, while the organic pigments remained un-altered.

2. Conclusions

The LIF analysis on pigments showed that the red pigments can be identified using their LIF spectrum peaks, shape and intensity. Carmine and Magenta pigments have peaks in the spectral bands at 380 nm and 420 nm, which are different from other pigments and therefore they can be easily identified. In the 475-510 nm and 600-640 nm spectral bands, all the pigments present peaks (except for magenta at 475- 510 nm), that is why the identification must be done using the peaks' shape and the difference of intensity between two different areas.

With the LIBS measurements there have been detected constitutive elements, like Cd or Fe, which allow us to determine the pigment type. The irradiation test showed that the non-organic pigments suffer a color alteration flaw, unlike the organic pigments. Therefore, the LIF and LIBS analysis are an important factor in taking the decision regarding the cleaning of the areas containing red pigments.

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DIAGNOSIS OF HISTORICAL STRUCTURES BASED ON DYNAMIC MEASUREMENTS – RESEARCHES OF CENTRE FOR URBAN CONSTRUCTION AND REHABILITATION CURE

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Abstract
The paper presents possibilities of application of modern structural health monitoring methods in cases of historic buildings. Three different cases have been selected to the analysis. They are all massive masonry historic buildings: the archcathedral belfry in Vilnius, the tower in the Wisłoujście Fortress in Gdańsk and the Lowland Gate in Gdańsk. Nowadays they suffer from different 'civilization' or environmental influences. The structures are seriously cracked and the investigations have been planned to find the main causes of the present situation. The authors decided to apply the dynamic diagnostics methods, in which measured mode shapes or just time responses are used as the main information about the structural behavior. The measurements were conducted during environmental excitations supplemented by traffic, bells swinging or waives caused by ships. Few different approaches have been used in the analyses, which allowed the formulation of several conclusions. First of all FEM modeling, natural frequencies calculating and comparing them with the measured ones gave information about building materials or settlement conditions. Secondly, comparison of the measured and calculated mode shapes enabled to identify the most defected regions. The modal curvature method has been used for this purpose. Finally, an analysis in the time domain leading to specification of dominant direction of the structural vibrations is described.

1.Introduction

In 2003, within the confines of Center of Excellence CURE, the programme of the European Union "City of Tomorrow and Cultural Heritage", the CURE leaders formed a partnership with, among others, Vilnius Gediminas Technical University and the Museum of History of Gdańsk. The cooperation provides a great possibility for mutual exchange of experiences and so far resulted in diagnostic researches conducted for selected monuments situated in Vilnius and in Gdańsk. The main methodological assumption in the Center's CURE activity is studying mathematical models, which reflect behaviour of historical buildings. In the authors' opinion, a rational modelling enables to find a reason of structural damage and to put a problem of prediction of the structural behaviour within time. Special attention is paid to non-destructive vibration testing of structures under ambient excitations as well as analytical and numerical approaches to damage detection and localization.

Modern mechanics provides almost unlimited possibilities for diagnosis of building structures. Knowledge of a specific discipline: dynamic diagnostics, which evolves since the last thirty years allows to determine changes in construction, for example: stiffness of elements' connections, settlement conditions, cracks occurrence or material cavities. It is obvious that early identification of such changes determines the structural safety. In dynamic diagnostics the basic information about the structural condition provide natural frequencies and mode shapes. In modern approaches, they are measured during environmental excitations, which act naturally on the structure, such as wind, traffic, water waves, technological processes, etc. In such a case one measures so called ambient vibrations. The specific procedures allow to filter out the structural natural frequencies from the whole measured spectrum and successively to specify the mode shapes' coordinates or the modal damping coefficients. The algorithms form a group named Operation Modal Analysis methods.[1] A comparative study of effectiveness of few of them in evaluating bridge dynamic properties from experimental data is presented in ref. 2. The authors compare the *peak picking* (PP), *frequency domain decomposition* (FDD), *rational fraction polynomial* (RFP) and *subspace identification* (SI) methods. Theory of those methods can be found for example in positions.[3-5]

Figure 1: Archcathedral Belfry in Vilnius.

Three monuments have been selected from the CURE library for discussion in this paper. They are all massive masonry constructions but they work in different environment, which involve various problems. The first one, situated in Vilnius, is the Archcathedral belfry (Fig. 1), the second is the tower in the Vistula Mounting Fortress in Gdańsk (Fig. 2) and the third one is the Lowland Gate in Gdańsk (Fig. 3). In those three case studies the authors wish to present a certain range of problems connected with diagnosis of historic buildings, starting from vibration measurements, interpretation of their results, parametric identification of numerical models of the structures and finally application of methods of defect identification. The role of vibration measurements as the main source of information about various elements of structural behaviour will be emphasized.

Figure 2: Vistula Mounting Fortress in Gdańsk.

Figure 3: Lowland Gate in Gdańsk.

2. Experimental

Presentation of the building structures

The Vilnius Archcathedral belfry (Fig. 1) was the first task. The structure is inhomogeneous as far as building material or walls' thicknesses are concerned, because it had been erecting during several centuries (from XIVth to XIXth). The lower part of the structure has circular cross section, thick walls (over 3 m) and small shooting windows. First three floors are built of stones and the fourth is of masonry. At the fifth, sixth and seventh floor the structure has an octagonal cross section with masonry walls about 1.3 m thick and large openings. Ceilings are built of wood with one except of a reinforced concrete floor between the 4th and the 5th floor built as a protection against bell falling down. The structural height without a covering helmet equals 41.4 m but the very top of the Belfry reaches 56 m. An external diameter at the tower's footing equals approximately 12.5 m.

At the sixth floor the new (from the year 2002) bells system is placed. It comprises of 6 heavy bells, electrically controlled. They hang on three massive wooden grids, crossing each other, supported on opposite walls. Next to the belfry a new road connecting two city's districts has been built lastly so there is increased traffic now. That two factors probably caused problems, as in each corner of the six floor one can observe lastly vertical cracks at least 0.5 cm wide and at about 3m long. There is then an assumption that the structure works in resonance during the bells swinging.

Another case is the tower of the Vistula Mounting Fortress in Gdańsk, masonry building dated in the XV century (Fig. 2). Many warfare and fires have destroyed the Vistula Tower several times. The latest disaster took place in 1953, when a hurricane has struck down 70% of the Tower, which was weakened after the Second World War. It has been rebuilt and nowadays diagnostic as well as conservation works last. The Tower is 22.65 m high, its external diameter is 7.7 m. The structure has 7 floors with reinforced concrete ceilings. Walls are built of masonry of various ages, because of many restorations. Walls thicknesses are: 1.45 m on the ground level, 1.2 m on the first floor and 1.1 on remaining ones. The Tower stands by the Leniwka River (actual name), on the layered ground, where damp or wet sands are alternated with aggregate mud. The foundation of the tower is only known to lie shallow below the ground level, made of boulders. This time the important issue was to specify the settlement stiffness, because the tower tends to bend aside.

The last case is the Lowland Gate in Gdańsk – historic masonry cubature building (Fig. 3), which was built in the year 1626. It is one of the best-preserved historical buildings in Gdansk. Originally it was a part of the City's fortifications and now the Gate is the only building left. The Gate is built of brick masonry with an exception for the back elevation, which is made of stones. Above the frontal part of the Gate a two stores upper extension is built. Between that part and the back elevation the Gate is covered by a two-slope concrete roof. Through the building passes an asphalt road of a good quality as well as passages on both sides of the road. In the eighties of the XX century a bulge of the north-west wall inside the building's passage appeared. To prevent a disaster, a part of the vault lying on that wall has been supported by wooden elements, which stand there till now. The vault is cracked across the Gate in several parts. The biggest crack is also visible on the outer site – on the concrete roof so it is considered as potential danger for the construction. In this paper an extension of the biggest crack will be analysed. The coherence function and a specially formulated displacement index will be used.

Description of the experiments

The vibration measurements have been conducted by usage of the 12-channel system PULSE 3560c and one-dimensional piezoelectric accelerometers. In cases of the tower and the belfry, the sensors were located along two vertical lines situated on opposite walls. Accelerations in a horizontal plane in two directions – perpendicular and parallel to the walls' surface have been measured. Locations of the sensors are presented at the Fig. 4 for the belfry and at the Fig. 5 for the Vistula Fortress tower. In both structures the measurements were conducted during the environmental excitations (wind and traffic mostly), however in the belfry also accelerations during the bells swinging were measured (see also ref. 6 and 7).

In the case of Lowland Gate, the sensors have been placed along five sections, shown at the Fig. 6. The sensors were situated in places of the most possible maximal vibration such as: walls directly above the ground level, support zones of the vaults, the vaults as well as the neighborhoods of the biggest cracks. One decided to measure accelerations in a vertical direction as well as in a horizontal one, but perpendicular to the walls' surface. The environmental excitations were a cause of vibrations in this research also, in which traffic played the dominant role (see also ref. 8).

In each experiment the measurements lasted at least 1024 s and maximal resolution was 256/s. The signals then had enough samples to enable averaging in the time or in the frequency domain.

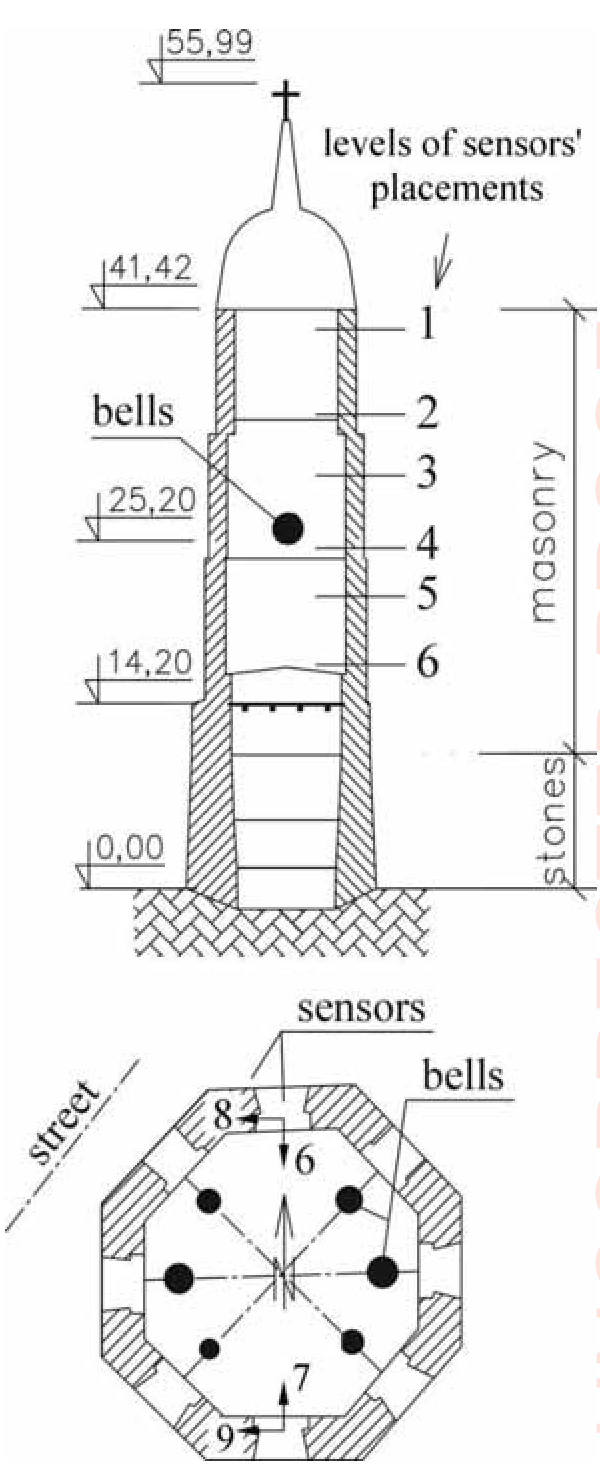

Figure 4: Scheme of the Vilnius Belfry with levels.

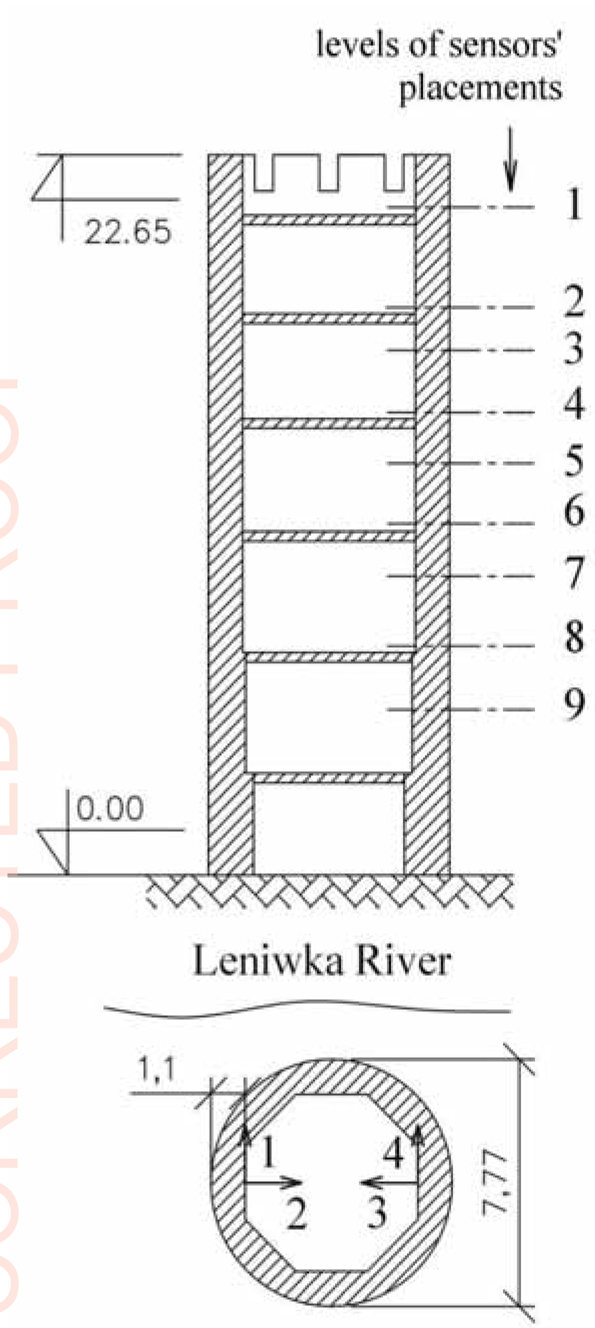

Figure 5: a) Scheme of the Vistula Fortress Tower where the sensors were placed; b) cross section of with nine measurement levels; b) typical cross level No 4 and typical orientation of the sensors section and orientation of sensors.

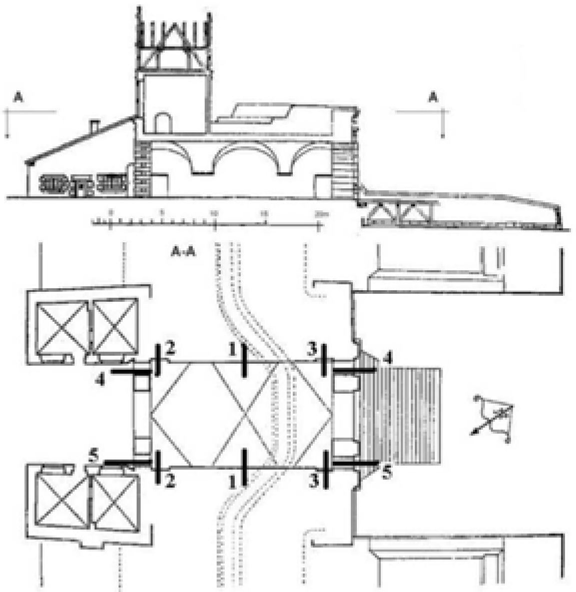

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Figure 6: Scheme of the Lowland Gate according to the literature[8,9] with five cross sections where the sensors have been placed.

3. Results

The modal characteristics of the structures have been identified using the Peak Picking method in which the auto- and cross-spectra as well as the coherence are the crucial functions.[3] The functions have been calculated for each measured signal. An example of the functions calculated for the Lowland Gate is presented at the Fig. 7. It is known, that for the natural frequencies of the construction there is a peak in the cross-spectrum and coherence is close to 1.

For the Vilnius belfry and the Vistula Mounting tower a damage index has been calculated in order to identify the most defected structural regions. The authors use the curvature method, in which the damage index is defined as a difference between second derivatives of mode shapes of the structure in damaged (actual) state and not damaged (original) stages. The structural section with the biggest value of the damage index is potentially the most defected one. The mode shapes related to the actual structural state are specified on a base of the vibration measurements (Peak Picking method in the described cases) and the modes for the original states are calculated in the numerical models. The second derivatives can be calculated from the central difference method, as the mode shapes are discrete functions.

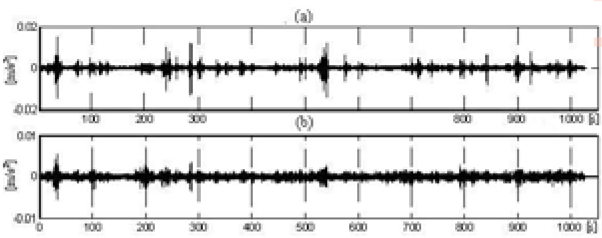

Figure 7: Examples of functions: cross-spectrum and coherence calculated for two signals measured in cross-section 2-2 of the Lowland Gate.

For the both structures the models have been built in the commercial program SOFiSTiK. The Finite Elements Method has been applied. The solid and shell elements have been used. Material properties and boundary conditions have been selected so that the few first natural frequencies of the models are similar to the measured ones.

The Archcathedral belfry in Vilnius

The first task was to answer the question if the swinging of bells is dangerous for the building. Thus, the amplitudes of accelerations measured during environmental excitations (wind, traffic) and after switching on the bells have been compared. Analysis in the time domain proved, that the bells cause magnification of the accelerations over 10 times. After the signals' transformation to the frequency domain (Fourier transform) and application of the Peak Picking method, the natural frequencies of the building have been specified. The first two of them are equal to f_1 = 1.29 Hz, f_2 = 1.46 Hz. After switching on the bells the measured signals become magnified exactly in the band including those frequencies. That proves that the belfry works in resonance when the bells are switched on. That is a very important observation, because it shows a cause of the cracks, which appeared on the VI-th floor of the structure and helps to prevent further propagation.

Another challenge was to identify the most damaged region of the belfry. It seemed that the visibly cracked section could be the one, however the CURE team decided to apply the curvature method in order to check if there are other, hided defects. The mode shapes of the structure in its actual state have been specified on a base of the Peak Picking method. The original state represent mode shapes calculated in a FEM model, which idealize the belfry (there are no damages). The first two natural frequencies calculated in the model are equal to f_1 = 1.279 Hz, f_2 = 1.293 Hz. As the values are similar to the measured ones, it can be assured, that the FEM model is well calibrated. The belfry has the biggest energy while vibrating with the first natural frequency. It if obvious then, the first mode shape specified in the experiment is of the best quality. This mode shape has been selected to the analysis. A comparison between experimentally determined first mode shape and the same calculated in the FEM model is presented at the Fig. 8. Damage index values have been calculated for sections 2,3,4,5 of the belfry, marked at the Fig. 4. Derivatives of mode shapes for sections 1 and 6 are not possible to calculate. The results are presented in the Table 1. The biggest values of the index are obtained for the section number 2 – directly above the visible cracks. Thus, one concludes that there is no any other section in the belfry, which is more defected than that in the VI-th floor.

Table 1: The damage index values calculated for the Archcathedral belfry in Vilnius.

Location of the section above the ground level (m)	Number of section	Damage index for Φ_{11}	Damage index for Φ_{12}
37.17	1	–	–
34.02	2	1.629	1.454
30.22	3	-0.977	0.283
27.33	4	0.570	0.15
24.22	5	-0.020	-0.907
18.46	6	–	–

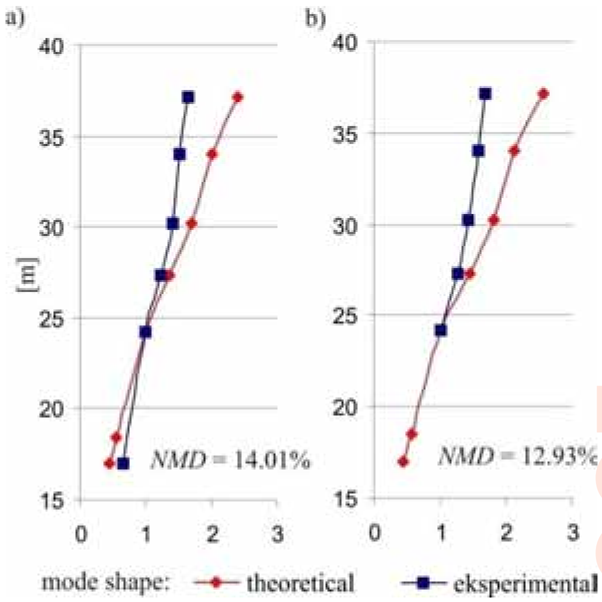

Figure 8: Comparison between theoretical and experimental first mode shape of the belfry, coordinates obtained for: a) the South wall – Φ_{11}; b) the North wall - Φ_{12}.

The tower in the Vistula Mounting Fortress

In this case the big challenge was to determine boundary conditions of the FEM model representing the tower's settlement. One decided to conduct a parametric identification based on the measured natural frequencies. First two natural frequencies are equal to f_1 = 1.41 Hz and f_2 = 1.44 Hz and they are related to swing vibrations in two perpendicular directions, with a rotation centre situated at the footing. One decided that a model of a stiff solid on elastic support can be a good mathematical representation of the situation. Having equations of a side vibration of this kind of structure, geometric characteristics of the tower and the measured values of the side vibrations frequencies, the supporting springs' stiffness have been calculated. Details of that analysis are described in ref. 7. The calculated characteristics of the elastic foundation have been used then to calibrate the finite elements model of the tower, necessary for calculating the theoretical natural mode shapes. Finally obtained first two natural frequencies of the model are equal to f_1 = 1.42 Hz and f_2 = 1.45 Hz.

Similar analysis as for the Vilnius belfry of the damage detection has been conducted for the Vistula Mounting tower. We do not have visibly defected section in this case. The mode shapes of the tower have been specified on the base of the Peak Picking method. The first two of them in comparison to the calculated mode shapes are presented at the Fig. 9.

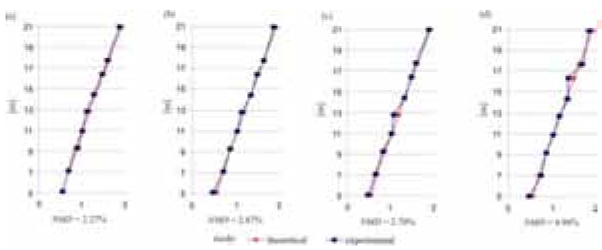

Figure 9: Comparison between theoretical and experimental first two mode shapes of the tower, coordinates: a) of the first mode on the South wall - Φ_{1S}; b) of the first mode on the North wall - Φ_{1N}; c) of the second mode on the South wall – Φ_{2S}; d) of the second mode on the North wall - Φ_{2N}.

The damage index has been calculated as described above. The obtained results for the tower are placed in the Table 2. Numbers of sections in the table relate to the Fig. 5. The calculated damage index values lead to conclusion that there are three defected sections in the tower. They have numbers 3,5,7. However in this case we have an example of false defect pointing. As one can see from comparison of the experimental and theoretical mode shapes, the sections number 3 and 5 are rather more stiff then assumed than weak. The displacements of those sections in experiments are smaller than calculated. Those sections cannot be then defected. On the other hand the results pointing at the section number 7 should be treated as a thru one. This section is situated above connection between the gothic part of the tower with the modern one.

Table 2: The damage index values calculated for the tower of the Vistula ounting Fortress in Gdańsk.

Location of the section above the ground level (m)	Number of section	Damage index calculated for mode shape			
		ϕ_{1S}	ϕ_{1N}	ϕ_{2S}	ϕ_{2N}
17.75	2	-0.656	-0.018	-0.725	0.358
16.4	3	-0.268	0.678	-0.764	**2.013**
14.43	4	-0.737	1.070	0.584	0.632
12.8	5	**1.209**	**1.391**	**1.777**	-0.385
10.95	6	-0.755	-0.436	1.039	-0.834
9.3	7	**1.677**	-1.160	-0.437	-0.718
7.1	8	0.472	-0.146	-0.601	-0.035

The Lowland Gate in Gdańsk

The main purpose of the authors' investigation was to determine the harmfulness of the road traffic on the structure and to establish the reasons of the failure state of the Gate. In order to do this one measured vibrations in several points inside the Gate: by the footing and on the vault during environmental excitations, in which traffic was the most visible. It appeared, that wooden supports of the vault are rather harmful then useful, because they transmit vibrations from the ground directly to the structure. Vertical vibrations of the vault in the supported regions have at least three times bigger magnitude than in other places.

Secondly, the structural behavior has been observed due to taking advantage of the frequency and the time domains' duality. By measuring ambient vibrations and applying the Peak Picking method one determined the Gate's first natural frequency. It is equal to f_1 = 2.5Hz. For this frequency the coherence values for the five sections marked at the Fig. 6 have been calculated. A high value of the coherence (close to 1 and practically bigger than 0.7) informs that the section is stiff, not cut by any constructive crack. On the other hand, lower value of the coherence means a serious defect in the section – in this case a constructive crack. The calculated values are given in the Table 3. Another idea was to analyze the structural behavior in the time domain. A special displacement index has been specified:

$$Z = 1 - \frac{1}{N}\sum_{t=1}^{N} \frac{|x(t) - y(t)|}{|x(t)| + |y(t)|}, \qquad 0 \le Z \le 1$$

Where $x(t)$, $y(t)$ denote two signals measured at common cross-section of the building and having the same orientation, N is a number of the signals' samples. If one obtains in calculation result $Z \approx 1$ that means that points x and y have a tendency to move in the same direction during vibrations. On the other hand, if the value is very low, we have information about opposite displacements of the two points during vibrations. Calculating the Z index for several pairs of the structural points we specify tendencies of the gate's points movement in relation to one another, which gave an overview of the structural behaviour. The values are presented in the Table 3.

It appeared that the structure displace as a stiff solid from one side to another in the horizontal plane but in the vertical directions it sways and the rotation centre is situated around the Gate's centre.[8] That kind of vertical movement could be a cause of the biggest crack on the vault, because if one considers the two opposite massive elevations, moisture ground and possible unequal settlement of the elevations the scenario, in which the Gate brakes in two parts seems to be possible.

Table 3: Results of the calculations of the coherence and Z index for each cross – sections of the Gate.

Cross - section	Case	Coherence	Z
1 – 1	Vault, vertical direction	0.80 – 0.85	0.29
2 – 2	By the footing, horizontal direction	0.75 – 0.80	0.25
	By the footing, vertical direction	0.75	0.32
3 –3	By the footing, horizontal direction	0.80	0.23
4 – 4	By the footing, horizontal direction	0.75 – 0.80	0.76
	By the footing, vertical direction	0.55	0.29
5 – 5	By the footing, horizontal direction	0.80	0.74
	By the footing, vertical direction	0.50	0.21

4. Conclusions

In this paper authors presented a wide scope of analyses, which can be done on the basis of the vibration measurements. The presented analyses are applicable for the massive masonry structures. This is important especially in cases of the historic buildings were non-destructive methods of diagnosis are preferred. The selected method of the experimental modal analysis – the Peak Picking method can be applied to signals measured during environmental excitations, which act naturally on the structure. No additional forces are used in the experiment, so the structure is safe from this point of view. On the other hand, it is possible to determine the structural parameters, like material properties or settlement characteristics if one conducts a parametric identification on the base of the experimentally specified modal characteristics. Then it is not necessary to take material samples or dig in the ground to see the foundation conditions.

5. Acknowledgements

This study was supported by the European Community under FP5 Programme, key action "City of Tomorrow and Cultural Heritage" (contract EVK4-CT-2002-80005), Center of Excellence CURE at Gdansk University of Technology in Poland. This support is kindly acknowledged.

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INITIAL STAGES OF CARBONATE WEATHERING – CLIMATE CHAMBER STUDIES UNDER REALISTIC POLLUTION CONDITIONS

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1. Introduction

Climate chamber are a reasonable tool in investigations of alteration processes of natural stones, especially of carbonates. Even though the concentration of SO_2 in the atmosphere has decreased, until today, most of the studies focused on the role of S-compounds which were considered to be the most dangerous component of emissions.

Contrary to SO_2 the concentrations of NO_x and especially ozone, primarily due to traffic, still increases. The role of ozone in oxidation of NO to NO_2 and SO_2 to SO_3 as well as its role at the formation of sulphate on calcite materials has already been the subject of some studies.

Typically, these experiments were performed at accelerating testing conditions by using gas concentration considerably above realistic emission values.

In this study we pursued a different experimental strategy. The concentrations of NO_2, SO_2 and O_3 have been close to realistic average values (corresponding to the max. mean half hour value in Austria measured in 2003): 0.150 to 0.200 ppm for NO_x and SO_2 and about 0.120 ppm for ozone.

The major aim of this contribution is to answer the following questions:
- Is it possible to detect a reaction of carbonaceous materials with airborne pollutants within a reasonably short time of several weeks, if realistic concentrations of damaging gases are used?
- Can the accelerating effect of the oxidation of SO_2 by NO_x and O_3 be proven in short time experiments?
- Can the reaction of nitrogen compounds be detected and defined?
- Do investigations of sample elutes using ion chromatography give suitable and reliable results in the chosen experimental conditions?

The results of the study are discussed in more detail elsewhere.[1]

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MINERALOGICAL AND PETROPHYSICAL COMPARATIVE STUDY OF CALCAREOUS STONES USED IN THE ARCHITECTURAL HERITAGE OF GRANADA (SOUTH SPAIN)

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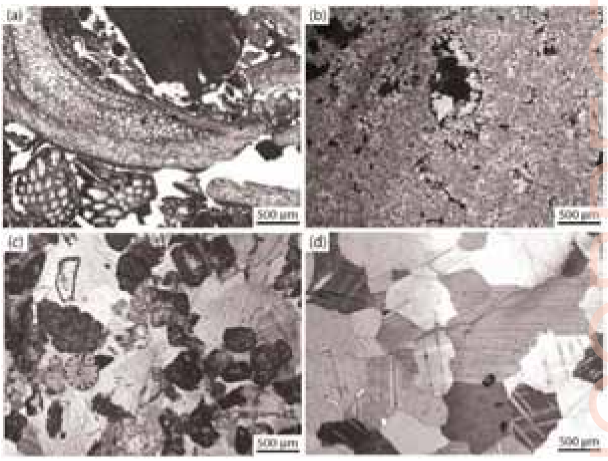
Calcareous stones from traditional Andalusian quarries have been used extensively in the architectural heritage of Granada (South Spain). Mineralogical and petrophysical characterization of fresh stones from quarries is essential to understand and quantify the weathering mechanisms they undergo under polluted atmospheres. To this end, properties of fresh and altered ornamental stones are compared to assess the effect of pollutants on them. This work focuses on the mineralogical, textural and petrophysical characterization of selected calcareous rocks traditionally used as ornamental stone in the architectural heritage of Granada.

Four calcareous stones with contrasted textural features, grouped into two classes, were studied. The first group includes two types of very porous rocks, namely Santa Pudia bioclastic calcarenite (SP calcarenite) and Albox travertine (AL travertine); the second group comprises two types of crystalline rocks: Macael marble (MB marble) and Sierra Elvira limestone (SE limestone) (Figure 1).

Figure 1: Thin-section microphotographs of porous (a & b)



and crystalline (c & d) calcareous stones. (a) Santa Pudia calcarenite under parallel polarized light. Note the profuse inter- and intraclast porosity. Bioclasts are mainly composed of brioozoan and red algae (b) Albox travertine under crossed polarized light. Sparitic calcite filled macro porous (c) Sierra Elvira limestone under crossed polarized light, coarse grain calcite overgrown bioclastic fragments mainly composed of crinoids (d) Macael marble under crossed polarized light showing a well developped granoblastic texture.

The mineralogy of the samples was analyzed by X-ray powder diffraction (XRD). Mineral identification and quantitative analyses were performed using the *XPowder* software. Moreover the mineralogy and texture of the samples were studied by polarized optical (OM) and scanning electron microscope (SEM). Parameters associated with fluid uptake and with-in-pore transport were determined by hydric tests (water absorption, drying and capillary uptake). To confirm the differences in the porosity among the four calcareous stones, mercury intrusion porosimetry (MIP) and BET gas adsorption were applied. By using the BET gas adsorption method the specific surface of solid materials was determined based on the principle of the monolayer, i.e. the number of gas molecules necessary to completely cover the surface of the material in a singlelayer.

The XRD study did not show any significant mineralogical differences between the four stones. In all samples calcite was the most abundant mineral although occasionally dolomite was present in lesser and variable amounts (e.g. SE limestone). Minor quantities of quartz and other trace phases (micas, oxides) were detected in SP calcarenite and SE limestone under OM and SEM. These techniques showed that the main differences between the stones were related to their texture and grain morphology, i.e. mineral size and shape, as well as in their pore system. Abundant macrofossils (bivalves, bentonic foraminifera, echinoderms and red algae) were observed in SP calcarenite (Figure 1).

The hydric tests revealed the greatest differences between the SP calcarenite and the other stones. SP calcarenite absorbed more water and at greater speed, reaching the height of the prismatic sample (2x2x10 cm) in 24 hours, while in other stones the water scarcely rose during one week. The pore system characteristics, i.e. open porosity and pore size distribution of fresh samples were studied by MIP. It was confirmed that SP is the most porous stone showing a typical bimodal distribution with one absolute maximum at 0.3 μm and another relative more diffused between 3 and 100 μm. AL travertine has a unimodal pore distribution with one maximum at 0.1 μm. The majority of pores in AL exceeds 200 μm and thus could not be detected by MIP. Due to the very low open porosity of crystalline rocks (SE and MB) a simple interpretation of their pore size distribution is not feasible. Table 1 shows that the highest values of BET surface area occur in SP calcarenite (0.7 m^2/g, mean value of three measurements) and the lowest in MB marble (0.1 m^2/g). The average pore diameter is higher in the crystalline stones (SE, MB) than in the porous ones (SP, AL).

Table 1: n_0= Open porosity (%); ρ_B= Bulk density (g/cm^3); ρ_S= Skeletal density (g/cm^3); S= Surface BET area (m^2/g); □=Average pore diameter (Å).

	n_0	ρ_B	ρ_S	S	□(Å)
SP	29 ± 8	3 ± 0.3	2 ± 0.4	0.7	20
AL	8 ± 1	3 ± 0.1	2 ± 0.1	0.6	21
SE	2 ± 1	3 ± 0.1	3 ± 0.1	0.4	25
MB	0.2 ± 0.1	3 ± 0.1	3 ± 0.1	0.1	26

1. Acknowledgements

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EASEL OIL PAINTINGS' PIGMENTS OF THE 19TH AND FIRST HALF OF THE 20TH CENT. (ANALYSIS CARRIED OUT ON PICTURES, ARTIST PALETTES AND HISTORICAL PAINTS)

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Artist palettes are not often used in technical analyses of artists' techniques and materials. The main reason is that not many of them are preserved. Whenever a palette is accessible, a study of the artists' materials and technique should be done. However, firstly a research in archives and written sources must be conducted, only then, followed by an analysis of the paint preserved on the palette.

A wide range of information can be revealed when analyzing a given palette. The order of the paint layout may follow the 19th c. customs and strict directions, however, it may also be very loose, and even chaotic. The number of different colours and their diversity is revealed as well. In addition, the issue, of whether a palette is nearly cleaned off paint or the paint is present in big impastos or perhaps it is in a form of smooth stains of colour, is significant. An observation of different mixtures is much easier to follow on a palette than it is on paintings. Even a matt or glossy appearance of the paint can indicate to certain degree the amount and the character of the media used. Often, dried drops of pure media present on a surface of a palette enable their identification.

Sampling a palette is not as problematic as it is in the case of a picture itself. Moreover, very frequently, pure paint is present, which was not mixed with other colours. This allows a more facile and reliable identification of pigments and binding media, and often it leads to distinguishing between media added to the paint by the producer and the ones added by the artist to change handling properties of a paint or the level of gloss.

On the other hand, it is quite seldom that an individual palette is used only for one picture. Normally, it represents a given period, rather than a particular object. There may also be paints on the palette hardly used by a painter while executing an image - but normally one can investigate this phenomenon by close comparisons, which remain still much easier and the data gained more reliable, when the pigments on palette are used as a reference.

In this paper the author tries to compare palettes and data obtained for different artists, simultaneously, showing the relations between them and the created artworks. What was observed were the changes of the range of colours used, furthermore, the significant advantages of examination of the paints on the palette, prior to the study of the painting, were demonstrated. However, in one of the cases a different situation is illustrated - the analysis of the artworks helped to date (to a certain degree) the palettes of the artists.

The two palettes examined are of Jan Matejko's (1838-1893), a Polish historical academic artist, who was the first head of Krakow Fine Arts Department and a teacher of many great painters. Fortunately, both palettes are dated and assigned to a particular painting. In the first case, there is an inscription made by the artist himself. The dedication to his brother points to the amount of hard work done with the picture *Joanna d'Arc* executed in the year 1886 (Figure 1). In the second case – a very representative palette with Polish national flag-like coloured ribbon and golden initials on it – the palette has a date curved by the artist in the dried paint. The year 1888 suggests that it was used for the greatest picture painted by Matejko in this year - *The Raclawice battle*.

Figure 1: Palette of Jan Matejko (1838-1893), dated 1886 (according to the dedication by artist).

Surprisingly, the pigments on the palette identified with the help of XRF and Raman spectroscopy proved a very wide range of colours, which is not so striking while observing Matejko's paintings. There are more then twenty colours on the palette. Especially rich is the part connected with iron based reds, browns and yellows in different hues. The white is lead, yellows represent - among cadmium and strontium yellow - also more traditional Naples yellow, organic yellows (precipitated on alumina) and ochre. Iron domination is present also in reds - there is just a bit of vermillion. Organic reds are precipitated on alumina. There is an order of colours on the palette going from the right to the left: whites, then yellows, reds and browns are laid till the bone black. Their amount and number of kinds is significantly greater than of colder colours connected more with plain-air painting - vivid greens and intensive atmospherical blues. Viridian is accompanied by two copper greens: emerald green and malachite. Blues are cobalt, ultramarine, cerulean blue and azurite. Exceptionally, not on the palette, but on one of the paintings from the 1880-ies, Prussian blue was identified in the deep glaze-like parts.

The paintings analyzed generally follow the palette. A complete research of the samples of pure colours coming from the palette, before analyzing the paintings, allowed in most cases obtaining reliable data from the latter only with the use of a quick and non-invasive portable XRF spectrometer measurements. It helped to minimize the number of samples taken from the painting, and if they were taken – then mainly just to establish the stratigraphy of the paint layers.

Another palette analyzed is the one of the symbolist painter Jacek Malczewski (1854-1929, Figure 2), the famous pupil of Jan Matejko. Contrary to his master, he used very strong, vivid colours in an expressive, non-descriptive way. Surprisingly, the range of colours identified on the palette is relatively narrow. Instead of lead white, zinc white is used. There is only one blue: ultramarine, and two greens only: viridian and chrome green. Cadmium yellow is extended by yellow ochre and chrome yellow. Reds are: vermillion, iron red and organic red precipitated on alumina substrate. The latter is used with blue to get violets. They were often juxtaposed with aggressive greens, in visual character similar to emerald green. Surprisingly, it appeared that in most cases it is a mixture of deep viridian, lightened with cadmium or chrome yellow and white. Likewise, sea-like blues similar to cerulean blue were achieved by mixing. They are composed of viridian, big amount of lead white and bit of cobalt blue. The strength and richness of colours is built with a narrow palette, but consciously juxtaposed and contrasted. Hardly any order in layout of colours applied can be seen on the palette. It reveals the process of searching for the best hue by mixing colours in every part of the uncleaned surface. Paint was applied just in the places still uncovered with colour.

Figure 2: Palette of Jacek Malczewski (1854-1929). Presumably from 1920-ties.

Another head of Krakow Fine Arts, the one who strongly reformed the traditional programme of the Academy by employing young professors and adding landscape, plain-air painting to the course, was Julian Falat (1853-1929, Figure 3). A brilliant landscape painter, most famous for his breathtaking depictions of winter and snow, as well as hunting scenes painted when he had been the court painter of Wilhelm II in Berlin. While observing his palette we can follow certain innovations. Colours are matte - there is not much media added. Pigments keep vivid hue being not covered with yellowed and darkened oil and resin. Violet is not achieved, as it was on the palette of Malczewski, by means of mixtures, but rather by ready-made pigment cobalt violet (cobalt arsenate). Viridian is accompanied by chrome green, and red is not only iron one, but cadmium (CdS x CdSe) as well. Cobalt blue and ultramarine are extended with cerulean blue.

Figure 3: Palette of Julian Fałat (1853-1929). Presumably from 1920-ties.

In former cases, previous studies of the palettes helped to understand the paintings. In the case of Josef Pankiewicz (1866-1940) – a friend of Pierre Bonnard, and the artist who brought Impressionism to Poland - the situation was quite the opposite. Nearly 40 of the artist's pictures were analyzed prior to the paintings. The pigments identified on the dated pictures allowed dating some palettes post quem. Cobalt violet appears on artist's paintings in 1908 and cadmium red in 1917. There are other colours characteristic of a certain period: cobalt greens were not commonly used by him before 1920-ties. Basing on these information, one of the two palettes must be dated only after this specific time. Yet another characteristic pigment of pinkish hue and containing cobalt (present on the second palette) was used almost exclusively in the series of pictures painted about 1929. It is quite probable that one of the two palettes is from this particular period.

Not only the pigments are easier to recognize on the palettes. Same applied to the dense, pure media used for painting found on the palette of Matejko, which were identified as poppy oil mixed with linseed oil and small amount of pine tree resin. Binding media of the paints of Malczewski were oil with small addition of copal resin. Paints of Fałat appeared to be tempera based on gums of fruit trees with addition of egg yolk and traces of copal resin.

The survey showed a possibility of following the evolution of artist palettes regarding not only the range of pigments, the character of layout of paints on the palette surface, but the use of media as well. The variety of kinds and hues of paints, undistinguishable on the painting (numerous umbers, ochres, siennas, reds of Matejko's iron pigments), or narrow palette of Malczewski (despite his colourful painting), were actually revealed thanks to examination of the palettes.

The research will be extended with a survey of historical tubes of colours, which are numerous especially in the case of Matejko. More than a hundred tubes of colours of German and French producers are preserved and additionally described in a book-diary of Biasion – a supplier of artistic materials from Krakow, in the years 1880-1883. A close comparison of the composition of paints from the tubes with the samples from the palettes and measurements made on paintings will allow full recognition of Matejko's technique and materials. This shall contribute to building a database of Krakow's environment painters of the second half of the 19th c.

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STUDY OF CONSOLIDANTS BASED ON SILICA DISPERSION APPLIED ON POROUS MATERIAL

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1. Introduction

One of the most critical problems in conservation of architectural stone surfaces is the treatment of the incoherent fragments coming from chemical and physical decay processes. In the case of siliceous and carbonate matrix generally the loss of the adhesion – cohesion is limited by two different methodologies: the application of organic consolidants like synthetic polymers used as fixative[1-6] or the application of inorganic products made above all by silica or barium hydroxide and recently by nanolimes or ammonium oxalate.[7-8]

In general the inorganic consolidants employed for the conservation of the architectural surfaces are generally made by silica and in particular by tetraethylortosilicate (TEOS). The ethyl silicate has a good compatibility with the stone and can penetrate in depth into the materials. The principal limit of the employment of TEOS is the acidity of the commercial solution due to the acid catalysts. Substitutes of TEOS are aqueous silica dispersions. In this case the operation is characterized by the application of a little dimension particles product with the attitude to penetrate also in smaller size pores and to improve the physical – mechanical characteristics of the material.

Recent studies have provided evidence of a low ability of the dispersions to penetrate in depth into support.[9]

In this study the penetration capability into a porous material of a solution of a commercial TEOS in isopropyl alcohol (pH = 5-6), a silica dispersion produced by basic catalysis (Stober procedure) and an aqueous dispersion of nanosilica (Ludox) with particles dimension of 12 nm was evaluated.

The investigation was performed by:
- *Evaluation of the consolidant – support interaction*: mixtures of the products with calcite in 1:1 molar rate were prepared. The interaction between the three different silica and calcite was studied by ^{29}Si-NMR spectroscopy.[10]
- *Distribution of products into the porous stone:* the silica were applied on stone by capillarity rise for 1 h. The product depth penetration was estimated by different colour of the stone and by scanning electron microscopy observations.

The silica evidenced unlike behaviours due to the structural differences. In xerogel coming from colloidal silica prevails the presence of Q^4 systems related to tri-dimensional systems while in xerogels coming from ethyl silicate prevail more planar "open" systems, much more available for a chemical interaction with calcium carbonate and quartz. The calcite reacts with xerogels involving significant structural modifications. In all cases the presence of Q^3 systems seems to influence on the reactivity of the siliceous consolidants towards the support.

The consolidant based on ethyl silicate proves more reactive than others and this effect could offer good reasons to suppose that ethyl silicate have a best re-aggregating effect on substrate. On the contrary, the measurements of cohesion on mortar samples treated with the colloidal silica and commercial TEOS consolidant do not give great differences between the products and in particular, ethyl silicate has proven to have less a cohesive effect on mortars than colloidal silica.

In general the silica dispersions have not much penetration attitude compared to the solvent capability and a chromatographic effect is verified as in the cases revealed for the acrylic polymer dispersions. The nano-silica from Ludox characterized by little particle dimensions has a limited penetration attitude probably due to the presence of surface active agents or other additives inside the dispersion. The behaviour of additive products will be studied and it will be defined how much the penetration of the nano-dispersion into pores of little dimension can influence the real consolidant efficacy.

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EVALUATION OF THE PERFORMANCE OF DESALINATION TREATMENTS IN A SELECTED CASE STUDY BY MEANS OF NON DESTRUCTIVE ANALYSES

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In historic buildings, both in coastal areas and along the main rivers, the salt loads cause huge damage to valuable monuments and require high costs for cultural heritage maintenance. In the European Project Desalination an innovative research methodology based on the use of non destructive techniques (NDT) has been developed to determine the state of conservation and to monitor the desalination treatment on site. In the case study of an ancient convent in Venice (Italy), the work focused on resistivity measurements of bricks, in order to verify and monitor, in a non invasive way, the effectiveness of the poultice treatments. Preliminary results demonstrate the effective increase, after treatments, of apparent resistivity for the upper substrate of the bricks, linked to desalination effect. Contrariwise monitoring these physic parameter in time, the case study reveals a significant decrement of resistivity after one year from the treatments, suggesting the important aspect of desalination durability, and proposing new questions on the poultices–substrate-environment relationship for future efficient interventions.

1. The Non Destructive Techniques: methodology

In monuments conservative interventions for scientists and technicians it is essential to verify the effectiveness of the selected treatment applied on site.[1] On this purpose, the research methodology developed in the project consists of a diagnosis, a treatment and a control phase, concerning respectively the characterization of supports, the application of treatments on site and the assessment of treatment comparing the different analysis performed before and after treatment The control phase is devoted to the treatment monitoring in time, considering the type of poultices applied, the bricks material characteristics and the environmental conditions. In this work, in particular, the resistivity meter analysis results supported by laboratory analysis are presented.

The resistivity of bricks was measured using a standard Wenner linear four probe array georesistivimeter, appositely designed for construction material analysis. The instrument allows several ranges of current input, furnishing the resistivity measurements in the range of 0-2 $M\Omega$ cm and permits the probe spacing between 0-10 cm, with the constant monitoring of the current inlet in the substrate measured. These features furnish a complete control of the accuracy of the real resistivity and allow monitoring of the most critical problem in this kind of evaluation: the probe-surface contact resistance. The probe spacing theoretically allows a 10 cm depth of material investigation, but several limits must be considered,[2] like the geometry of the element we are measuring, the inhomogeneity of the material, the distribution of the current lines linked to the array selected, and positions relative to the edge of the structure analysed. A constant control on the parameters correct response and resistivity results permitted to evaluate the bricks real resistivity pre treatment and post treatment.

The test site chosen is a masonry wall of ex Terese convent (XVII century building) in Venice, Italy. The wall suffered sea salt weathering (efflorescences, detachment and spalling) and the sources of sea salt recognized are sea flooding, rising damp and marine aerosol[3-4].

The diagnosis phase (support characterization) identified the presence of different bricks in terms of composition, colours and structures[5-6]. Resistivity measurements together with laboratory tests have been performed to assess the relationship between salt transport and moisture content before and after desalination treatment phase, consisting in the application of five types of desalination poultices on the selected wall. The control phase was performed in two steps, one month and one year after treatment, in order to verify the effectiveness of the intervention to monitor the process in time and to determine the behaviours of substrates. Resistivity measurements have been supported by moisture content analysis and poultice samples salts content determination (Figure 1a).

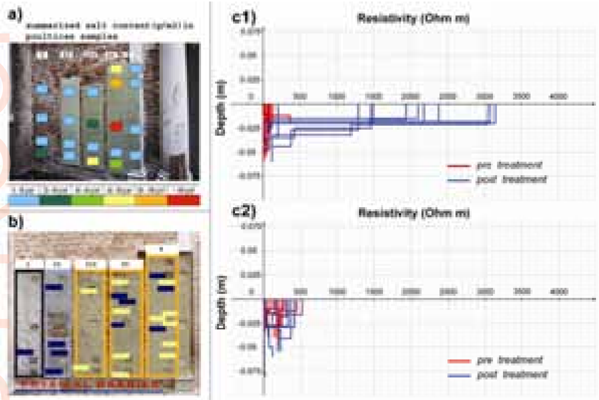

Figure 1: a) Summarized salt content (g/m2) in poultices extracted samples. b) Brick difference in resistivity values pre-post treatment application (orange – high difference; blue – low difference). c) Resistivity layers models (res.-depth) for the two bricks groups identified (pre treatment - red; post treatment – blue).

2. Results

The electrical properties measurements performed on bricks before the treatments highlight very low resistivity values (tens of Ω m), in agreement with the laboratory analyses that reveal relatively high moisture and salts content values. Pre and after treatment resistivity models show the clear modification of the physical parameter condition and reveal the effectiveness of the desalination process (Figure 1c1-1c2). However, these conditions are not satisfied all over the wall, setting the fundamental substrate-poultice-environment relationship: different kind of bricks presents different behaviours.

The electrical properties estimation was correlated with the analysis of the poultices extracted samples (Figure 1a – 1b). An high resistivity difference between pre and post treatment condition correspond to an high salt content in poultices, revealing an efficient desalination of the brick.

After one year from the treatments application, the repeated resistivity measurements highlight a clear decrease of the upper substrate layers (2-2.5cm) electrical properties, that reaches almost the initial values of the pre-treatment condition (Figure 2). The desalination effect is rapid but not permanent, moist content and salt transport return to fill in the voids re-establishing the initial condition.

Figure 2: Resistivity layers models for bricks pre-treatments (red), 1 month after treatment (blue) and 1 year after treatments (green).

The variable resistivity values and desalination effectiveness within the brick masonry depend on mixture mineralogical composition, structural properties, density, porosity, moisture content and salt content. Comparing resistivity results with the kind of bricks identified different resistivity domains are detectable. Red and yellow bricks present high difference in resistivity pre and post treatment values, while pink bricks present low variance in resistivity properties. More salts extraction occurs with the decrease of the bricks compactness (red and yellow, low density and high porosity) respect to high compact bricks (pink, high density and low porosity). The physical – petrographical properties influence moisture content and salt transports as well as influence the salt extraction by poultice.

The methodological approach developed reveals that the desalination process is influenced not only by the treatment applied but also by the substrate characteristics. It represents a reliable tool to investigate the substrate structure and poultice performance. The Non Destructive Technique adopted, compared with the poultices performance, allows to define the treated masonry as a "complex substrate" characterized by different structural properties and physical parameters of each element.

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CULTURAL HERITAGE AND NEW TECHNOLOGIES: A GPS GUIDE TO ROMAN TOWN EMONA

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In the paper, we aim to assess the potentials of mobile technology for presenting and engaging with the cultural heritage of Roman town Emona, now partially preserved in the modern Ljubljana. Mobile technology provides new possibilities to increase access to and interpretation of cultural heritage by providing both location-based information and guidance through this information based on the visitor's interests and needs.

1. The heritage of Emona

Emona, a Roman colony in the province of Pannonia, was erected around the beginning of the 1st century and existed for approximately five hundred years.[1] Today, the heritage of Roman town Emona is partially preserved in the city-centre of Ljubljana, the Slovenian capital: several monuments, among them impressive remains of southern city walls, and two archaeological parks form a substantial complex that should be the object of intensive public interest and engagement. However, this heritage is -- in spite of a century long endeavours of experts -- poorly visible, hard to recognize and difficult to understand.[2] Why? It lacks a context, a necessary basis for understanding. Besides, the monuments are located away from frequented roads, poorly or not at all marked. Especially obscure to an average visitors are modern architectural reminiscent of Roman remains.

Context is of utmost importance in establishing meaning. As the original context, the Roman city, no longer exists, Emona's monuments need additional explanations, a newly built context. We sought an alternative to human guides, and decided to use mobile technology.[3]

2. A GPS guide

In the last decade, the computer-aided communication has moved from the computer desk to a wide range of situations in everyday life. Today, mobile technologies (mobile phones, mp3 players, handheld computers) are seen as a normal, familiar part of daily life. This post-desktop human-computer interaction in which information processing has been thoroughly integrated into everyday objects and activities is covered by the term "ubiquitous computing". As opposed to the desktop paradigm, in which a single user consciously engages a single device for a specialized purpose, someone using ubiquitous computing engages single or many computational devices and systems simultaneously, in the course of ordinary activities, and may not necessarily even be aware that he/she is doing so.

Ubiquitous computing has a potential to enrich our interaction with the environment providing a series of information that are not available locally, at the place, but dispersed in the internet or special databases. Because context provides meaning for things, places and situations the recognition of contexts is the key point of ubiquitous computing. This theme is dealt with in a separate field in the ubiquitous computing branch: context-aware computing. Context-aware computing refers to a general class of mobile systems that can sense their physical environment, i.e., their context of use, and react according to their environment, adapting their behaviour. The contextual computing aims at making software applications context-aware. Context-aware computers are devices that can orient themselves in the real world and provide information about what is around them – for example, now increasingly used small computers with GPS capability.

Figure 1: Looking for information around modern architectural reminiscent of the Late Roman rotunda. Photo Dimitrij Mlekuž.

To build a Digital Guide to Emona, we used a Windows Mobile handheld computer with GPS capability. The GPS provides the main contextual information for the visitor of Emona: his/her location and its spatial relationship to the monuments. GPS enabled guides are useful outdoors, for the touring historical towns, botanical gardens, cultural landscapes and similar uses.[4] Such systems enable users to recognize and interpret remains of the past in the landscape. Contextual information, linked with additional information -- textual descriptions, photographs, reconstructions, videos, recorded spoken stories -- provide rich and enhanced information about the places, monuments and situations.

In the first phase of our work, we used two available platforms to explore the possibilities and limitations of both. Both of the platforms were tested by our visitors as well, as we wished to assess the users' feedback. Their responses indicate that though a novelty (and as such for those less experienced sometimes awkward to use), the Digital Guide is welcomed – especially by younger visitors and those prone to explore for themselves --- and thought provoking.

First, we tested Caerus, a platform developed at University of Birmingham.[5]. Caerus is a context aware educational resource system for outdoor tourist sites and educational centres. It consists of a handheld delivery system and a desktop administration system, providing tools to add new maps, indicate regions of interest, add multimedia tours, and deliver to Pocket PC devices with GPS capability. Caerus is designed as a classical guide, enhanced with context aware capabilities. This means that at defined locations additional information is provided by the system. Main screen displays map with hotspots where short notes, in-depth hypertext descriptions combined with images, videos or soundtracks can be displayed. Caerus is heavily dependent on user interaction. It is user who decides what information he wants to hear, look at or read.

Additionally, we tested Mediascape, a platform provided by Futurelab and Hewlett-Packard.[6]. Mediascape was designed mainly for educational purposes. Mediascape delivers Mediascapes, mobile, location-based experiences that incorporate digital media with the sights, sounds, and textures of the world around you. Obviously, Mediascape is conceptually quite different from Caerus: Mediascape aims at blending digital images, video, audio and interactions with the physical landscape, whereas Caerus is designed to be a capable digital guide for outdoor locations. The best feature of Mediascape is that it is virtually without user interface, it is almost entirely driven by context. Interaction with user is minimal, all events, display of pictures, videos or sounds are triggered by context or location of user. The potential of Mediascape is therefore mainly in creation of context aware "soundscapes" or sound environments, where sounds -- and not just pre-recorded speech, but also background sounds, noises etc -- gives cues about the monuments, locations and situations.

In the second phase, based on the experiences of using those two platforms, our Digital Guide is designed. It offers the benefits of having a personal guide to reveal the hidden stories behind the obvious sights, providing text, images and video. It supports a range of visitor needs and interests, as it enables theme-based tours. Most important, every monument is -- via the Digital Guide -- connected to photos, reconstructions, facts, stories and similar, thus providing context for this monument and thus establishing its meaning.[3]

Figure 2: Touring with a Digital Guide: visitor can explore freely, monitoring her current location on a digital map. Photo Dimitrij Mlekuž.

3. Active interaction

Mobile technology supports educational tours and encourages learning within an authentic context.[7] The challenge is one of understanding and exploring how best we might use these resources to provide new possibilities to increase access to and interpretation of cultural heritage through ambient teaching and learning.[8]

In the third phase of designing the Digital Guide, we intend to include collaborative features and features which would enable user to play an active role in the discovering and interpreting heritage of Emona. First feature is "geotagging", where users can virtually "tag" or mark places or monuments which they find interesting, inspiring, boring, quizzical etc. Just as a museum curator puts a label next to an artefact on display in order to help tell a story, the new technologies allow for similar sorts of tagging of the spaces outside the museum walls.[9] Similar feature is e-graffiti, where users can place tier own virtual graffiti or notes about places or monuments, which can be shared with other visitors. We want to combine this feature with geocoded photos, where users are encouraged to take photographs of monuments and places, and the system would provide contextual information about those photos. In a long term, a new, user based guide would emerge, creating a debate among this users-made guide and "official" ready-made guide.

We believe that such user-engaging platform can enable collaborative learning and interpretation and could lead to a multi-vocal interpretation of the past and Emona's heritage. Mobile technology not only provides new possibilities to increase access to and interpretation of cultural heritage -- more importantly, it enables active interaction and meaning-making in a natural and personalized way.

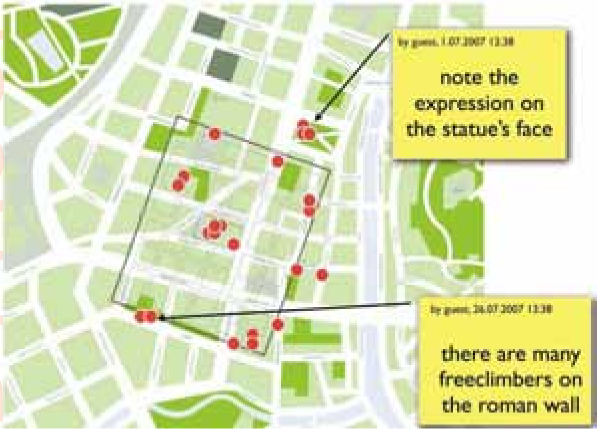

Figure 3: E-graffiti left on the Digital Guide.

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CONSERVATION PRACTICE MEETS RESEARCH – IMPROVING THE SYNERGY TOWARDS SAFEGUARDING OUR CULTURAL HERITAGE

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Scientific research is playing a rapidly changing role in the protection, conservation, and enhancement of our cultural heritage. The number of scientists, scientific organizations, and scientific disciplines dealing with conservation has grown significantly in the last decades. Nanoscience, laser science, climatology, molecular biology, medical physics, computer graphics, development studies and social anthropology, for instance, have brought new views to the field. As much as such an increase and diversification of scientific disciplines and actors offer a great potential to improve our understanding of cultural heritage and its significance, and to improve its conservation through applied research, it also implies new and more pronounced challenges related to the meaningful application of science in conservation. Those challenges include:

- the need for improved scientific literacy in the conservation community to fully and critically evaluate, contribute to shape research initiatives, and actively participate in the application of science and of the technologies deriving from it;
- the need for improved 'conservation literacy' in the scientific community to better understand the realities of the conservation field through the knowledge of theoretical, historic, legal, ethical and practical aspects, of the terminology, contexts, significance assessments, and of its interdisciplinary and multicultural professional community;
- the need for improved communication and dissemination of scientific research results in a meaningful way to conservation practice;
- the need for improved coordination of efforts between research institutions in order to avoid duplication;
- the need to (re)orient or focus research through assessment of actual needs of conservation in an effective way, and by critically reviewing the impact of conservation research, in order to prioritize the allocation of funds in partnership with research funders.

Overcoming these challenges will increase the synergy and success achieved through the interaction of science and other disciplines for the safeguarding of cultural heritage. How can this be accomplished? What mechanisms and channels can be developed for meaningful exchanges among scientists, conservators, colleagues from other disciplines, and the users of cultural heritage?

For ICCROM (the International Centre for the Study of the Preservation and Restoration of Cultural Property), one powerful response to these questions is through the development of special training initiatives that promote shared interdisciplinary decision-making in conservation, and improve 'conservation literacy' and scientific literacy.

ICCROM's international course on 'Sharing Conservation Decisions' offers a dedicated platform, and a nurturing environment for scientists and conservation professionals from other disciplines to jointly improve their competences to engage in shared conservation decision-making in meaningful ways. As part of that process, the role of scientific research to inform and underpin conservation decisions is critically discussed and put into perspective within the broader picture of multiple and changing contexts, values, and actors involved in the conservation of cultural heritage. The course illustrates and highlights the benefits of improving science communication, scientific and conservation literacy, and true interdisciplinarity in conservation and research. It fosters effective dialogue and collaboration between conservation practice and research, aiming at improving needs assessments, cost efficiency, sustainability, and the overall impact of conservation decisions and actions to safeguard our cultural heritage. This is achieved through a 4-week intensive immersion programme with a purposely designed combination of activities such as interactive lectures and panel sessions with leading professionals from various disciplines, structured practical activities in multidisciplinary groups, study visits, case studies, role playing, etc. Aspects of the course curriculum will be highlighted in the presentation. 94 conservation professionals from 55 countries, having professional backgrounds in various disciplines, including scientists, conservator-restorers, curators, architects, archaeologists, and managers/policy advisors have participated or been involved in the 5 biennial editions of the Sharing Conservation Decisions course so far.

ICCROM also makes a systematic effort to promote interdisciplinarity in conservation, and to improve scientific literacy in participants of all its training activities. The latter is implemented through embedded course sessions or modules on the understanding of scientific principles of materials behaviour and their conservation, which more recently has focused on local materials and traditional methods to foster the development of sustainable solutions, on critical reading of scientific literature (including graphs), on the formulation of research questions and experimental design, etc. The development of a specific activity for scientists interested in improving their 'conservation literacy' is currently being contemplated. Aims are to increase awareness about theoretical, historic, legal, ethical, and practical aspects of the conservation of cultural heritage; to provide a clear and global understanding of the context of conservation decisions, as well as of the role of science in that context; to improve skills to communicate scientific issues to non-scientists to assess science-related needs of conservation, and to interact with the interdisciplinary and multicultural conservation community.

By encouraging and supporting initiatives and approaches that promote proactive, mutual understanding and learning between conservation practice and research, policy-makers and funding bodies can develop and strengthen effective mechanisms to improve the safeguarding of our cultural heritage.

EUROPEAN MASTER LEVEL EDUCATION ON PROTECTION OF CULTURAL HERITAGE: NATIONAL EXPERIENCES AND EUROPEAN PERSPECTIVES

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Abstract
To safeguard and preserve World Cultural Heritage, in risk of climate changes, environmental stresses and natural disasters, scientific and technical tools, from materials science and engineering, structural analysis, geology, survey engineering, to archaeology, history of art and architecture, are employed.

Nowadays, Protection of Cultural Heritage displays the features of an emerging interdisciplinary scientific and technical sector. Advanced diagnostics, environmental impact assessment, strategical planning and compatibility assessment regarding materials and conservation interventions, environmental management for the sustainable preservation of Cultural Heritage account, among other innovations, research advances providing solutions to protection problems.

University postgraduate education needs to merge competences of basic disciplines in order to promote and sustain the new professional profiles required.

In the present work, the European features of postgraduate education regarding protection of Cultural Heritage are surveyed. In the light of 10 years experience of the MSc on "Protection of Monuments" at the National Technical University of Athens, the perspectives of a European Master on the Protection of Cultural Heritage are explored. Given the capability of European centers of excellence to provide modules of an interdisciplinary program and the framework of European mobility, by exchanging credit units, it seems that the vision of a European Master in Protection of Cultural Heritage might become reality.

Furthermore, European knowledge produced by research and technological advancements might be integrated, transferred and reproduced inferring sustainability to the implementation practice for preservation of Cultural Heritage.

1. Introduction
In the spectrum of European MSc diplomas and specialization courses fostering architectural restoration, archaeological studies, materials and conservation of cultural heritage, the NTUA experience is studied in the present work as a functioning interdisciplinary effort.

The postgraduate program *"Protection of Monuments" is* offered at the NTUA continuously for 10 years with the objective to provide advanced education and specialization in the field of the protection of monuments to architects, engineers, archaeologists and other scientists relevant to the field and respond to the following needs in the field of Cultural Heritage:

Advanced diagnostics and monitoring of deterioration process in architectural surfaces of historic and traditional buildings,

Environmental impact assessment and mapping on real scale-real time production,

Selection, application and evaluation of proper, effective and compatible conservation materials and techniques for restoration interventions,

Strategic planning of conservation interventions, environmental management for the protection of monuments, complexes and sites, preservation management of monuments, complexes and sites.

The participating NTUA Faculties are: Architecture as coordinator, Chemical Eng. as responsible for direction B, as well as Civil Eng., Surveying Eng., Electrical and Computer Eng., Mineralogical Eng., Physical and Mathematical Eng. and others. The program consists of two directions: *A: Conservation & restoration of historic buildings and sites, B: Materials and Conservation Interventions*.

In the present work emphasis is given in direction B.

2. Structure of the MSc postgraduate program "Protection of Monuments", direction B "Materials and Conservation Interventions", NTUA.

Eligibility
Students are selected through an open call and a selection procedure that includes evaluation of CVs, a written test on basic relevant issues and an interview. The prerequisite is the 6th level of education: i.e. 4 to 5 years University studies from a broad range of disciplines (engineers, architects, archaeologists, natural scientists, conservators of university level et als).

Syllabus Structure
The duration of studies is divided into three semesters while the teaching strategy is based on 4 key Educational Tools:

(a) Lectures

- Laboratory and on site exercises (NDT, instrumental techniques and semi-industrial devices elaborated by GIS and finite element models),
- In situ investigation and field trips,
- Research Dissertation Thesis,
- Nine courses are offered for the completion of studies,
- Three (3) mandatory core courses (common to both directions); (*120 hours:* 15 credit units),
- Three (3) mandatory courses per direction (*240 hours:* 30 credit units),
- Three (3) optional courses regarding specific issues, techniques and technologies (choice of three out of eight offered) ; (*120 hours: 15 credit units*),
- Laboratory and on site exercises. Technical themes' reports (*120 hours:* 15 credit units),
- Research Dissertation Thesis (*one semester:* 30 credit units).

TOTAL credit units: 105.

Table 1: Syllabus structure for the direction B' "Materials and Conservation Interventions" of the interdisciplinary postgraduate program "Protection of Monuments", NTUA.

1.	Mandatory core courses (common to both directions)
1.1.	Theory and history of restoration
1.2.	Introduction to the diagnostics (materials decay and structural pathology) and restoration

1.3.	Institutional framework for the protection and management of cultural heritage
2.	Mandatory courses for direction B "Materials and Conservation Interventions"
2.1.	Science and engineering of building materials and materials of architectural surfaces
2.2.	Science and engineering of materials and conservation – restoration – protection interventions
2.3.	Environmental management for the preservation of monuments and sustainable construction
3.	Optional courses for direction B "Materials and Conservation Interventions" regarding specific issues, techniques and technologies (choice of three out of eight offered)
3.1.	Corrosion and conservation of metal objects of art and constructions
3.2.	Specific techniques of materials and conservation interventions for the earthquake protection of monuments
3.3.	Pilot compatible implementation of conservation interventions
3.4.	Environmental management planning for the preservation of monuments
3.5.	Environmental management, materials and technologies for the protection of museum exhibits
3.6.	Materials, techniques and technologies for the conservation and preservation of movable cultural heritage and objects of art
3.7.	Archaeometry
3.8.	Diagnosis of pictorial cultural heritage
4.	Laboratory and on site exercises. Technical themes' reports
4.1.	Diagnostic techniques and methodologies (Analytical and non-destructive methods)
4.2.	Materials and cleaning interventions on laboratory and monument scales
4.3.	Methodology and assessment techniques for consolidation and protection interventions on laboratory and monument scales
4.4.	Study of the behaviour of building materials to humidity transport phenomena
4.5.	Characterization of historic mortars
4.6.	Characterization and synthesis of compatible restoration mortars
4.7.	Study and assessment of the behaviour of historic structures under static and dynamic stresses
4.8.	Documentation and management of the interphase monument / environmental data
4.9.	Actual and virtual environmental and museum management for the protection of museum exhibits
4.10.	Sustainable planning of materials and conservation interventions. Implementation of assessment methodologies (life cycle analysis et als) regarding minimization of energy and consumption environmental impacts
4.11.	Interdisciplinary laboratory: Communication exercises between different aspects of the same issue.
5.	Field visits
6.	Research Dissertation Thesis

In the case of the direction B it is mandatory for the graduate students to attend a set of laboratory experiments - demonstrations and prepare 2-3 laboratory project reports that sum up 15 credit units, while in direction A, architectural design and documentation themes account for the same credit value.

These Laboratory and on-site Exercises aim the:

- Application and performance evaluation of effective and compatible materials techniques and conservation interventions: Cleaning, Consolidation, Protection, restoration mortars,
- Assessment of the structural performance of repair materials techniques and design (structural analysis, earthquake testing, finite elements models),
- Strategic planning of sustainable preservation of monuments, complexes and sites,

which are achieved through the use of:

(b) Non-Destructive Techniques

In lab scale, where students are provided the necessary background in materials evaluation and for in situ investigation – field trips, where they examine and assess materials on real structure scale. NDT techniques such as Fibre Optic Microscopy (FOM), Infrared Thermography (IR Thermo), Ultrasonic Pulse Velocity (US), Digital Image Processing (DIP) and Ground Penetrating Radar (GPR) are commonly employed.

(c) Instrumental Laboratory Techniques

For the mineralogical, physical, chemical, mechanical characterisation of materials studied, the NDT techniques results could be validated using instrumental laboratory techniques, such as: Mercury Intrusion Porosimetry, Differential Thermal and Thermogravimetric Analyses (DTA/TG), Thermomechanical Analysis (TMA), Fourier Transform Infrared Spectroscopy (FTIR), UV Visible - Infrared Spectrometry, Scanning Electron Microscopy with energy dispersion by X-Ray Analysis (SEM-EDAX), and others.

These exercises are integrated by the contribution of Semi – Industrial Devices such as Ageing Test Chambers and Materials Production and Configuration

Table 2: Laboratory experiments - demonstrations for the direction "Materials and Conservation Interventions" of the interdisciplinary postgraduate program "Protection of Monuments", NTUA.

4. Laboratory experiments – demonstrations
4.1. Techniques and methods for materials characterization and decay diagnosis
4.2. Techniques and methods for cleaning interventions on laboratory and monument scales
4.3. Techniques and methods for consolidation interventions on laboratory and monument scales
4.4. Study of the behaviour of structural materials to humidity transport phenomena
4.5. Characterization & synthesis of compatible restoration mortars - characterization of historic mortars
4.6. Behaviour of structural systems to static and dynamic stresses
4.7. Monuments protection - environmental management

(d) Dissertation thesis (MSc thesis)

For both directions it is mandatory for each student to prepare a dissertation Thesis which will then be examined by a certain committee. The Thesis examination committee comprises of five members, mostly professors from NTUA, with experience relevant to the subject. Often external members of the scientific community are included in the thesis committee, such as distinguished scientists from industry and the ministry of culture.

From 152 Dissertation Theses (within 10 years of the Master):

– 35% continued as PhD,

– 30% is published in International Journals and Scientific Books,

– 47% is published in Greek and International Conferences and

– 53% with regard to research and applied projects, justifying their research character and their value of application.

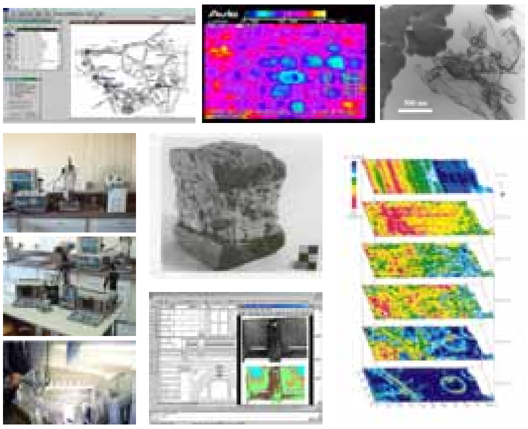

Figure 1: Examples of applied theses of research value.

3. Criteria to assess the program / Characteristics of the Program

Interdisciplinary character

The students' provenance covers a wide range of disciplines. In 152 postgraduates of the Direction B: 53% are Chem. Eng., Industrial / Materials Eng., Physicochemical Scientists and Conservators, 34% Architects and Structural Eng. and 13% Archaeologists and Historians of Art.

Table 3: NTUA Master "Protection of Monuments", Direction B' "Materials and Conservation Interventions".

Acad. Year	Applicants	Enrolments	Graduates
1998-1999	28	14	12
1999-2000	32	17	15
2000-2001	33	11	11
2001-2002	35	17	16
2002-2003	32	17	17
2003-2004	51	17	16
2004-2005	58	17	17
2005-2006	53	17	15
2006-2007	32	15	14
2007-2008	26	17	16
TOTAL	380	159	149

Table 4: NTUA Master "Protection of Monuments", Direction B' "Materials and Conservation Interventions".

1998-2008	Applicants	Enrolments	Graduates
Architects	35	16	14
Chemical Engineers	77	42	40
Civil Engineers	107	34	31
Rural and Surveying Engineers	8	3	3
Other Engineers	18	8	8
Scientists (mainly Chemists)	52	22	22
Archaeologists	53	21	20
Conservators (University Degree)	16	10	9
Other	14	3	2
TOTAL	380	159	149

The lecturers are: 85% NTUA Profs: (38 % Chem. Eng., 15 % Architects, 15 % Civil Eng., 7 % Surveying Eng., 10 % Other disciplines) and a 15 % are invited professors from Greek and European Universities or distinguished scientists and professionals, mostly from relevant "industry" (Ministry of Culture, Construction Industry, Materials industry etc.).

Table 4. Lecturer's distribution according to their discipline in the postgraduate course "Protection of Monuments – Direction B': Materials and Conservation Interventions", National Technical University of Athens, Greece.

40 %	School of Chemical Engineering – NTUA
15 %	School of Architecture – NTUA
15 %	School of Civil Engineering – NTUA
7 %	School of Rural and Surveying Engineering – NTUA
10 %	Other Schools of NTUA (School of Applied Mathematics and Physics, School of Mining Engineering and Metallurgy, School of Electrical and Computer Engineering)
10 %	General Sciences (outside NTUA, e.g. Engineers or Archaeologists from Minitsry of Culture)
3 %	Theoretical Sciences (Archaeology, History)

Diffusion, application of advanced research topics and assessment of professional best practices

– advanced diagnostics and monitoring of deterioration,

– environmental impact assessment and mapping of materials and structures decay and pathology on real scale and in real time,

– selection, application and evaluation of effective and compatible materials and techniques for conservation interventions, as well as reverse engineering for their production,

– strategical planning of conservation interventions, environmental management for the protection of monuments / sites / historic cities, sustainable preservation

Use of various advanced and applied educational tools, such as lectures, laboratory exercises, fieldwork, and Dissertation Theses

In particular, the program syllabus places particular emphasis on:

– computational and mathematical methods of analysis (GIS, GIS fuzzy logic, finite elements modelling, multicriteria analysis, discriminant analysis et als)

– seismic risk assessment and protection evaluation (fragility curves, earthquake tables et als)

– instrumental laboratory techniques, semi – industrial scale chambers and in situ non destructive techniques.

The gained know-how is applied in the field by the annual organisation of in situ educational visits in Museums, Monuments, Historic sites and cities, examples:

- Acropolis of Athens
- Neoclassical Historic buildings of Athens (Athens Academy, National Library of Greece, National Archaeological Museum and several neoclassical buildings) (cleaning, strategic planning of conservation interventions of the facades)
- Archaeological Site of Eleusis (sustainable preservation of Archaeological Sites from industrial pollution)
- Medieval City of Rhodes (non – destructive techniques' application: FOM, US, IR, DIP)
- Venetian fortifications of Heraklion in Crete (environmental impact assessment by GIS management)
- Byzantine Fortressed city of Mystras
- Nea Moni Chiou
- Osios Loukas Monastery in Fokida and other monuments and sites
- Traditional ekistics cores in Aegean islands
- Hagia Sophia Basilica and Byzantine Monuments in Istanbul (earthquake protection by preparation of compatible repair mortars simulating historic ones – NDT application in the dome area for the revealing of plastic mosaics)

Employment analysis

According to the existing documentation, postgraduates are employed at a rate of 33% at the Ministry of Culture, 20% as Researchers (Universities, Research Centres et al.), 15% in construction companies, 10% in engineering studies' bureaus, 15% in the broader public sector and 7% in the relevant industry and private sector.

Table 5: NTUA Master "Protection of Monuments"; Direction B' "Materials and Conservation Interventions"; Distribution of enrolled 22 year old graduates / working adults per academic year.

Acad. Year	22 year old graduates	Working adults	Total	22 year old graduates percentage	Working adults percentage
1998-1999	10	4	14	71%	29%
1999-2000	9	8	17	53%	47%
2000-2001	6	5	11	55%	45%
2001-2002	7	10	17	41%	59%
2002-2003	10	7	17	59%	41%
2003-2004	12	5	17	71%	29%
2004-2005	8	9	17	47%	53%
2005-2006	8	9	17	47%	53%
2006-2007	9	6	15	60%	40%
2007-2008	10	7	17	59%	41%
TOTAL	89	70	159	56%	44%

Table 6: NTUA Master "Protection of Monuments"; Direction B' "Materials and Conservation Interventions"; Gender distribution of enrollments per academic year.

Acad. Year	Women	Men	Total	Women percentage	Men percentage
1998-1999	8	6	14	57%	43%
1999-2000	7	10	17	41%	59%
2000-2001	8	3	11	73%	27%
2001-2002	14	3	17	82%	18%
2002-2003	8	9	17	47%	53%
2003-2004	10	7	17	59%	41%
2004-2005	13	4	17	76%	24%
2005-2006	12	5	17	71%	29%
2006-2007	12	3	15	80%	20%
2007-2008	14	3	17	82%	18%
TOTAL	106	53	159	67%	33%

4. Evaluation

Evaluation procedures and evaluators

The program was evaluated by

- Postgraduate students (every year) evaluated the program experience as satisfactory (over 3.5 in 5).
- Internal evaluators. Members of In-house University Professors (in 5 and 10 years of the program, last one in 2008): G. Batis, E. Biris, Ch. Bouras, D. Dimotikali, F. Goulielmos, Ch. Ioannidis, N. Kalogeras, E. Korres, M. Koui, E. Maistrou, A. Moropoulou , K. Mylonas, N. Spyrellis, E. Vintzilaiou, D. Zivas
- Visiting Professors of internationally recognized universities (2000 and 2003): Prof. Van Grieken (University of Antwerp), Prof. G. Biscontin (University of Venice), Prof. A.S. Cakmak (Princeton University)
- External evaluators. Internationally acknowledged experts in the field (2000): Dr. Sp. Pappas (Council of Europe), Dr. S. Arzeni (OECD), Dr. Chr. Sabbioni (EC EAG "City of Tomorrow and Cultural Heritage), Prof. E. Zezza (CUM-Community of Mediterranean Universities).
- University Professors 2008: Prof. G. Scherer, (Princeton University), Prof. Roko Zarnic, (Ljubljana University), Prof. G. Biscontin (University of Venice).

Evaluation outcome

The results of the evaluation indicated that MSc Program's recognition and perspectives are attributed to its multidisciplinary character (reflected mainly on the syllabus), scientific level, cohesion and longevity.

The reasons justifying further continuation, development, internationalization and viability assurance of the MSc in "Protection of Monuments" are:

– the advanced knowledge, training and high level of specialized education offered by the program,
– its multidisciplinary character,
– its effective structure (combination of theory with fieldwork and exercises, orientation of Dissertation Thesis to real problems in the field of Protection of Monuments),
– the fact that it responds to issues of the scientific community's research needs and to the new professional profile of scientists and engineers developed in the field of cultural heritage protection,
– the new labour posts-opportunities based on sustainable preservation heritage and new European strategies.

5. European advanced courses as pilot for a European master

Advanced Study Course – conference ITECOM

The above concept (interdisciplinary postgraduate program) was upgraded to a European level by developing an Advanced Study Course ITECOM "Innovative Technologies and Materials for the Conservation of Monuments" (Contract No: EVK4-CT2002-65002), focusing on innovative technologies and materials for the protection of monuments. The two weeks Course aimed at the promotion of education on science and engineering for the protection of cultural heritage and was integrated by ITECOM Conference *"Innovative Technologies and Materials for the protection of Cultural Heritage. Industry, Research,* Education: European acts and perspectives", aiming the creation of a platform for the integration of research, industry and education in the field of Cultural Heritage protection.

Table 7: European profile of the project – Distribution of selected students.

Belgium	1
Bosnia Herzegovina	1
Bulgaria	2
Cyprus	1
Czech Republic	1
France	1
Germany	2
Ireland	1
Italy	10
Greece	12
Latvia	1
Poland	1
Portugal	2
Romania	2
Serbia	1
Turkey	3
TOTAL	42

The evaluation results were very positive and were reported to the EC.

Interdisciplinary courses of Princeton University

To this experience, significant contribution added the interdisciplinary courses of Princeton University about Byzantine Istanbul considering the city as an open Lab, with the participation of Bogazici University of Istanbul and National Technical University of Athens", that led one step forward to the need of establishment of a European Master (MSc).

"Educational Linkage Approach In Cultural Heritage – ELAICH"

Furthermore, this scientific program, approved by European Commission - EUROMED HERITAGE IV 2008, has the objective to develop an educational tool with a multi-modal interface, based on solid innovative didactic-methodological foundation through a mixture of traditional course materials, modern e-learning applications and "intelligent" in-situ practical work, in order to contribute to the dissemination of advanced study courses in the Mediterranean partner Countries connecting Europe, Africa and Asia, and encouraging the accessibility to the knowledge of cultural heritage.

Hence the emerging autonomous scientific field on science and engineering of materials and technologies for the protection of cultural heritage is pointed out and articulated in postgraduate educational level.

6. Conclusions, Challenges and Perspectives

The safeguarding of our Cultural Heritage is of major concern to the European community as it is an important part of our living environment, of our past, and of our future.

The European Research Priorities for the Preservation of Cultural Heritage include:

– Assessment, monitoring, diagnosis,
– Materials,
– Intervention Techniques.

As far as the sustainability and added value of Cultural Heritage is concerned most attention is given in the fields of energy and environment, management, exploitation and maintenance, city and territorial Aspects.

The means of meeting these Goals are:

– Sustainability,
– Directives, Guidelines and Technical recommendations,
– Socio-economic aspects and strategies,
– Disaster prevention and risk management,
– Information Communication Technology,
– Education and training.

The modernization agenda for Universities set by E.C. (COM – 2006 – 208 FINAL) to the European Parliament encourages the enhancement of inter – and transdisciplinarity. Protection of Cultural Heritage is an exemplary field where European universities reward excellence at the higher level by joint initiatives like European MScs and PhDs in Cultural Heritage. Excellence also requires that Member States review the opportunities they provide at Master, Doctorate and post – doctorate levels, including the mix of disciplines and skills involved.

At European level, excellence at graduate / doctoral schools should be encouraged by networking those which meet key criteria: critical mass, trans- and inter-disciplinary, strong European dimension, backing from public authorities and from industry, identified and recognized areas of excellence, provision of post-doctoral opportunities, suitable quality assurance. In particular, the peer learning clusters set up within the Education and Training 2010 work program offer an effective means of exploring how the challenges facing EU universities can be met.

The national experience and the European priorities indicate the need for the creation of a European Master of Science

(MSc) in materials, techniques and conservation interventions for the protection of monuments.

It is therefore suggested a modular curriculum offered by the interested European and other world class Universities. Greek Law No 3685, 16/07/2008 permits intra-countries, intra – universities cooperation to a common MSc diploma, compiling exchangeable credit units through mobility. Protocol agreements should proceed to this direction, with NTUA as a core University. European PhD candidates will be able to account credit units by attending various courses from the MSc syllabus, in various universities and countries, organizing in this way the European research and education Area, by employing innovative materials, techniques and strategies for the Protection of Cultural Heritage. International co operations should be structured.

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COST TRAINING SCHOOL IN CH AS AN INSTRUMENT OF TRAINING AND NETWORKING IN EUROPE

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The Cultural Heritage (CH) is one of the unifying factors of our society and today it is clearly perceived both as an important educational and economic resource for all the European countries. This is demonstrated by the continuous growth of the cultural demand and by the constant attention that the responsible institutions (national and local authorities, museums, universities, research centres) put on the improvement of their organisation and on the extension of services to all public categories. The conservation of Cultural Heritage has therefore become, in the past decades, a highly relevant issue in European society and the driving force for public and private investment as well as for research, education and training.

As far as education is concerned, the European system is now capable of forming a broad range of professionals (restorers, conservation scientists, managers, public relation managers) though a well developed high level training institutions (e.g. the schools of the major restoration centres), universities (e.g. masters and doctorates in conservation science, applied sciences, tourism, managing and sustainability of the CH) and also private companies. The system assures a solid academic training in all of the disciplines involved in the conservation and preservation of the CH. Nevertheless there is a need for improvement, particularly in the domain of conservation science. On academic and industrial level scientists are producing fast and continuous advancements that are often transferred only with unacceptable delay to the conservation practitioners.

COST, European Cooperation in the field of Scientific and Technical Research, is one of the longest-running instrument supporting co-operations among scientist and researchers across Europe. Several COST Actions (6251, A272, C173, C20, G1, G74, G85, D42 and IE0601) have been built around selected themes of the CH conservation. They became in the recent years the most dynamic and efficient instrument for promotion or development of the most advanced research on CH and for the exchange and dissemination of their results. One of the successes of such COST Actions has been the institution of specialised COST Training Schools, emanating from single Action or even interdisciplinary networks of several COST Actions. COST Training Schools are one of the instruments of COST and are aimed to provide dissemination from the Action activities or intensive training in either a new emerging subject or in technology offered by the laboratories of the Action with unique equipment or know how. They are conducted as one week units with high level teachers, lectures combined with hands-on exercise, designed for up to 40 participants with different backgrounds. As an example, the first European training on application of synchrotron radiation in CH, "New Lights on Ancient Materials 2005" has been organised by the COST Action G8 in the new Synchrotron Facility in Soleil, France. Training Schools are not intended to provide general training/education, but to offer specialised training in specific methods or techniques related to a particular category of assets. An example is the Training School on ceramics conservation organised in Bordighera where different experimental methods which can be applied to analysis and restoration of ceramic materials have been taught.

The organisers of the schools usually provided all lectures on the CDs and when possible tried to integrate the teaching course into the university programme. In such a case the school was open to the wider audience and in some cases ECTS Credit Points could be obtained. Those attending the schools were basically but not exclusively young researchers from across Europe but Training Schools may also cover appropriate re-training as part of "life-long learning". In view of the situation in Europe described at the beginning, the schools have fulfilled the very delicate role of transferring, to young students aiming at entering the world of the CH, the most recent innovations, promoting at the same time the work of leading European researchers, and creating the perspectives for a closer interaction between the students and the European research community. The schools have attracted hundreds of applications making the selection very difficult. The statistics drawn from the students evaluation forms, tells us of a very high degree of satisfaction and further demand for similar activities. The experience of organisers and teachers reveals even more on other achievements, like the motivation of students to pursue on building their carriers and the creation of links and common interests that will remain in their future activities.

As a model, the COST Training Schools can be envisaged as a very efficient tool to improve even further the training of the best European students, enriching their academic curricula with the experience of research. COST has established through the schools an exemplary opportunity for the dissemination of results and will certainly work hard in the future for making this training opportunity available to more and in a more efficient way, possibly as a school annual series, as a COST training seasonal venue or as a COST on-line training.

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COMMUNICATING THE HERITAGE OF EMONA: WHAT DOES PUBLIC WANT? POTENTIALS AND STRATEGIES

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1. Introduction

Archaeological heritage management is a complex process, which includes everything from legal and physical protection to maintenance and its use in the everyday life of modern society. Heritage belongs to all the people, a public good, which states or other communities protect and manage in the name of the people and preserve it for future generations.[1] Improper management can easily result in heritage that was once dynamically passed from generation to generation being alienated from its primary context. As such it becomes distant to the people that it belongs to.[2] Such alienation means the end of the authentic link between the community and its heritage. In this article an attempt is made to illustrate the problem of such alienation and further on re-approaching of the heritage to the citizens on a case study of Roman archaeological heritage in the city of Ljubljana in Slovenia.

2. Historical background and the issues

In the modern city of Ljubljana, the presented heritage of the Roman town of Emona includes two archaeological parks, the complex of the southern Roman defensive wall (in Mirje) and several smaller units, dispersed in the city centre. These presentations are the result of almost a century of effort by archaeologists and conservators to preserve this heritage and present it to the public. The outline scheme of the presentations was created in the period after the First World War and remained almost unchanged during the 20th century.[3] The main idea was to preserve large areas in situ. The basic model of the presentation was an archaeological park, where all the presented architectural remains become an aesthetic space, reserved for cultural enjoinment by intellectuals. From the very beginning of the presentations the absolute monopoly over the transfer of heritage information and decision-making about its meaning, was (in the academic as well as in less formal environments) always in the hands of the archaeological and conservation profession. They independently made decisions about the public needs about the heritage and how this should take place; however, the public had no voice in this process.

The present conditions show that effectiveness of the transferred message about the meaning of the heritage of Emona was weak. The townspeople do not include their heritage in their everyday activities.[4] Visits to the archaeological parks is in large segment limited to school groups and as such presents a once in a life time experience for an average citizen of Ljubljana. The results of a questionnaire showed that some presentations – such as the presentation of the walls of Emona in the pavement of Ljubljana – are not at all understandable to the townspeople.[5] One result of such alienation is that the heritage of Emona frequently becoming a target for vandalism. It seems that only one of the presented monuments is actually in use. However even this one is not used according to the plans of its establishers – the presented parts of the Roman defensive walls in Mirje are used by the townspeople as a climbing spot and a place to meet.

It seems that the public attitude towards the presented heritage is more or less indifferent. Despite of this, the results of a questionnaire carried out on the streets of Ljubljana[5] and even more the response on the new archaeological discoveries (NUK 2) that produced a vibrant media debate, show that that is not so after all. The citizens of Ljubljana do care about their heritage, they are proud of it and they wish to preserve it for the future. Archaeology even seems to be more interesting for Slovene media every year – more and more articles are published. The increasing public interest in the archaeological heritage indicates a growing wish for active participation in the process of its preservation and use.

Figure 1: The presentations of the walls of Emona in the architecture and in the pavement of Ljubljana are hardly understandable to the townspeople. Photo: Ana Plestenjak.

Figure 2: One result of such alienation is that the heritage of Emona frequently becoming a target for vandalism. Photo: Bernarda Županek, Archive: City Museum of Ljubljana.

Unfortunately, the archaeological profession is in this aspect very static. It does not have a clear vision on how to handle such intentions. It tries to preserve its monopoly. Research carried out among archaeologists showed that particularly young experts can not see a deeper meaning in public involvement.[6] They recognize only the threats (potential threats), as the benefits of such participation (long term survival) stay hidden from them.[7] On the contrary older archaeologists do recognize the importance of such cooperation. However, they admit that they do not pay enough attention to the public relations.

3. Strategies for presentation

Thus the archaeological profession today stands before a great challenge: How does one manage the heritage of Emona in order for it to become an active part of the everyday life of the townspeople? How may the role of the heritage of Emona inside Ljubljana be conceptualized in these days of intense social changes?

The city council of Ljubljana as the owner of archaeological heritage in the city of Ljubljana, chose public-private partnership for developing solutions for heritage management. It is preparing a project for the presentation of the archaeological remains from the Roman period in the cooperation with the City Museum of Ljubljana and the commercial company Arhej d.o.o.

During the development of these strategies, it was presumed that an interest in the heritage of Emona on the side of the townspeople exists. Therefore any form of future changes should be primarily of the benefit to the public and not the experts. As the heritage belongs to all the people, it should be as well accessible to everyone – in informative as well as in physical terms. The second important issue arises from the analysis of the present conditions of the heritage of Emona. The main problem is its incomprehensiveness and exclusion from its original context.[8] Single presented monuments seem to be like a string of isolated spots, from which it is impossible to understand the form and cohesion of the ancient city. Contextualization with a brochure or a weak message on informative panels does not satisfy the average visitor. Therefore it seems that too little effort was placed upon the communication of the meaning and importance of the heritage of Emona.

Thus it is important to provide a suitable context and connect all the monuments in a unique form to outline their connections. Besides the renovation and modernization of the informative panels, it is necessary to establish new ways of presentation that could provide a deeper understanding and experience of the Roman city for the members of the public. Modern interpretation should be clear, understandable, classified in levels and pertinent to the present day issues. One of the more important steps in this way is a creation of the GPS guide of Emona.[8] It is based on the understanding of the interaction of a visitor with the environment and allows all the communicating interactions of mobile information technologies.

It is of great importance to communicate with the public during the development of successful ways of management. Therefore a decision was made to attract different interest groups to collaborate in the development of the new contents and meanings, as well as to help with the restoration works. It was assessed that in this way a new relation between the townspeople of Ljubljana and the already presented heritage could be made and as a consequence a new perception and understanding of the heritage could be established.

The current offer is already varied with events that enable an authentic connection with heritage. Workshops for children, young people and older townspeople are enabling active involvement and deeper connection with the heritage. Other social events are also happening (concerts, theatre, etc.) on the sites that are not necessary connected with the heritage itself. The usefulness of the heritage to modern society is being created made in this way. The response to these events is good; the visitors want repeat performances. Besides it seems that the response is especially good when the events are free of charge.

Figure 3: "Caesar is visiting Emona"«, an event in archaeological park Zgodnjekrščansko središče, Museum summer night 2007. Photo: Robert Erjavec.4. The problems and the pitfalls.

It is particularly important to create a self sustainable system of heritage management in the long term, which means that it will probably be impossible to totally avoid the commercialization of the heritage. The fact is that with the expansion of interpretation, informal education has come closer to the entertainment industry.[9] Consequently the story behind the object has become more attractive than the object itself. Other factors which exist in modern society – such as commercial value, hyper-consumption and escapism – contribute to the fact that entertainment is taking over the role, which previously belonged to education. Therefore the concern that the past is becoming a toy and heritage nothing more than a consuming product is legitimate.[10] This is also true of the question of the authenticity of the heritage.[11,12]

While preparing the program of the revival of the heritage of Emona, one of the basic statements was that market orientation, aiming for profit and quick repayment of financial investments that are the guidelines of the heritage industry, can not become the priorities of this project. They present a serious danger for the heritage: quality, authenticity and expertise are rarely in the interest of capital. Commercial values orientated towards the present profit last as long as the profit itself. On the other hand cultural values are deeper and wider.

5. Conclusions

A proper balance of all the factors –professional expertise and public inclusion, protection and use, market orientation and assurance of authentic experience – is the main task of modern heritage managers. If heritage is supposed to be a part of a dynamic society, it has to become an active factor in the decision-making process. The aim of heritage creation is sharing.[13] Only a proper balance of interests provides a satisfaction on all sides and long term survival of the past remains.

Heritage is created and lives as a social process and practice, therefore it should also be managed in this way.[4] In addition to protection, it is also important to enable a qualitative communication with the visitors, public participation and opening the gates of the experts. Nowadays heritage is most of all a communication practice.[14] Therefore it is the best practiced in public programs, projects with public inclusion and similar activities. Only in this way heritage is something alive: it revives through experience, activities, practice and engagement.

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MEDITERRANEAN CONSERVATION ALLIANCE

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Conservation and valorisation of Cultural Heritage is a fundamental element and an essential mission of the Mediterranean Countries where the major part of the ancient and fascinating witnesses of the human art and creativity may be found. Ancient metal artefacts, from iron to precious noble metals artefacts, are high value objects for their intrinsic historical nature and for the great and sophisticated skill used to produce them. To identify the demand of conservators and researchers concerning decay causes and mechanisms, reliable traditional and/or innovative conservation materials and methods are the most important basis for the conservation and exhibition of ancient metal artefacts in the Euro-Mediterranean basin. The MEDAL project (financially supported by the European Community, FPVI-INCO-SSA) intends to contribute to the diffusion of knowledge, experience and methodologies dealing with the conservation of metal ancient artefacts from Mediterranean Countries. The project helps Mediterranean researchers to have access to knowledge and expertise existing elsewhere in the world and it provides and promotes opportunity to participate in scientific exchanges at an international level. With the MEDAL idea of building up a permanent Mediterranean Conservation Alliance, it will be possible to increase the effectiveness and scope of cultural heritage conservation on a wide European and Mediterranean scale through new and tailored approaches, anchored in local actions, and to contribute to the development of the conservation science in Europe and in the Southern Mediterranean Countries as suggested by EU policy.

The leitmotiv of the project is to take profit of the experience gained by research groups that have participated in national and European INCO-Med projects aimed to identify the degradation causes of ancient metal artefacts, to find reliable conservation methods and to select the most safe exposure conditions able to ensure a long life and the best fruition to these precious witnesses of the human creativity and technology. The consortium of the MEDAL project is representative of important countries for what concerns the study and the conservation of ancient cultural heritage (Egypt, Italy, Syria and Turkey). The expertise and the disciplines of the researcher involved in the project include archaeology, chemistry, physic, computing and material science.

The overall objectives of the MEDAL project are to spread in the Euro-Mediterranean basin and neighbouring countries the experience, the information and the knowledge already acquired on the conservation of the tangible metallic cultural heritage by developing dissemination tools and activities which will consider the wide spatial and functional diversity of the metal cultural heritage and identity. The project is also aimed to the create a new knowledge through training courses on reliable diagnostic techniques and on conservation materials and procedures as well as on standardised testing methodologies able to ensure safe exposure, management or storage conditions. This knowledge includes the significance and dynamics of the cultural heritage, the evaluation of the threats and the opportunities arising from the interrelation of culture with the main social and economic trends. The role of Cultural Heritage both as a capital asset with ethical and economic value and a stimulus to change will be taken into account, implying that new, wider notions of dissemination will be taken into the picture compared to previous research efforts developed within the INCO programs.

In detail the objectives of the MEDAL project, now in its second year, will be reached through three different typologies of activities: i) Training and dissemination, ii) Web site design and development, iii) Large scale investigation of needs and requirements in conservation field.

Dealing with "Training and dissemination" activities, in order to disseminate information as widely as possible, a series of one week workshops are foreseen in different Mediterranean countries. They are focused on reliable methods and materials for conservation, storage and exhibition of ancient metal artefacts as well as on the innovative diagnostic methods including portable equipments for in situ characterisation. Moreover, in order to better reach the MEDAL objectives, the videos of the workshops are published on the project web site.

The 1st Metal Conservation workshop was organized in Turkey, from 6th to 9 th May 2008, at EGE University, Faculty of Letters, Department of Protohistory and Near Eastern Archaeology, Izmir. Forty applicants, students, young researchers, conservators and professionals, attended successfully the workshop. The second one will be held in the Syrian Arab Republic in November 2008. A"Two weeks stage for young Mediterranean Researchers and conservators" will be held in Italy, Rome, Institute for the Study of Nanostructured Materials, National Research Council, and Turin, Politecnico, from 9th to 19th September 2008, where some experimental conservation activities, training of advanced analytical facilities and visits of laboratories will be organised.

At the end of the project a Conference will be held in Egypt for building a Mediterranean interdisciplinary forum with conservators, researchers in material science and policy makers. The discussion will focus on how the acquired knowledge and technology as well as the dissemination activities carried out during the present and previous European projects may be collectively evaluated and transformed into improved practices for conservation, storage and exhibition of metal ancient artefacts.

Dealing with the "Web site design and development", as shown in Figure 1, a dedicated Anglo-Arabic Web Site (http://www.medal-project.eu) has been developed and is continuously implemented. In the web site previously acquired results of large-scale investigations of ancient metal collections are shown by using also videos. Common and unusual case studies of degradation of ancient metal artefacts are described with standardised or reliable tailored conservation methods and materials. Exhibition and storage precautions and testing methods are reported and the most relevant literature references are listed and reported. A particular attention is devoted to the section dedicated to the frequent asked questions (FAQ) which will be followed daily, thus giving to the visitors in real time answers and information able to solve end users problems and to give specific information.

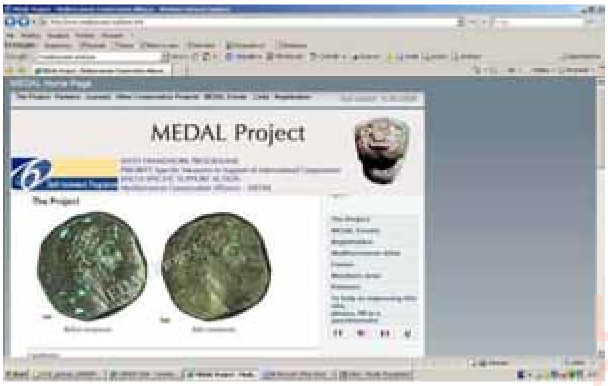

Figure 1: Home page of the Web site of the MEDAL Project.

Finally dealing with the "Large scale investigation of needs and requirements in conservation field", a Questionnaire has been distributed to identify the demand of conservators concerning the ancient metals conservation in the Mediterranean Basin. The results will be collected and analysed in order to implement the Anglo-Arabic web-site to answer to these expectations.

The following Questionnaire has been proposed:

1. Could you classify yourself by activity area?
Archaeologist □ Curator □ Restorer □ Conservator □
Architect □ Engineer □ Chemist □ Physicist □
Geologist □

2. Do you consider yourself solely a metal conservator or are you a conservator who works on metal artefacts along with other materials? Metal conservator □, Metal conservator who works on metal artefacts along with other materials □

3. With which experts do you collaborate to select a conservation treatment? Archaeologists □, other conservators □, curators □, architects □, chemists □, geologists □, physicists □, engineers □ for selecting a metal conservation treatment?

4. If you are currently involved or have been involved in a project (or projects) concerning conservation of ancient metals, please give a short description of the project (programme, title, coordinator etc. possibly with references of a website or a brief description):

5. How important do you consider the dissemination of European project results concerning ancient metal conservation? High □, Medium □, Low

6. Do you think that it is important for your activity an Anglo-Arabic web-site dedicated to metal conservation where the most relevant results achieved within European funded projects are described? Yes □, No □

7. For which objects do you think that the dissemination of results of large scale European projects is needed most? (e.g. archaeological bronzes, precious metal objects, engraved artefacts, iron weapons, coins, gilded objects, ...) 8. Which kind of expectations you have when you imagine a web-site dedicated to the ancient metal conservation?

9. Which kind of metal artefact conservation are you mostly interested in? Archaeological □, Historical □, Copper alloys □, Iron □, Silver □

10. The main problems that you have faced during conservation, exhibition and storage of ancient metal artefacts are related to: the efficacy of the cleaning □, the efficacy of the conservation □, the efficacy of the stabilisation treatment □, the long-term stability of the treatment □

11. Are you testing new conservation materials or are you optimising new conservation methods? Yes □, No □ and are you interested to disseminate your results in the MEDAL website? Yes □, No □

12. Which sections do you think are most useful on the Anglo-Arabic website? Conservation terminology □, Glossary of metallurgy □, Conservation remark □, Section dedicated to some exemplary frequent or uncommon cases of corrosion and degradation occurring in ancient metal artefacts during burial, exhibition or storage □, Section dedicated to the state of the art concerning the most used materials and methods for ancient metal conservation □, Section dedicated to the most important literature references and procedures used for metal conservation □, Section dedicated to the analytical techniques used for studying the degradation processes □, Section dedicated to the frequent asked questions (FAQ) □, Section dedicated to the most relevant European projects aimed to identify metal conservation procedures where are reported the Coordinator information and the abstract □

Which sections would you like to include on the website?

13. The MEDAL projects will organise two thematic one-week workshops that will be taped on video and made available on the website. The workshops will be held in Turkey (12th month, March 2008) and in the Arab Republic of Syria (18th month, September 2008) and will be dedicated to methods and materials for conservation, storage and exhibition of ancient metal artefacts as well as to the innovative diagnostic methods including portable equipments for in situ characterisation.

Would you be interested in participating to these one-week workshops? Yes □, No □

Would you be interested in disseminating your experience by teaching? Yes □, No □

EDUCATING TOMORROW'S CULTURAL HERITAGE LEADERS USING INTERDISCIPLINARY, CASE-BASED LEARNING

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1. Introduction

In 2004, the UCL Centre for Sustainable Heritage launched an innovative mid-career Master of Science course in Sustainable Heritage. Focus meetings with prospective employers, professional bodies and potential students from different disciplines supported the emphasis of the course on protection and management of cultural heritage within the context of environmental, social and economic sustainability. The pedagogy of the course draws inspiration from executive learning and teaching.

In four years, this course has attracted interest from four continents and twenty-five countries world-wide, including Europe (Austria, Britain, Cyprus, Finland, France, Germany, Greece, Poland, Portugal, Spain); the Middle East (Bahrain, Egypt, Israel, Jordan, Syria); the Far East (China, India, Japan, Malaysia, Pakistan, Taiwan, Thailand) and the Americas (Argentina, Canada, Mexico, US, Venezuela). Forty-seven students including architects, art historians, conservators, curators, planners, scientists and surveyors have studied on this course.

2. Key learning and teaching strategies

The aim of the course is to instil leadership qualities in highly skilled and versatile practitioners through (i) team teaching, (ii) an interdisciplinary learning environment and (iii) mutual understanding of the values, knowledge and skills of different disciplines. This extended abstract describes how this is achieved, through a number of key learning and teaching strategies.

The first key strategy is the selection of suitable participants; candidates are evaluated for their potential to benefit from the unique approach of the course, particularly in terms of how their leadership potential can be developed. As a course for mid-career professionals, an important criterion is the knowledge and experience they bring to the classroom and the course seeks to bring together a diverse range of disciplines, backgrounds and experiences to enrich the learning experience of all the students.

At the beginning of the academic programme, the course seeks to create an open and thoughtful learning environment, with time at the beginning of the course focussed on discussion of fundamental issues such as the value and significance of heritage and its sustainability. In the first part of the course, 'Heritage Value and Sustainability', the key concepts of why heritage is important to different peoples and cultures (Heritage Value) and its sustainability, in terms of environmental, economic and social factors are worked out. These provide a framework for the interdisciplinary aims of the course and for the interactions of the students, who come from many different disciplines and cultures, but who can all contribute from their own perspective to the debates on how to achieve heritage sustainability. Thus all students are empowered to contribute to this debate, which is addressed throughout the course, not just in discussion but also through group project work and individual student research. A key strategy for achieving this learning outcome is the team teaching approach, whereby two or more teachers work together in the classroom. One teacher will lead each session and the support teacher can introduce additional ideas and alternative viewpoints. The support teacher is often better placed to observe the students' interactions and pick up on and draw out discussion. The course makes uses of a number of practitioner teachers who bring their vital experience to their teaching. An additional role for the course leader, when acting as support teacher, is to demonstrate the links between session themes and to ensure that a coherent intellectual thread weaves through all parts of the course.

Interdisciplinarity is further supported by the course's case- and problem-based approach to learning. Throughout this Master of Science course the students are introduced to cases drawn from real heritage practice where they are required to think about and discuss actual and alternative courses of action in these cases. Cases and problems are designed so that an interdisciplinary approach is required – a problem may necessitate the input of many different specialisms for a suitable solution to be worked out.

As the main aim of the course is to instil leadership qualities, the development of a debating, mutually supportive classroom environment paves the way for this to be achieved. However the actual development of leadership is through placing the students in situations where leadership skills such as team leadership, chairing of meetings, organising and planning work must be practised and exercised in order to fulfil a task. This is done through a series of carefully planned group exercises and projects of increasing complexity and commitment. These begin with small group exercises in class, extending to the preparation of formal presentations to a panel of external experts in a role-play situation to a much larger project later in the course, where students spend part of each learning day addressing a brief set by a real heritage organisation, Heritage Malta which requires them to report their findings and recommendations in a formal presentation to the Board and senior management (figure 1). This is a genuine consultant-client situation in which the client (Heritage Malta) is seeking answers to the brief and recommendations that they can implement. The students are advised by the course teachers on the nature of the task and what degree of organisation of their activities is needed to fulfil it, but the students are given the responsibility of choosing how to organise themselves, plan their work and deliver the brief.

Figure 1: MSc Sustainable Heritage student group project presentation to Heritage Malta Trustees, November, 2007.

3. Course delivery

The learning and teaching strategies described above are supported by the mode of delivery of the course, which is different from traditional Masters of Science courses in the heritage field. The Master of Science in Sustainable Heritage is designed on the block teaching model, whereby each course module is structured with a phase for student preparation in advance for extensive reading and immersion in the subject matter, followed by a continuous two week period of classroom learning, and a concluding phase of individual research, writing and submission of a formal written piece of assessed work. This mode of delivery enables and requires the students to acquire much of the background knowledge of the course through advance study, where study materials are made available through an online virtual learning environment, so that the students come to the classroom primed with this knowledge and are able to engage in discussion and debate. Thus the classroom teaching can deal with the subject matter at a deeper level than simply delivering new knowledge to the students: instead they question and discuss what they have learned and apply it to exercises and projects. Following Bloom's taxonomy[1] the focus in the classroom is on the higher level educational objectives of application, analysis, synthesis and evaluation rather than acquisition of knowledge and its comprehension.

The teaching aims are greatly enhanced by the block teaching method: during a two week period of learning, the students and course leader, together with the individual session teachers work together everyday, all day. This concerted delivery of the course enables the students to work most effectively on their group exercises and projects, which are undertaken both in the classroom and on study visits that support the course themes. Students have indicated that they find this mode of delivery highly beneficial to their understanding and developing knowledge of the subject matter. This has found to be particularly the case for students undertaking the course whilst in professional employment; they find the opportunity to focus wholly on the course themes to be a most effective study method.

4. Conclusion

In conclusion, the Master of Science course in Sustainable Heritage has successfully adapted executive learning and teaching methods to the heritage field. Whilst this is more resource-intensive than traditional Masters teaching methods, it has been demonstrated to be an effective approach for the mid-career students for whom the course has been designed.

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EDUCATION AND TRAINING: FROM RESEARCH TO STAKEHOLDERS AND BACK

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At UCL Centre for Sustainable Heritage (CSH), research knowledge transfer and engagement with stakeholders is highly regarded. Research knowledge transfer is used to design short courses, and in the MSc in Sustainable Heritage. Both strands are actively fed by our current research, and we welcome end-users and consultants to our training and education. Our strong view is the development of a circular notion of education and training for the heritage sector (Figure 1). Reflection and evaluation form part of this approach; feedback can influence research and again subsequent training.

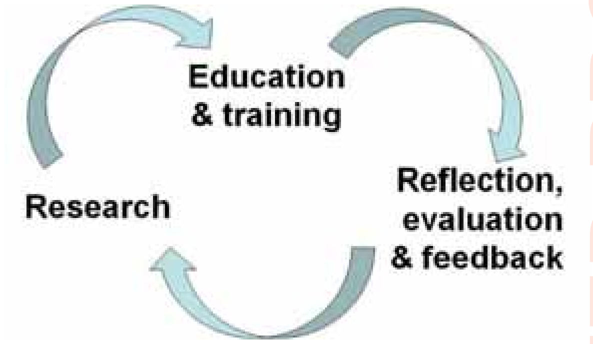

Figure 1: The circular notion of the knowledge flow in training and education for heritage sector.

CSH recently undertook a project to survey the impacts of its short courses (2006-2008), and to gather the feedback on training needs within the heritage and conservation sectors. The following courses have been organised in this time frame:
- Conservation Housekeeping,
- Historical Paper: degradation and non-destructive testing,
- Hospitality & Filming,
- Integrated Pest Management,
- Light & Humidity,
- Preventive Conservation Workshop: tools & techniques for best practice,
- Surviving a Disaster (Figure 2),
- You've monitored the environment, now what?

The review methodology invited past course participants to take part in an online questionnaire; this was supplemented by individual and telephone interviews. These are the key findings of the survey:
- The courses have delivered clear improvements in participant knowledge.
- The majority of participants had discussed the course they attended with their colleagues.
- Most colleagues had shown interest in the courses and about one third of participants indicated that their institution had used the course material to improve work practices or policies in their department.
- The majority of participants are interested in further training; their interests and suggestions indicate the diversity of training needs in the heritage sector.

This research is significant in that it enables longitudinal evaluation of training impact, which will then be communicated back to research and to stakeholders through course improvements. This is a cycle which needs to be applied to the whole heritage sector; research must meet practice.

Figure 2: Participants assess and document water/fire damaged books during the Surviving a Disaster course, Walmer Castle, November 2006. Photo credit: Nigel Corrie, English Heritage.

For more information, please visit our homepage:

http://www.ucl.ac.uk/sustainableheritage

A GEOLOGICAL WALK OF HISTORIC BUILDING STONE SITES IN THE CITY OF MAASTRICHT (THE NETHERLANDS)

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The centre of Maastricht, the capital of Limburg Province in the south of The Netherlands, has an abundance of natural stone used in building facades and ornamental paving. Making a geological walk in the City, the observed main types of historic building stones are described. Provenance, mineralogy, fossil content and mining history of each stone type are presented as well as time of application, weathering phenomena and restoration methods that can be read from the blocks in the buildings. Maastricht can trace its origin back to Roman times. At the place of a fortified camp from the 4th century a municipal centre started to develop in the Middle Ages. An earthen wall provided the first form of protection but stone walls were eventually built around the city in the 13th - 15th century. In these walls, use was made of Palaeozoic sandstones, transported by ship along the river Meuse from the Ardennes in Belgium. A locally quarried Upper Cretaceous limestone, known as Maastricht limestone, constitutes an important part of the City walls. The Maastricht limestone dominates the spectrum of rock types used in historical buildings from the gothic period up to recent times. This fossiliferous limestone has a high porosity and is rather weak. However, it is time-resistant and therefore it is still being advocated and used in modern architecture. Also flint nodules expelled from the Maastricht limestone layers can be found in the oldest city wall sections, besides boulders and stones transported by the river Meuse. Another common stone type in Maastricht is bluish grey limestone from the Carboniferous that is present in two main types. The first one is known as Namur stone and the other freestone is called Belgian bluestone or 'petit granit', both mined in the Ardennes. The 'petit granit' is a coarse grained bioclastic limestone dominated by crinoid's stems and brachiopod shells, and thus has nothing to do with real igneous granite. A remarkable building stone is the Nivelstein sandstone, Miocene silica sand with hardly any cement between the quartz grains. The geological walk focuses on the historical building stones. However, also some of the dimension stones from oversea areas like Brasil and India brought to the City in the past decades will be dealt with.

3D REPLICA OF THE BASARABI CHURCHES

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The paper deals with 3D reproducing of artifacts, using laser technology and with building real objects (from the Basarabi Caved Churches).

Discovered on 1957, the Basarabi- Murfatlar Ensemble is one of the most impressive archaeological sites of Europe, consisting of churches dated from 9th - 11th century. Because it is placed in a chalk hill and the values of the humidity get very high, even up to 100%, the surface of the churches was exposed to an emphatic degradation, which resulted in the loss of some of the inscriptions. Making two consecutive scans, more than 20 months apart, degradation of the surface was observed to be less than 500 µm.

The visual information about the monument may be preserved in a 3D vitual museum. To achieve this, the churches are digitized by laser scanning, from which high resolution models are produced. A tof scanner, a portable system and offering high resolution results, is used. Due to its high resolution (150 µm), inscriptions from the walls can be recorded. Besides the high resolution models of the details (figurative representation or symbols), digital models of the churches where made at a medium resolution (less than 1 mm), which suffices to distinguish the Romans marks.

Laser technology is used to acquire the geometric information of the object's surface, after which the data are processed in specialized 3D software. The wavelength of the laser used is 690 nm, while the power is 15 mW. As only one wavelength is used, the result is displayed in a grey scale. With the use of colour photography and software tools, 3D digital color model of the object may be obtained (Figure 1).

Figure 1: Mesh Model of one of the most well known details from Basarabi, the bird motive. The colored model is obtained using photo matching tolls of the processing software.

The models are available at http://inoe.inoe.ro/basarabi, and may be accessed via worldwide web, via hyper text transfer protocol (http://) and require the user to a download a simple 3D viewer plug-in (from the INUS Technology website). The model, in an ICF format, is optimized to be viewed under IE, version more recent than 6.0, and allow options like zoom, pan, rotate (and auto-rotate) and walkthrough. The models currently available are in low resolution - the size of the pages is less than 1MB, and may be handled using the web browser.

Another possible accesses of the 3D model is by using the 3D incorporated objects in a portable document format (pdf). Adobe 8.0 or higher is needed. Compared to the previous method, this one offers multiple visualization of the model (wireframe, solid or even vertices) and measurement tools (including sections). It also allows the user "to play" with the incident light, thus offering a possibility to explore the object's surface.

Another option is the so called "3D printing" using r.p. technology. In this way, a 3D object may be obtained from the digital model. Layer grow method is used, with the height of a layer of 80 or 100 µm (software controllable parameter), and with a speed of 2-4 layers per minute (Figure 2). The result, a very true copy of the real object, may be exhibited in museums, which is an attractive solution for both – the visitors and the authorities.

Figure 2: 3D printed model of the bird detail.

COMMUNITIES OF INQUIRY' AND 'BLENDED LEARNING' – TEACHING AN INTERDISCIPLINARY APPROACH TO CONSERVATION OF ETHNOGRAPHIC OBJECTS

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This poster abstract presents the ERASMUS-project called "Ethics and Ethnographic Objects Conservation (EthCon)"[1] jointly organized by three institutions teaching conservation: HAWK University for Applied Sciences and Arts Hildesheim (Germany), Helsinki Metropolia University of Applied Sciences (Finland) and University of Amsterdam (The Netherlands).

EthCon is funded as an "Intensive Program" (IP) within the European Lifelong Learning Program over the period of three years. Each year a 2-week seminar brings together students, teachers and (museum) specialists working with ethnographic objects in various ways: like anthropologists, curators, collection managers, exhibition designers and natural scientists. Focus is laid on the ethical approach of heritage professionals towards objects and entire collections, in order to develop an interdisciplinary methodology for the preservation of ethnographic objects including preventive conservation during display, storage and possible travels as well as restoration aspects. Within this range also material analyses, risk assessment, art theft, museum security and illicit traffic of cultural goods are dealt with.

Ethnographic collections contain a large diversity of objects, made out of a lot of different materials: substances that are in many cases badly known, easily degradable and often formed to elaborated constructions. An even higher grade of complexity results from combining the viewpoint of material science with the cultural context the object is originating from: What was the original meaning or use of the object? What was the original appearance, the colour? How to detect possible religious and mystical meanings of objects and how to maintain them on display or during conservation treatment? This is only a selection of questions to face in decision making. Solitary answers can be provided by each profession, but an understanding of the aspects involved and a common language is needed to find the complete answers. Every profession must know at what stage of the decision making process to involve the others and what are the right questions to ask.

To meet this challenge the framework of a European seminar was chosen also to use the cultural and professional differences as a resource for learning and for generating effective responses in specific contexts.

Moreover new ways of combining different methods of teaching and learning blended with the modern media were explored during the first seminar in Amsterdam in 2008. "The key to successful blended learning lies in:
- Selecting appropriate delivery methods for specific learning outcomes
- Effectively combining diverse learning events"[2]

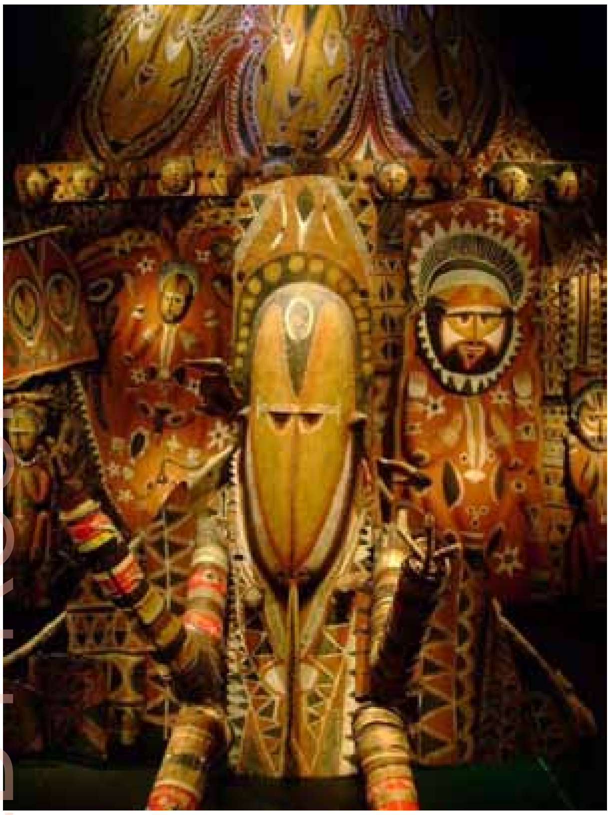

Figure1: Ensemble of ritual masks.

An information and communication portal ("EthCon-Forum")[3] has been set up prior to the event. This enables students as well as teachers (and specialists) to prepare themselves for the subject. Readings, relevant information from the museum partners and internet links were selected by the teachers and provided in the forum to ensure that the group would have the same level of knowledge on some topics and could use the same vocabulary (English) in the discussions. Also after the seminar information like students learning diaries and group photos were put on the EthCon website and students as well as teachers could still use the communication tools amongst each others.

For the case studies students were introduced to the learning method of "Communities of Inquiry". The strength of the community lies in the merging of knowledge of all of the participants, instead of each individual trying to find out everything about the subject on his own.

What's new about this 'working together' is the systematic way in which all available knowledge is used to create a new comprehension in the subject. It also meant a different role for the teachers that were involved in this project. Instead of presenting themselves as experts, their role was to help the student-expert-groups to find out which knowledge was already available in their group, which knowledge was missing and how they could bridge the gap to find answers to their questions.

The students groups worked according to the following scheme of Community of Inquiry to:

(1) Define the problem and the desired outcome

(2) Make an inventory of the knowledge in the team

(3) Analyze the strong and weak points of the team

(4) Brainstorm to formulate questions, possible solutions and a plan of action

(5) Gather relevant information, define which sources can be used

(6) Investigate/research from different disciplines

(7) Develop different concept solutions

(8) Present and explain the results to other groups, 'try-out'

(9) Choose one outcome based on evaluation of step 8

During the seminar in 2008 also 'conventional' teaching tools like lectures, discussions and students presentations preparing and resuming the subject and the group working were successfully applied. Although emphasis was laid on granting access to the museums libraries and to internet for the students for solving problems in their working group first, still the ICT part of the project could be extended and only first steps were taken to integrating 'Blended Learning' into the student's curriculum.

Major museums with ethnographical collections have agreed to co-operate in this project, because 'real-life' context is essential to the learning process of the students also. In the first year the Tropenmuseum, the National Museum of Antiquities and the National museum of Ethnology in the Netherlands, offered expertise and objects from the collections for case studies. For the next IP in Germany the Roemer- und Pelizaeus Museum in Hildesheim and the University of Göttingen will be partners.

The expected outcome of this IP is a more systematic approach towards ethnographic collections. When this approach is fully developed and after gaining experience with the tools throughout the project (to be achieved in the coming two years) this shall result into a web based communication platform about this subject open to whole community in ethnography and an e-learning course.

Figure 2: Discussion in front of displayed objects.

Figure 3: Demonstration of a handheld X-ray fluorescence analyser.

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INTERNET-BASED TRAINING MODULES FOR CONSERVATORS

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Abstract

The education system has changed, particularly regarding lifelong learning. Many universities have reacted to this challenge. The Hornemann Institute produces e-learning courses for further education in German and English. With this multimedia course, the Hornemann Institute offers specialists in the field of conservation of cultural heritage customized study at their own rate of speed and free selection of time and place. Dividing the courses into modules permits free selection of contents according to specific needs and background. Only requirement for the courses is an internet-access. The participants of the courses can communicate with the authors or the tutor via telephone or email.

1. Introduction

The Hornemann Institute is developing online continuing education courses for persons who are dedicated to cultural heritage preservation. As this target group faces rapid changes in their profession, there is a great demand for career accompanying further training. The institute has concentrated primarily on courses drawn up by the teaching staff of the university. Initially these courses are intended for full-time students of the Faculty Preservation of Cultural Heritage. The courses are implemented in the full-time study program at the authors' discretion: Some instructors offer the courses to supplement current lectures, others as follow-up study. And others make use of the courses as preliminary preparation to ensure that all the full-time students possess the same basic knowledge when beginning full-time study. This then allows more time for the practical part of the study.

In addition, some courses are open to anyone concerned with the conservation of cultural heritage. The Hornemann Institute is responsible for the organization and the administration. Distant students will be granted a Hornemann Institute certificate upon successful completion of the program and passing a final on-line examination.

2. Experimental: The course "Microbic Infestation of Objects of Art and Cultural Heritage"

by Barbara Hentschel, graduated conservator for wall-paintings, and Prof. Dr. Karin Petersen, teaching microbiology.

Course content

This course is composed of three modules. The first one is an introduction into microbiology. It allows students with no corresponding background to learn the basics of microbiology and thus to be able to follow the course. This is of particular importance for non-university implementation, as microbiology in the conservation of cultural objects has not been pursued much outside the university.

The second module, which is smaller, is more practice oriented: it explains the different sample-taking techniques and which types of sample material are suited for which analyses and tests.

The third module contains various methods of detection and analyses of microorganisms that pose a threat to cultural objects. The user learns not only easy to use analyses techniques but also very specific and modern specialist ones.

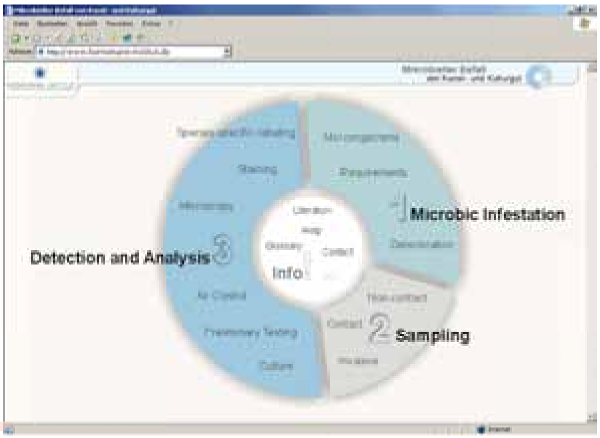

Figure 1: The main navigation element, the so-called 'Base'.

The set up of the courses of the Hornemann Institute

The set up of the courses is always the same. With implementation of a central navigation element, the so-called 'Base' is visible from all the course sites, so the user never loses orientation. In different colours and large enough for good legibility, the main items of the outline, the so-called modules, list the chapters with (abbreviated) titles in a clockwise order we suggest the learners follow, and most previous students have done so. The base does not show the sub-chapters. The centre of the Base gathers the resources relating to the entire course: A help-button with explanatory information on the use of the course and technical issues; the bibliography, the glossary of terms not explained within the text and the contact addresses.

Each page follows a fixed layout or set up: At the left edge of the page is the navigation bar with chapters and subchapters and at the bottom a bar with the available pages of the current chapter or subchapter. The text part in the centre is the main part of each page. All additional information is 'hidden' in separate windows: Bibliographic references, links to websites, excursions on related topics and special explanations or definitions Terms that are included in the glossary are highlighted in the text body by blue coloured letters. A click opens a window displaying the explanation. The right side of the page is reserved for illustrative photographs, drawings and video sequences. To reduce downloading times, these multimedia sections are offered in a thumbnail view in a special section on the right beside the text.

Figure 2: A page from the course "globe conservation".

Tests

The course is intended as a self-study course. "Checkpoints" permit monitoring learning progress and are therefore highly motivating. The types of tests are: matching, filling in gaps and multiple choice. Correction follows immediately and automatically. More extensive essay tests are sent to the institute via e-mail. The authors set the length and allowed time for these tests.

Tutor

All questions to the contact addresses are directed to the Hornemann Institute, where the ones concerning technical issues are answered directly by the staff. Questions concerning the content are directed to either the tutor or the author/s.

Upon request, the Hornemann Institute can install an internet forum that can be accessed from the course site. The authors and tutors could decide whether the discussion will be public or limited to course participants. Should the authors so desire, the institute will also provide a chat platform for intense exchange among the participants of the course.

Evaluation

Full-time students and distant students were asked to evaluate the courses. The response of both target groups was quite favorable. This might not be surprising in the case of the distant students as they chose the internet as their medium. The very positive response from the full-time students came a bit unexpectedly. Indeed, meanwhile an increasing number of teaching staff of the University of Applied Sciences and Arts have come to see the possibilities of using on-line courses for teaching the principles of a course in order to be able to spend more time for hands-on learning in workshops.

In contrast to other study material, on-line course contents can constantly be updated by the authors and the learners never risk working with obsolete outdated material as may happen with printed media. The didactic versatility and interactivity of the continued education courses and the ability to adapt the study material to own individual needs is very motivating for both full-time students and working distant students. Learning is flexible and adaptable: the courses permit individualized learning at the learner's own speed and to the depth the learner desires. Moreover, motivating is the fact that the learner can check his/her progress him/herself.

Users are able to access the course contents whenever and wherever they want. There are no travel costs and no time lost on the job.

Graphs and dynamic animation make it difficult to understand contents more accessible. Short video sequences (approx. 10 sec.) of practical examples make clearer what is relevant. However, not everything that is possible is didactically useful. The multimedia elements must contribute to learning.

Internet-based communication elements such as e-mail, chat rooms, discussion forums allow the instructors and users to exchange experiences and work on tasks together. The institute tutors can also be reached by telephone and will assist in technical problems or problems relating to the subject.

Printed media are better suited for long texts than the new media – no one wants to read a thousand pages on a computer screen. Good study courses focus on where established media show their limitations. The average time a learner spends at the computer is forty-five minutes. He should be able to grapple with a subject in this time. So we ask our authors to provide precise and concise material.

3. Results

Presently, there are three other English written courses available.

Examination of Transparent Coatings on Furniture and Wooden Objects, by Prof. Dr. Maierbacher-Legl, Dipl.-Rest. Julia Schultz M.A., Dipl.-Rest. Merle Strätling M.A.

This course emphasizes a practical approach to coatings examination, from overall inspection techniques to spot analysis:

It covers observation with visible and ultraviolet light, solubility tests, examination of cross-sections, microchemical tests as well as histochemical staining methods. Useful tips are provided for the use of specific equipment and facilities. Health and safety issues are also addressed. In addition, the course conveys fundamental information about the primary materials used in different types of coatings, their chemical and physical properties, as well as factors influencing deterioration and surface phenomena.

Funding for this course has been provided by the European Union.

Figure 3: Analysing transparent coating films.

Restoration Theories and methods from the mid-20th Century until Today, by Prof. Dr. Ursula Schädler-Saub

The course written in German focuses on the history of restoration as explained through the different restoration theories and their practical application in Italy and elsewhere since the late 1940s. The course also deals with color theory in order to better understand the practical application of retouch methods that will be introduced in great detail. Commentaries regarding the most important international charters on conservation and restoration will help in questioning the present view of restoration and to do justice to these texts in daily practice. The author is Prof. Dr. Ursula Schädler-Saub, professor at the University of Applied Sciences and Arts, Faculty Preservation of Cultural Heritage. Ursula Schädler-Saub herself coaches the course through e-mail.

Globe conservation, by Dr. Patricia Engel and Michael Höjlund Rasmussen

While older celestial globes were made of metals, since Behaim's Erdapfel from 1492 globes have been made of paper, papier-mâché, wood and parchment. The first chapter of the course gives a description of the cultural and historical background of the topic and describes the history of the globes from 3000 BC to the 20th century.

This is followed by helpful suggestions for the documentation of a globe and an overview of damages. The latter provides pictures of typical damages on the globes along with case-by-case explanations. It will enable conservators to identify damages – even rare ones - and help the laymen to deal with their problems.

The main chapters deals with specific suggestions for conservators concerning concrete practical conservation requests including the preparation of some materials and the techniques of GORE Tex Sandwich and surface cleaning.

The last chapter explains the practical storage problems, the climatic conditions and the correct packing and transportation of globes.

Figure 4: Damaged globe.

4. Conclusions

Imagine being able to learn from world-class authorities while sitting at home. Imagine being able to work on your job and for your family and have the possibility for further education. Imagine finding actual information online without time wasting searching in libraries or costly ordering via interlibrary loan system. E-learning is for many people on the job a very good solution for their further education. For Information about the courses see: www.hornemann-institut.org

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SURVENIR PROJECT- A DEDICATED INSTRUMENT FOR COLLECTION SURVEYS

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1. Introduction

The cultural heritage market niche is particularly research-intensive. It is further characterised by the long time from research to the market, therefore, investments into conservation and preservation solutions are optimally developed in cooperation between companies, the stakeholders and the knowledge centres.

The 6th Framework project SurveNIR is an example of such development, where a concerted effort led not only to the development of a highly specialised unique product, it has also been extensively tested and will be transferred to the market in the near future. The instrument that has been developed offers an entirely non-destructive, multi-analytical, reagent-less approach to characterisation of historical paper. This can be done in a matter of instants, enabling completely objective collection surveying. The process of collection surveying is highly important as it enables the user to assess needs and formulate priorities, and is thus an essential step in collection management.

The project also had a very pronounced knowledge-transfer dimension in that a number of workshops were organised including events aimed at the general public and the press, where the developments were publicised. From the viewpoint of an SME, the extraordinary risks involved in such highly technological developments can only be adequately addressed within the EU Framework programme.

2. The Project

Collection surveys are necessary in order to reveal the condition of a collection, the general conservation needs and in order to plan preservation activities. For such a task, a simple instrument is necessary, which allows us to survey a collection in a non-destructive, non-invasive and chemical-free manner.

During the SurveNIR project, co-funded by the European Commission 6th Framework Programme (2005-2008), a consortium of research institutions and end-users built a dedicated NIR spectroscopic instrument, which enables the user to determine a variety of chemical and mechanical properties of paper, including naturally aged paper. The approach has been validated in several European collections in the British Library (London), Victoria and Albert Museum (London), National Archives (The Hague), National Archives (Stockholm), National Museum of Denmark (Copenhagen), National and University Library (Ljubljana), and State Archives of Dubrovnik.

Traditionally, the condition of a paper-based object or a whole collection is assessed visually, and simple physical and chemical tests are performed, such as the folding test1 or determination of the pH of paper using pH-indicator pens. Neither of the two tests can be described as non- or micro-destructive, since the folding test is performed in such a way that a paper corner is actually torn away, and the pens leave some of the dye used as a pH indicator on the object. Even the determination of paper pH using a flat surface electrode, which is probably the most often used methodology in paper conservation workshops, is destructive as an area of paper has to be wetted in order that the measurement can take place at all. In addition, traditional surveying methods are also highly subjective.[2]

Based on the chemical and spectroscopic analysis of more than 1500 historical samples from AD 1650 onward, we developed a method, which enables us to characterize historical paper in respect of the gelatine content, mechanical properties, lignin content, pH, degree of polymerization of cellulose and other properties[3,4] A lightweight and portable instrument has been developed and designed in cooperation with conservators and curators (Figure 1).[4] The approach provides museums, libraries and archives with a non-destructive chemical-free low-cost surveying tool that provides more in-depth information than the traditional methods and is at the same time user-friendly and does not require extensive technical knowledge by the surveyor.[5]

Additionally, software has been developed, which allows the surveyor to work in three different modes:
- Single item assessment: for condition assessment of an individual item, where chemical and physical data are needed for several locations on the same object,
- Random collection survey: for surveys of large collections, where a subset of a collection is first pre-selected and on the basis of a condition assessment of the subset, the condition of the whole collection is deduced (with a pre-calculated confidence interval and a level of significance),
- Total collection survey: for smaller collections, where all objects in a collection can be surveyed.

The software provides partial least squares methods both for single sheets (graphical or archival documents) as well as for books. In addition to providing chemical and physical data on the paper, the software also enables the user to build a survey questionnaire based on a set of descriptive criteria, which can be freely defined, e.g. binding condition, evidence of mechanical damage etc., however, these need to be evaluated visually.

3. Dissemination

The project and the results were disseminated extremely intensively. We held two workshops (The Hague, The Netherlands and Ljubljana, Slovenia) and a conference (Ljubljana, Slovenia) in addition to six dissemination events held at partner sites while the case studies were carried out. The media coverage was extraordinary, apart from the high-profile academic publications, SurveNIR appeared on the TV and special feature articles were published in Chemistry World, Chemical and Engineering News, Analytical Chemistry, Photonics Spectra, and in a number of newspaper and magazine articles. We were also present at two expert exhibitions and three science fairs. Effective dissemination is key to the acceptance of new technologies in heritage research.

4. Conclusions

From both the scientific and the business point of view, SurveNIR was a success. In three years, we managed to perform scientific research of the highest quality and develop an extensively tested marketable product. The application-oriented research will enable Zentrum für Bucherhaltung GmbH to commercialise the SurveNIR software and the instrument in 2008. The end-user partners were very strongly involved and contributed with their expertise, samples and critically evaluated the developments. However, in order to make this huge effort at all possible, a concerted European effort was absolutely necessary.

5. Acknowledgement

The authors gratefully acknowledge the support of the European Community, 6th Framework Energy, Environment and Sustainable Development Programme, contract no. SSPI-006594 (SurveNIR).

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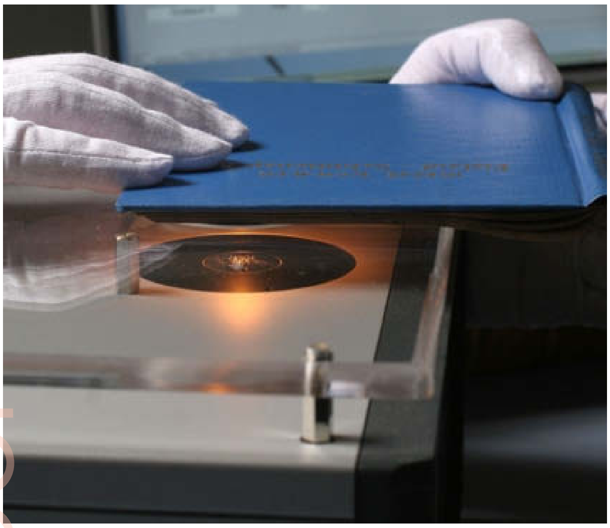

Figure 1: The SurveNIR instrument for non-destructive evaluation of paper chemical and mechanical properties for collection surveying, based on chemometric evaluation of NIR spectra.

RECENT DEVELOPMENTS IN NON- AND MICRO-DESTRUCTIVE ANALYSIS OF HISTORICAL PAPER

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1. Introduction

Assessment of the condition of historical objects and materials is essential for informed preservation. However, taking samples has in most cases become unacceptable and the information to be gained is carefully weighed against the potential loss of historical materials. In the recent years we have witnessed rapid developments in methodology and instrumentation for the non- and micro-destructive analysis of historical paper. Many traditional techniques have been rather invasive in terms of sample size; some are also time-consuming, which limits their usefulness in the case of large numbers of samples, often encountered in paper-based collections.

A number of endogenous and exogenous factors affect the stability of paper. The acidity of paper, expressed by pH, is among the crucial ones. A novel electrode has been built, which enables reliable measurements to be done using only a few micrograms of fibres. Volatile compounds emitted from paper have also been shown to be information-rich and can be used to examine material quality. Spectroscopic techniques are among the least time-consuming and if combined with chemometric treatment of data, a number of paper properties can be determined non-destructively. To this end, the use of fibre-optics enables us to examine historical documents and even inks, with minimal contact with the original material. This anticipates similar developments for materials other than paper.

This contribution reviews recent research likely to affect routine investigations in paper conservation and research laboratories. Some methods can deliver reasonably reliable simultaneous evaluation of a variety of properties without any damage of even the most precious works of art on paper.

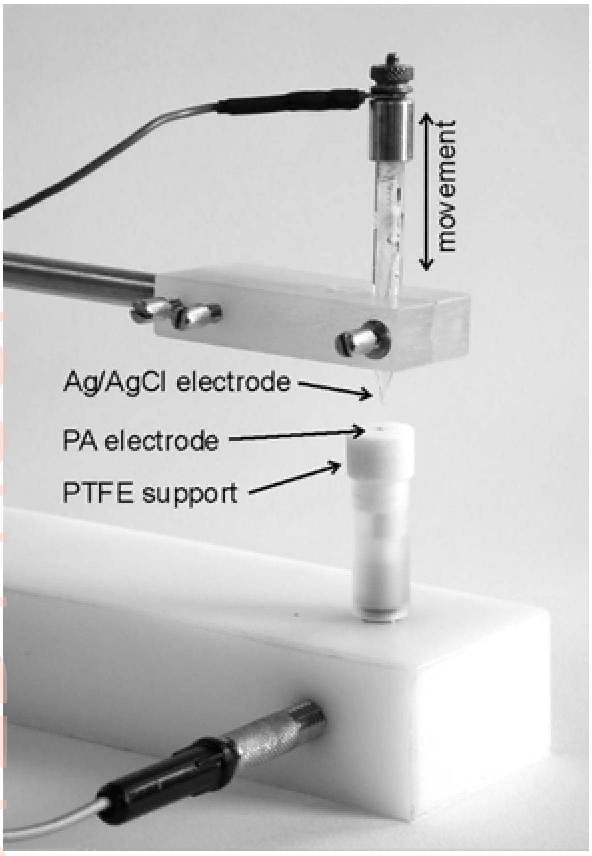
2. A novel pH electrode

Recently, the development of a new microelectrode for determination of pH of paper was reported.[1] The flat polyaniline-coated glassy carbon pH-sensing electrode (Figure 1) can be used in a number of ways:
- Directly on paper without sampling
- Using micro-samples obtained by hollow-needle sampling
- Using fibres removed from paper surfaces.

Using this electrode, potential damage to the original object is thus greatly reduced in comparison with other commercially available electrodes.

3. Determination of molar mass of cellulose using micro-sampling

Degradation of cellulose inevitably leads to loss of mechanical properties in paper and it has been shown that retention of fold endurance correlates with the degree of polymerisation (DP, average number of monomer units in cellulosic macromolecules), and thus with molar mass. Using the procedure of micro-sampling with a hollow needle (sample mass a few 10 µg), we can obtain information on the molar mass of derivatised (carbanilated) cellulose from paper. This procedure can be applied to papers containing a bigger proportion of lignin, which has so far not been possible.[2]



Figue 1: Electrode holder with the reference Ag/AgCl electrode made of glass above the 1-mm-diameter polyaniline (PA) indicator electrode in PTFE support. After sample wetting, the reference electrode is shifted towards the sample positioned on the PA indicator electrode until contact is achieved.

4. Determination of pH on the basis of volatile compounds (VOCs)

During paper degradation, a variety of volatile degradation products are formed. Using solid phase microextraction (SPME, Figure 2) and analysis by gas chromatography, it was shown that the VOC profile of degrading paper consists of a large variety of compounds, some of which are formed as cellulose and some as lignin degradation products. In a recent study, it was also shown that the concentration of organic degradation products, particularly furfural, depends on the pH of the paper sample.[3] Thus, the pH can be estimated in a convenient manner and non-destructively by analysis of volatiles.

5. Near infrared spectrometry (NIR) with chemometric data analysis

Spectroscopic methods are of particular importance in heritage material analysis, especially if the measurement process is safe for the object. With the added advantage of portability, analyses no longer need to be carried out in chemical laboratories. They can be done in-situ, i.e. in a non-laboratory environment.

Due to the complexity of near- and mid-infrared spectra of naturally aged paper, a partial least squares approach has recently been used for correlation of spectral data with chemical[3] and mechanical properties.[4]

6. Chemiluminometry

Chemiluminescence, the extremely weak light commonly emitted by organic molecules during oxidation, can be used as a source of information. A new instrument has been built to measure the emission of this light and to assess whether the techniques can be used to map paper degradation.[6] The instrument also allows measurements to be performed without destructive sampling.

The technique has since found its way into heritage science and has been used in studies of parchment degradation and lately of the degradation of historic plastic materials.

7. Successful technology transfer

Several new methods of micro-and non-destructive techniques and methods for characterisation of paper enable us to determine reliably some of the most important properties of historical paper.

Most of these methods and instruments have been developed in close cooperation between SMEs, end-users and higher education institutions in applied projects, financed by the EU Framework and EUREKA programmes, but also by national (Slovenian), personal, and end-user funding. Many methods (the determination of pH, size exclusion chromatography, NIR) are now being commercially exploited through the provision of services by SMEs. Two of the instruments (the NIR spectrometer and chemoluminometer) have found their way to the market and thus represent truly successful knowledge transfer.

Figure 2: Contact sampling using SPME. Left: the SPME fibre inserted in a book, left: wrapped in aluminium foil for the duration of sampling (24 h).

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INNOVATIVE TECHNOLOGY FOR THE CONSERVATION OF STAINED GLASS WINDOWS: A USER-FRIENDLY PORTABLE DEVICE COMING FROM THE EU-VIDRIO PROJECT

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The research undertaken within the European VIDRIO project (contract n EVK4-CT-2001-00045) [1] was aimed at getting a more profound understanding of the impact of the environment on glass and grisaille, at evaluating the effect of different protective glazing systems, in order to identify the best practice to preserve ancient stained glass windows close to their original condition, also taking into account their exposure to mass tourism [2, 3, 4, 5, 6, 7, 8, 9].

The study carried out during the project was focused on three buildings where important medieval stained glass windows are preserved: Saint Urbain Basilica of Troyes (France), Sainte Chapelle of Paris (France) and Cologne Cathedral (Germany), the last two included in the UNESCO's World list of Cultural Heritage. In each site, two windows – one with and one without protective glazing - were monitored and studied, at three different levels - high, middle and low [10].

The CNR-ISAC, coordinator of the project and in charge of the microclimatic analysis, in collaboration with an Italian SME, TECNO PENTA sas, developed an innovative, user-friendly and low cost device (*dew sensor*) to directly detect condensation on the glass surface. This device could be employed in the control and maintenance plans of the stained glass windows [11].

The working principle of the new sensor is based on a known effect, i.e. the diffusion phenomenon of a light beam in the infrared band on the surface with condensed water. When condensation takes place on the glass surface, the beam emitted is diffused, so a weaker beam is collected by the receiver.

Here after the main technical information on the new dew sensor is summarized:
- glass was used directly as reflecting surface;
- phototransistors were chosen as receivers because they are more sensitive to reveal the phenomenon;
- the best emitter wavelength was identified in the near infrared band (800-950 nm);
- the angles of incidence/reflection and the distances emitter-glass and glass-receiver corresponding to the maximum efficiency were determined;
- an innovative technical solution (Figure 1) to minimize the interferences to the signal was applied: the sensor was equipped with two different sets of emitter-receiver, one closed within an anhydrous environment, the other in open air. The difference between the two signals changed only in case of attenuation of the signal due to the condensation detected by the open pair;
- to reduce the luminous interference and the difference in the conditions of illumination on the two pairs, every receiver was equipped with a narrowband filter;
- to reduce thermal influence the box containing the sensors was made of plexiglas and its dimensions were minimized, making the instrument more suitable for the application on ancient stained glass windows (especially when installed in the interspace);
- the switching on of the sensor was not continuous but limited to the time necessary for the measurement, this to avoid thermal drift due to electrical power feed, to minimize the influence of the measuring system on the microclimatic conditions and to keep the sensor signal more stable over time;
- a new software was developed to drive the sensor in choosing the measuring set up, in changing the off set and sensibility, and consequently in reducing or avoiding some problems related to changes in the calibration due to variations of the state of the surface (pollution deposition, weathering processes), to interferences due to different illumination conditions, drift in the signal, etc.;
- the sensor can be connected to an alarm system activated when the dew sensor output reaches a certain value corresponding to the start of the condensation phenomenon.

Figure 1: Prototype of the new dew sensor (60 x 60 x 35 mm).

Because of its working principle, the dew sensor is able to reveal the condensation phenomenon in its first phases, i.e. just at the formation of the first molecular layer on the surface of the material, physically named monolayer, when we cannot yet speak of the formation of liquid water and when the chemical bonds between the molecules, consequently the energies involved, are still strong. The signal is semi-quantitative, that means that the height of the peaks that indicate the presence of condensation is proportional to the intensity of the event itself. The possibility to give also quantitative results is being studied.

In Figure 3 is reported an example of the direct investigation of condensation carried out in the Sainte Chapelle (Paris). The graph shows the signals of the first version (following the prototype) of three dew point sensors installed on two ancient windows – one protected and one unprotected - and on the glazing; important condensation was detected on the protective glazing, less on the unprotected window, the least on the protected one at the internal side.

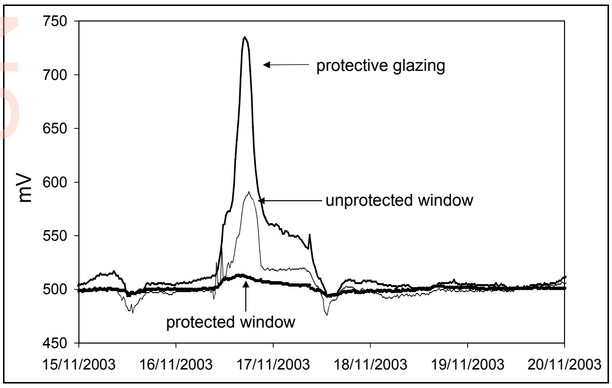

Figure 2: Sainte Chapelle, Paris - Direct investigation of condensation on glass surface by mean of the new dew sensor.

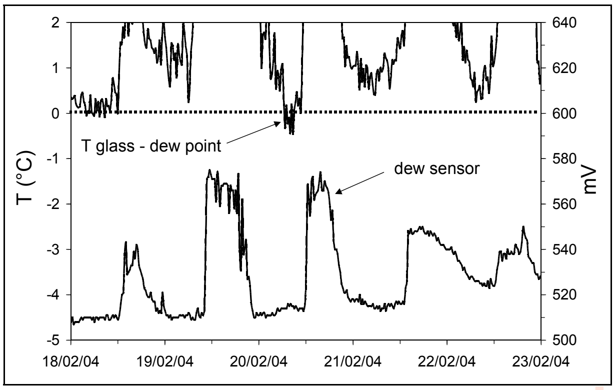

Figure 3: Cologne Cathedral - Comparison between direct and indirect measurements of condensation on a protective glazing.

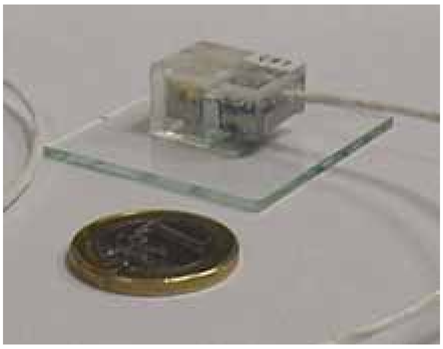

Figure 4: First miniaturized version of the dew sensor (20 x 15 x 11 mm).

Though the direct survey of condensation with the dew sensor is in general accordance with the traditional microclimatic measurements (calculation of the condensation conditions starting from the measures of the main physical parameters), the former is more accurate and reliable than the latter. Figure 3 shows a comparison between direct and indirect measurements of condensation performed on protective glazing, at the low level, of Cologne Cathedral. When the dew sensor signal already clearly indicated condensation, it happened that the difference between glass temperature and dew point of the air didn't reach zero value, i.e. in theory no condensation took place. This behaviour can be explained by taking into account that traditional sensors have technical limits, especially under extreme hygrometric conditions, and that the errors related to the measure of a single parameter propagate through the calculations [11].

Since the building of the first prototype, the dew sensor was further developed, improved, validated in the laboratory, optimised and applied successfully on different (from glass, i.e. stone) surfaces in sites of interests in the field of Cultural Heritage: besides the three ones mentioned above, Lascaux Caves in France, Petrarca's tomb in Italy, Hagar Qim Temple in Malta.

Many problems related to its work and use, in particular those linked to the interference of light, were carefully evaluated and studied in laboratory, in order to find the best and easiest solutions to get a useful, reliable, cost-effective, user-friendly and portable instrument.

A European patent (PTC/EP2005/050665) has been filed and other funding has been obtained by means of a spin-off project to develop the prototype and begin the miniaturizing of the device in order to introduce it into the market. This spin-off project, supported by the Italian Ministry of University and Research, lead to the creation of a new SME: R.E.D. s.r.l. (Research & Environmental Devices [12]) where TECNO PENTA sas and CNR are partners.

In Figure 4 the first miniaturized version of the sensor is shown, characterized by many technological improvements with respect to the prototype, in particular concerning the optical components and the geometry of the casing. This miniaturized sensor is now installed in the Lascaux Caves (Figure 5), where the condensation phenomenon on the rock surface is being monitored (Figure 6). The investigation by means of the new sensor is being performed within a research project aimed at correlating the microclimatic conditions inside the Caves with the risk of micro-biological growth.

The working of the newly built device is so promising that it should result to specialised industrial production and to new enhanced applications and deployments.

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Figure 5: Lascaux Caves, France – Direct survey of condensation on the rock surface by mean of the miniaturized dew sensor

Figure 6: Microclimatic instruments installed in the so-called Painted Gallery of the Lascaux Caves, France

SYSTEMATIC MAPPING OF THE LITERATURE TO IDENTIFY RESEARCH NEEDS ON CLIMATE CHANGE AND CULTURAL HERITAGE

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1. Introduction

There is nothing a government hates more than to be well-informed; for it makes the process of arriving at decisions much more complicated and difficult.

John Maynard Keynes quoted in Robert Skidelsky[1]

Facts or information alone are not evidence and evidence is not limited to research findings. Availability, accessibility and validity are also central to what counts as evidence. This paper gives an account of a project's methodology for identifying research needs on climate change and cultural heritage by systematic mapping of the literature. Between December 2007 and March 2008, the UK Government's Department of Culture, Media and Sport (DCMS) commissioned the Centre for Sustainable Heritage, University College London to carry out this survey.[2,3]We had the difficult task from the start of designing a methodology that was capable of proving a negative, in other words to identify research *gaps* and therefore the lack of availability of information on the impact of climate change on cultural and sporting assets, including cultural heritage. New evidence never enters a pristine environment. It has to fit into policy makers' world view, which derives not only from scientific and systematic research evidence, but also from anecdotal experiences and tacit knowledge. It has to compete with power relations and competitions over agenda setting. Therefore the second task we faced was to satisfy the multiple stakeholders of DCMS, namely the agencies and departments that run the various public cultural and sporting bodies that fall under its remit. These included: the Arts Council of England, British Library, Commission for Architecture and the Built Environment, English Heritage, The National Gallery, National Maritime Museum, Natural History Museum, National Museum of Science and Industry, The Tate, The Royal Parks, The Victoria and Albert Museum, Sport England, The Big Lottery Fund, The British Museum and The Museum of Science and Industry Manchester. The third task was to ensure that the survey would mobilize the policy support needed to turn research into practice. It takes more than knowledge and evidence to make policy. Creativity and imagination play a significant part in transforming ideas into workable practical recommendations. The methodology for systematic mapping of the literature to identify research needs on climate change and cultural heritage had to fulfill these requirements.

2. Context

There have been a number of reports both in the UK and at a European level that have identified research needs in the area of cultural heritage. These sources, which are organized in Table 1, illustrate the overlaps and differences between the research priorities they have identified. What these sources reveal is the variety of methodologies that have been used; the table was the first attempt to unify these sources within a matrix that served as a useful model for the methodology developed to map research needs in the area of climate change and cultural heritage.

Developing a controlled vocabulary

The first part of the study set the objectives that would help scope the range of post-1997 literature on the climate changer mitigation and adaptation relevant to cultural heritage; establish the criteria for searching 'grey literature' and produce a bibliographic report, based on an agreed list of controlled vocabulary, that is, the terminology to be used in the search that was agreed with DCMS. The controlled vocabulary was then organized into high level key terms and a subsidiary level of word strings as follows from Table 2.

The key terms in Table 2 are the historic environment; museums, galleries, Archives and libraries; heritage use; cultural heritage and public behaviour. Each key term has between 4 and 10 word strings which develop further the meaning of the key term. The controlled vocabulary was intended to be comprehensive in order to ensure that gaps in information as well as existing information could be identified.

Scoping the literature

Overall an uneven distribution of the literature (Figure 1) was found with over half of the word strings identified by DCMS producing 5 or fewer publications. A large proportion of the literature focuses on influencing public behaviour, biodiversity and landscape, in contrast to the low number of publications on the impact of climate change on museums, galleries, archives and libraries, and on collections and facilities with the exception of material conservation. Heritage also has among the most publications in significant subject areas, namely buildings, material conservation, land use, landscape, operations and maintenance and policy.

The main climate change threats and impacts were also identified from the reports listed in Table 1 and compared to the key terms in the study to produce an overview of the distribution of the literature (Figure 2)

The 10 most significant environmental change parameters,[4] namely temperature, precipitation, sea level rise, floods, groundwater changes, frost, humidity changes, wind, effects on vegetation and on pests, fungi and lichen were paired with the high level key terms to reveal that most publications (52% of the total) are on the effects of temperature change and the effects on vegetation, with the highest number of publications relating to effects on parks and gardens, while the smallest number relate to the effect of frost, pests, fungi and lichens. In addition, a number of other publications considered the synergistic effect of climate change and air pollution, which was included as a separate category. All 11 environmental change parameters have been covered in publications on the historic environment to a much greater extent than museums, galleries, archives and libraries, while cultural heritage has very limited coverage. This part of the study formed the basis of the emerging methodology.

Devising a methodology

The methodology for identifying existing publications and gaps in information consisted of devising 10 matrices for each one of the key terms and comparing each in turn to all the key 11 environmental change parameters using established search engines including Web of Science, Google Scholar and Scopus to search the literature. By using the key terms and word strings consistently, searches for complicated combinations of terms and climate change effects on range of activities, such as collections, conservation practices, operations and maintenance, facilities, biodiversity, landscape, behaviour and policy could be repeatedly traced.

Table 1: Areas in need of research as identified in a number of UK and European reports namely: (4) Cassar, M. (2005) *Climate Change and the Historic Environment*, University College London for English Heritage; (5) Brimblecombe, P. and Grossi, C. (2004) *Scoping Report: Sector Research Activity*, University of East Anglia for English Heritage; (6) Cassar, M. et al. (2001) *Technical Requirements for Solutions in the Conservation and Protection of Historic Monuments and Archaeological Remains: Final Report*, European Parliament Scientific and Technological Options Assessment Unit; (7) Fisk, D. (2005) *Construction Research and Innovation in the Heritage Sector: Foresight Planning for a Research Strategy for the Construction Industry*, prepared by English Heritage for nCRISP, Draft Report MK1, unpublished; (8) Ed. Cassar, M. and Hawkings, C. (2007) *Engineering Historic Future:, Stakeholder Dissemination and Scientific Research Report*, University College London; (9) House of Lords (2006) *Science and Technology: Minutes of Evidence Memorandum by University College London*, The Stationery Office; (10) UNESCO (2007) *Background Document from the Working Group Meeting to develop the Policy Paper on Impacts of Climate Change on World Heritage Properties*, UNESCO; (11) UNESCO (2003) *Item 7.1 of Provisional Agenda: Issues related to the State of Conservation of World Heritage Properties: the Impact of Climate Change on World Heritage Properties*, WHC-07/31.COM/7.1, Paris.

Sources	1	2	3	4	5	6	7	8
Hazard recognition and risk quantification and prioritisation	x					x	x	x
Extreme weather effects: damage probabilities and conservation	x				x		x	x
Cross-field monitoring (eg. interaction among different ageing/decay mechanisms; reconciling different metrics	x	x	x		x	x	x	x
Simulation modelling (eg. CFD modelling of env. and phase changes and amplification mechanisms)		x	x				x	
Predictive modelling of real complex phenomena	x		x			x	x	
Indoor/outdoor monitoring and assessment of vulnerability/ performance	x				x		x	x
Materials interface: environment – new - old	x	x	x			x	x	x
Conservation & maintaining value		x						x
Materials conservation & sustainability eg. marker; durable; traditional; new repair/conservation		x	x			x		
Response of materials and assemblies to microclimates		x	x					
Long term behaviour of materials eg. nanoscale degradation and treatment			x					
Biodeteriorattion and biotechnology			x				x	
Traditional and advanced physical and chemical technologies; re-engineering of techniques and instrumentation			x			x		x
Environment , the low carbon economy, renewable energy and historic buildings				x	x	x		
Remote sensing , bio-sensing and fail-safe technologies	x	x	x			x		x
Non-destructive/micro destructive techniques	x							
Simulation and IT tools	x	x				x		
Datasets, databases and mapping	x							x
Adaptations to Climate Change	x							
Wireless protocols for data transmission	x							
Indicators, thresholds and standards	x	x	x			x		
Damage mitigation strategies for materials and assemblies		x	x					
Integrated conservation management and public values		x	x				x	

Table 3 illustrates the gaps (in grey) as well as existing information. It reveals unbalanced coverage of climate change effects in the literature with significant gaps in key areas. Twenty six out of the 110 categories (from multiplying the 11 climate change effects with the 10 key terms) produced no references. Another 42 categories had 5 or fewer references, indicating gaps where there is scope for research and/or publication in these areas. From a total of 50 references on climate change effects and museum, galleries, archives and libraries, 60% were references to the effects of changes in temperature and humidity. The paucity of literature suggests that there is scope for further research activities on other climate change effects on moveable heritage.

3. Examples of matrices

The matrices on the impact of climate change on the historic environment and on museums, galleries, archives and libraries respectively, provide a useful illustration of the differences in the range, number and distribution of publications and a clear indication of the gaps in published information.

Historic environment

In Figure 3, historic buildings (dark red) and historic environment (bright red) yielded the most references. However the lack of references that combine frost and historic buildings (dark red), and pests, fungi and lichens in all categories (dark red, bright red, green, orange and yellow) suggests that there is great scope for further research and dissemination.

The distribution of results is summarised in the matrix (Table 4).

Table 4 shows references in more than 70% of the boxes. It is an example of the most complete and uniform spread of references with 163 references in 40 out of the 55 boxes. The majority of references are skewed towards temperature and precipitation, although a significant number of references also relate to vegetation.

The highest number of references is on the effects of temperature (first column), on ground water and on vegetation. Of significance is the absence of any publications which consider historic estates as part of land, water, nature, buildings and other structures. Nevertheless, there is a fairly consistent spread of publications across the sector and climate change parameters.

Museums, galleries, archives and libraries

In contrast, Figure 4 shows that only in selected aspects of museums, galleries, archives and libraries has work been published on the impact of climate change, namely temperature and museums, libraries, museum storage, exhibitions and display, operation and maintenance and conservation. The most climate change parameters have been published. on the impact on conservation and the operation and maintenance of museums, galleries, archives and libraries. In fact, 34 out of at total of 50 references on museums, galleries, archives and libraries relate to conservation and operation and maintenance.

Table 5 shows very little evidence of publications on the effect of climate change on museums, galleries, archives and libraries with the small exception of temperature effects which largely result from studies on the impact on human comfort and environmental control. This is mirrored by studies on humidity and pests, fungi and lichen, which despite the low number of references, it is where publications are concentrated. The enormous gaps in the literature (where 89 out of 110 boxes are blank and only 3 boxes contain more than 5 references) indicate that future research should focus on this area.

4. Conclusion

The scope of this project and its three-month duration meant that this study could only be a preliminary mapping exercise and not a critical analysis of the literature. It should also be emphasised that a lack of published literature does not indicate a definitive gap in research since the study did not set out to identify unpublished research. Nevertheless, the lack of published literature on the effects of temperature change, flood and humidity on collections in museums, galleries, archives and libraries indicates a definitive research gap that unless addressed, will have significant consequences for the management of collections. Overall the spread of references was patchy with the most consistent spread of references for the historic environment and few for museums, galleries, archives and libraries, heritage use and cultural heritage.

More broadly, this study demonstrates that the policy-research interface cannot be assumed to be without problem, linear or direct. The research did not lead policy; it did not drive policy which would have contained an element of scientific inevitability. Neither did policy lead the research; research was not driven by policy which shaped the research. While the evidence had to be timely, intelligible and available on demand, the study was not commissioned as 'research for policy's sake' which would have made it highly selective. The study was intended to share information, to inform practice, to make heritage organizations more aware of climate change and to make their operation more environmentally responsible and sustainable.

Thus, instead of the research serving the policy agenda directly, its benefits are more likely to be indirect and may take longer to be realized. Rather than producing 'punchy policy messages', the aim was to illuminate the landscape within which policy decisions are made. The aim of this study in this respect was evidence-*informed* policy rather than evidence-*based* policy because as stated at the beginning evidence is not the only contender for policy influence. There are at least 4 other powerful competitors: ideology, interest, institutional norms and practices and prior information – the grubby rather than the pristine environment mentioned earlier. What is nearer the truth in this case, is not the quotation from John Maynard Keynes which started this paper, but a quotation from the UK Government White Paper on *Modernizing Government*[12] which stated: 'This Government expects more of policy makers. More new ideas, more willingness to question inherited ways of doing things, *better use of evidence and research in policy making…*'

5. Acknowledgement

The authors gratefully acknowledge the support of the UK Government Department of Culture, Media and Sport for commissioning this research.

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Table 2: Partial list of key terms and word strings describing cultural assets used in the review of the literature.

Key Terms	**Historic Environment**	**Museums, Galleries, Archives and Libraries**	**Heritage Use**	**Cultural Heritage**	**Public Behaviour**
Word Strings	Historic Buildings	Collections	Conservation practices	World Heritage	Influencing Public Behaviour
	Historic Environment	Museums	Heritage	World Heritage Sites	Education
	Historic Estates	Gallery	Heritage Use	International Programmes	Visitor Behaviour
	Archaeology	Archives	Widening Access	Government	Access
	Cultural Landscapes	Libraries	Transport		Recreation
		Storage	Operations		Outdoor activities
		Exhibitions	Maintenance		
		Display			
		Operations and maintenance			
		Conservation			

Table 3: Total number and distribution of references on the effects of climate change on cultural and sporting assets. Source: reference 3.

Key terms	Temperature	Precipitation	Sea level rise	Flood	Ground water	Frost	Humidity	Wind	Vegetation	Pests, fungi, lichen	Air pollution
Historic Environment	32	18	12	13	19	2	16	14	27	2	8
Heritage use	10	5	10	7	5	4	1	4	3	0	3
Museums, Galleries, Archives & Libraries	19	2	2	3	0	1	11	1	3	6	2
Sport Assets	27	7	4	6	3	0	2	4	10	0	8
Sport Use	4	1	1	0	2	0	0	1	2	0	0
Arts	10	3	1	2	1	0	0	1	0	0	2
Parks and gardens	26	9	6	10	5	0	0	3	114	0	1
Creative Industries	16	7	1	0	0	0	1	0	0	0	4
Influencing Public Behaviour	38	15	7	8	2	0	1	6	2	0	5
Cultural heritage	5	2	2	3	1	1	0	1	3	0	5
	187	69	46	49	38	8	32	35	164	8	38

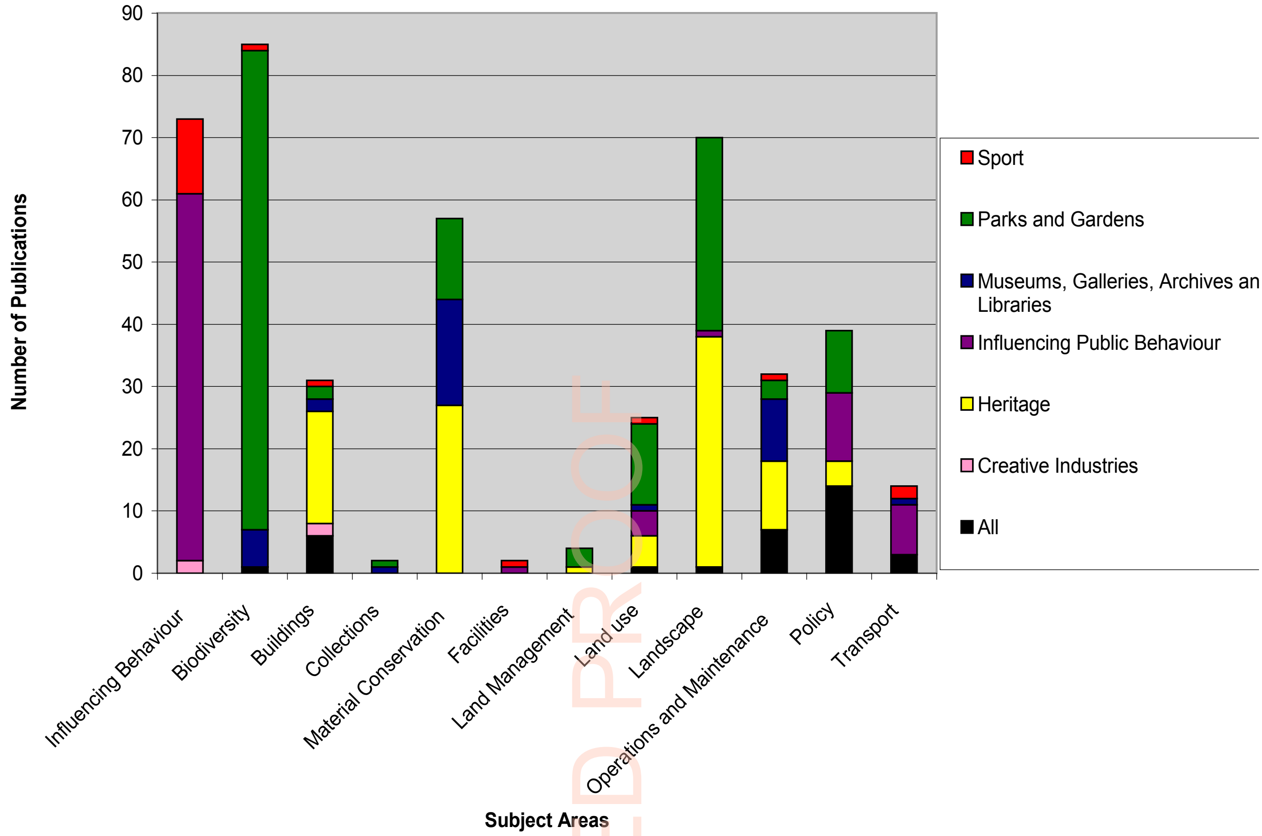

Figure 1: Overview of the publications distributed across subject areas by areas of responsibility of DCMS. Source: reference 2.

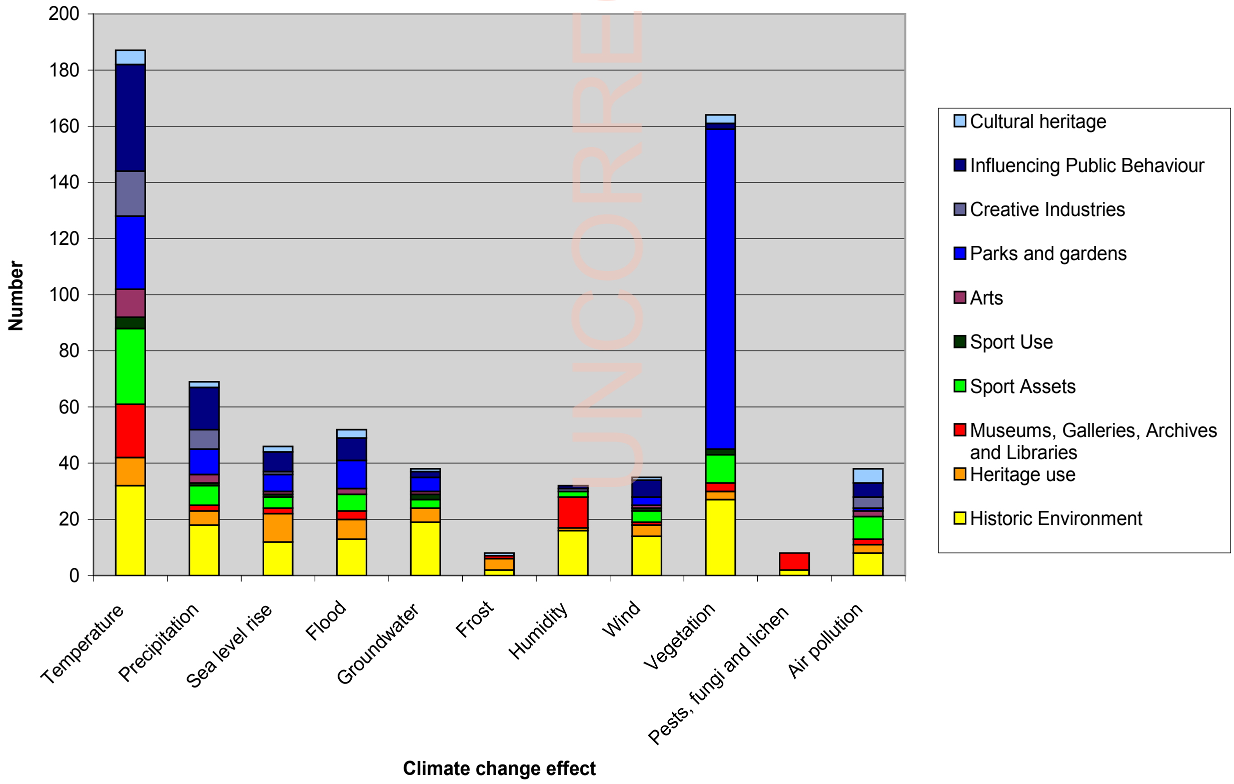

Figure 2: Distribution of the literature according to the higher level key terms compared to the 11 most significant environmental change parameters. Source: reference 3.

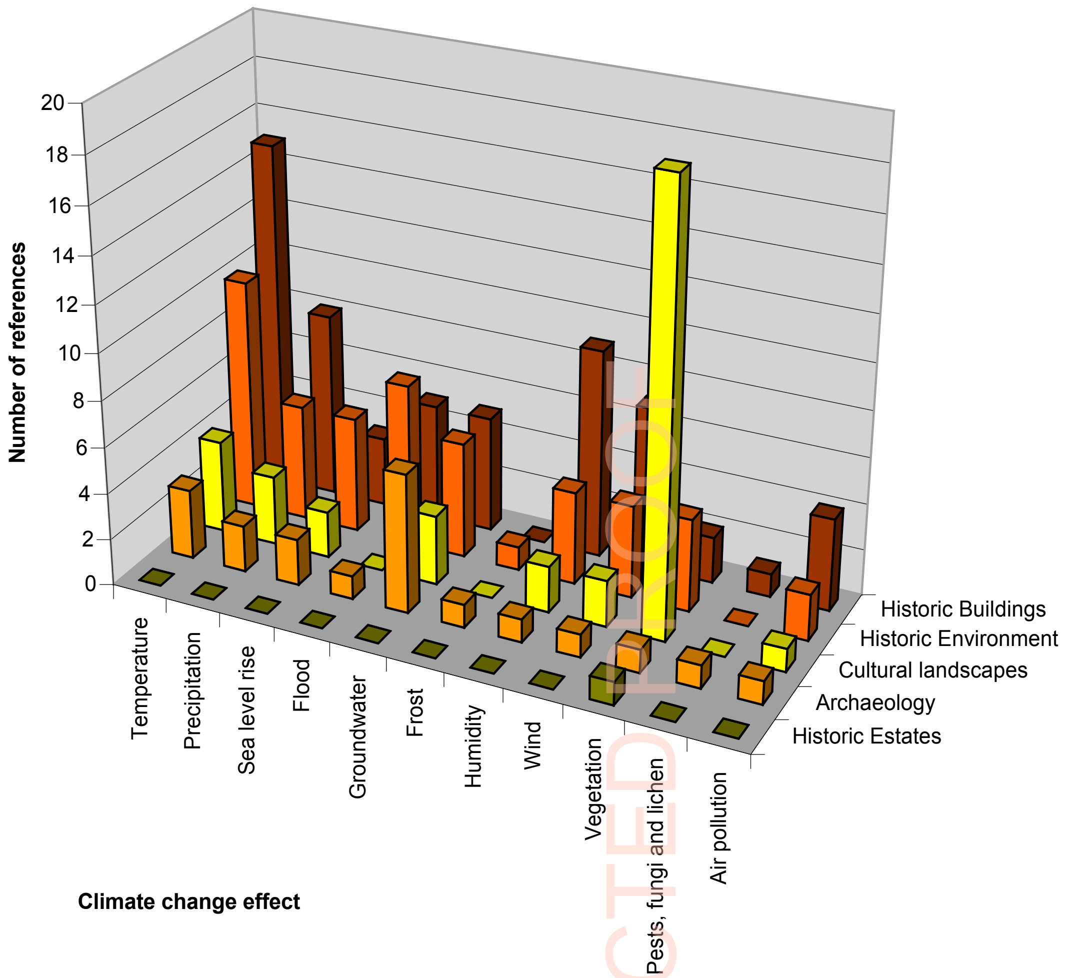

Figure 3: Distribution of references on the effects of climate change on the historic environment. Source: reference 3.

Table 4: Distribution of search of publications on climate and the historic environment plotted on a matrix.

Historic Environment	Temperature	Precipitation	Sea level rise	Flood	Ground water	Frost	Humidity	Wind	Vegetation	lichenPest, fungi and	Air pollution
Historic Buildings	15	8	3	5	5	0	9	7	2	1	4
Historic Environment	10	5	5	7	5	1	4	4	4	0	2
Historic Estates	0	0	0	0	0	0	0	0	1	0	0
Archaeology	3	2	2	1	6	1	1	1	1	1	1
Cultural landscapes	4	3	2	0	3	0	2	2	19	0	1
	32	18	12	13	19	2	16	14	27	2	8

INFORMATION TECHNOLOGIES AND CULTURAL HERITAGE: INNOVATIVE TOOLS FOR THE SUPPORT IN THE PARTICIPATIVE MANAGEMENT OF HISTORICAL CENTRES

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1. Introduction

Saving a few exceptions, all European urban areas are or contain a historic centre. Preserving historic centres require a different approach than usual for a monumental site. Historic centres are alive and its management has to simultaneously respond to the needs of socio-economic development and the protection of the built heritage with their local values and identity. This idea is reflected in the concepts of active conservation and integrated conservation. Based on these considerations, current trends are geared to the identification of new management tools, which incorporate the social and economic dimensions that characterize the historic centre and to facilitate the participation of all actors involved in the conservation of the whole, administrations, experts and citizens. Participation requires tools. The information presented in this article is based on the results of a project aimed at developing tools that support the process of participatory management and decision making on projects to revitalize historic centres. The approach proposed in this project, very innovative in its application to the historical areas, is framed on the lines defined by the United Nations and the European Union. The project will develop different types of tools. The proposal put forward in this paper is the combination of high content innovative information technologies as support tools and interface facilitator of management at different stages of a project to revitalize the historic centre (diagnosis, planning, realization, management and exploitation). The technologies used are Web2.0, Geographic Information Systems (GIS) and Augmented Reality (AR). The characteristics of these technologies allow successfully address some of the key requirements of the approach. Among other noteworthy, accessibility to the information for different user profile and in a transparent manner, collaborative support (Web2.0), access to geo-referenced information (GIS), possibility of editing, integration and access to information onsite (AR), etc. This is an ongoing project and the results will be validated through the application of management tools to historic town of Segovia. As a continuation of the project is expected to extend the application of the tools developed in the project at various European cities.

The project presented in this article is called PATUR and represents a bet on participatory management of historic environments. The project design and conduct a search for new tools that facilitate the management versus the traditional tools. Wanted an approach from the user compared to traditional approach from administrative institutions. The project develops technological tools and other more traditional not applied so far for the purpose of this project. This paper focuses on the technological tools. In the technological age in which we live, new technologies can facilitate the management and decision-making process in the conservation and revitalization of an historic centre. These technologies can be applied at different stages of these projects, with each one suited to a different stage. In this project we focus on the use of three different and innovative technologies. Now we briefly describe each of them, as well as its main application for participatory management of a historic centre and the main benefits it brings.

2. Technologies

2.1 Web 2.0

Under the name of Web 2.0 it will encompass a range of features and functionalities, usually in the form of Web applications, whose main characteristic is the orientation towards the end user. The user becomes a generator of content. From the scenario of static pages, there was a step towards web applications (browsers, e-commerce, etc.), and from there to environments where the user is the generator and manager of contents (Web 2.0).According to the philosophy of the Web 2.0, the Web is the platform, is the net on which users interact. It evolves from desktop applications to web environments, bringing the software tends to be a service and not a product. The web focuses on the user and the user creates the Web. Each user provides some information. Some of these principles provide this technology some features that make it particularly suitable for the development of tools to support participatory management of urban centres. Among others: collaborative editing, web support, user management, change history, insertion of comments, search tools, recent changes, attach documents, etc.

2.2 Geographic Information Systems (GIS)

GIS are applications specially designed for management and manipulation of data that are geographically referenced. These systems are useful in processes of territorial management and planning. A GIS system combines graphic and alphanumeric information. Developments in recent years of these applications have been spectacular; they have proliferated with the development of software tools both commercial and free of use.

Within the PATUR project we have designed and developed a tool to support participatory processes for the information management and decision-making in the revitalization of a historic centre. We have combined the two core technologies described above: Web2.0 (Wiki and Blog) andGIS. From a functional point of view, this is a tool accessible via web from where users have access to stored information. The data model of the system is divided into two major groups, on the one hand spatial information and on the other hand the thematic information. Different types of users can access to this website in order to enter information and display the stored information. Application is available at the following web site: http://212.8.105.36/patur.

For the management of spatial information is essential to use a GIS. In this application the aim is to manage information associated with a major spatial component and further integrate it into a web environment, so as to exploit the advantages it offers (ubiquitous access, user-friendly interface, dissemination, etc.). Therefore, within the broad range of GIS products what is needed is a map server, i.e. a tool that can process requests from clients, and send a reply according to the petition. There are several service map tools, among all we selected MapServer. The GIS in the PATUR project represents each plot of the historic centre. Each of the plots contains thematic information associated to this location. Reviewing information is based on search criteria, the results are displayed graphically on the map (GIS) (Figure 1). For information on one of the elements resulting from the search that element is selected on the map. Thematic information associated with each element is included within the Wiki and can be accessed from the GIS through links (URLs). It is also possible to edit information associated with an element directly from the GIS.

Thematic information is stored in the system using two applications based on Web 2.0 technologies, we have developed a

Wiki and Blog. These tools have benefited from major developments and are being integrated in a natural way within the concepts of social networks. However, according to the knowledge of the authors, never before have been used this type of project management tools for revitalizing historic centres. There are currently a large number of tools both commercial and free to use for creating Wiki spaces. The choice of one tool among all existing is not easy and the best way to choose one of them is by eliminating, through the definition of user requirements. Using the tool WikiMatrix for that purpose 5 results met all the criteria, among them JSPWiki was selected for the development of the Wiki and Blog for participatory management of the historic centres framed within the project PATUR.

Figure 1: Geographic Information System in PATUR project

2.3 Mobile Augmented Reality (AR)

AR is nowadays a novel technology that is acquiring great relevancy as a research and development area [4][5]. This technology extends the perception and interaction of the user with the real world, providing information that users can not detect directly with their own senses. With the help of computers and other special devices, this technology places the user in a real environment augmented with additional information generated by computers. There are numerous environments of application of these technologies that requires both mobility and access to the information at any time and any place; in these cases the utilization of mobile devices becomes necessary. In the construction sector in general, and specifically in the area of cultural heritage there are many activities that require mobility of the user in which the application of AR technology is interesting.

There are two tasks associated with the management of urban centres in which it has identified an interest in applying the technologies of mobile AR. First for the diagnosis of the historic centre and secondly to the task of selecting alternatives for planning and managing interventions in the historic centre.

One of the main tasks facing the manager of a historic centre is to avoid degradation while retaining the historical value. For this reason, any intervention that takes place on the environment should be especially carefully managed. Only when performing a proper diagnosis of the environment and its reality is possible to follow a high quality intervention. The integration of new information technologies has been crucial to the improvement of these processes. New technologies, such as AR can provide new tools in order to support the user during his job and achieve better results. We have developed a tool for the support to the diagnosis of the historical centre based on mobile devices (PDA) using multimedia contents and AR technologies (Figure 2).

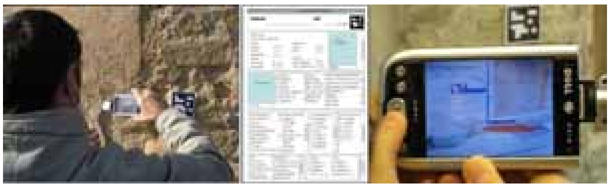

Figure 2: User, diagnosis sheet and PDA during the diagnosis process.

The selection of alternatives is another of the crucial tasks in planning and managing interventions in historic centres. There are no tools to assist in this task and the final decision is quite subjective depending on the person responsible for making the decision, besides the information that he/she has to make that decision are often 2D maps and reports that do not help too much to understand each one of the options and differences between them. We believe that a process of participatory selection of alternatives, not limited to a single person but involving a number of experts and tools, would help them to better understand each way. We have developed a tool based on mobile AR technology that allows previewing onsite three-dimensional models of the alternatives raised. Once viewed in-situ, each of the experts participates in a virtual forum, on the web, to reach consensus in selecting the alternative. In this discussion forum real and augmented photographs are used to support the arguments of each participant.

Some of the major benefits of the tools developed using AR are identified here; the development of a tool based on mobile devices for supporting the diagnosis of a historic centre,, the definition of a systematic process of data collection, remote access and editing of information collection, visual support for diagnostic work such as physical accessibility and the ability to be guided through the environment. The task of selecting the tool based on alternative technologies AR provides the ability to view on-site alternatives raised. During these sessions augmented photographs can be taken that help to support the arguments set forth in the discussion forum, all with a view to reaching consensus when selecting an alternative intervention in a historic centre.

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LASER CLEANING IN CONSERVATION PRACTICE: THE ANALYSIS OF A SUCCESSFUL TECHNOLOGY TRANSFER PROCESS

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1. Introduction

The protection and conservation of Cultural Heritage (CH) have motivated in Europe research programs aimed to the most appropriate measures for preventing the artefacts from degradation and loss. Unfortunately the governmental attention to this sector is scarce in many Countries. Resources dedicated to CH sector are limited. Research for this sector has low priority.

Research programs at European level would have provided a stronger motivation for promoting synergic programs at national level, but once again also the budgets for CH were limited to a few tens of million Euros, and the impact of their projects is still to be assessed. One way to do it is to study the follow-up of each project, analysing the development of innovative technology, verifying the start-up of new products, their actual utilisation in preservation and conservation and finally the advancement provided in the stake-holders activities.

Out of these premises, a lack of investigation emerges about the organisation and economic aspects related to the technology transfer process in this sector, while to know their crucial elements would be of great interest in order to drive the projects outcomes toward sustainable solutions.

This work regards the scientific research carried out on Laser Cleaning of artefacts, which represents a case of radical innovation in conservation techniques that has completed the process of transfer to the end users. The aim is to present an original analysis of the organisation factors that made this innovative research a case of success in the last ten years, in order to offer new topics of debate to the communities of research institutions and stake holders, and to give a contribution to the governance of innovation in this sector.

2. The History behind laser cleaning

Laser cleaning of artworks is an example of research with a very long time of incubation, which began after the first demonstration by John Asmus and Lorenzo Lazzarini in Venice in 1972. A second phase of activity started in France at the beginning of 90s, with the development of more adequate laser systems and their application in restoration of a relevant number of cathedrals (Notre Dame, Chartres, etc.). In 1994 the first European research project on this subject, "Laser manuporteable for stone conservation", LAMA, was financed in the 4th Frame Program, starting a series of projects also in the subsequent FPs.

In the same period in Crete UV laser cleaning was applied to another restoration problem, the removal of icons repainting. In Germany some European projects were devoted to the problems of medieval glass and to the problems of antique documents, but without practical utilisation. In the Netherlands another European project developed a prototype with the activation of the laser being controlled on-line by a spectroscopic sensor (LIBS). This approach was never considered acceptable by painting restorers, being in contradiction with the most consolidated restoration theories[1]. Some problems came out: yellowing effects after laser removal of the crusts were observed; discoloration of pigments by the effect of laser irradiation was also determined. Especially in France the side effects on stone were discouraging further experimentation.

All these experiences produced at the end of the XXth century the general opinion that in spite of the promises laser cleaning was substantially not yet fit[2] for being successfully employed in the removal of degraded layers, the most delicate phase of restoration.

In the late '90s in Tuscany our CNR group proposed non-standard laser systems that in a decade became products and methodologies utilised on a number of masterpieces in many Countries.

3. Our experience in Tuscany

Since 1993 our CNR group was involved in a series of projects with different aims and organisation. In the Special Project of CNR Cultural Heritage, 1996-2001, we studied the physical interaction of laser methods for cleaning of artworks. In the two projects RRAT (1997-2000) and RIS+Toscana (2000-2001) the aim was to develop laser systems with specific emission parameters selected for cleaning of stone and gilded bronze respectively, with a well assembled partnership including experts of restoration (Opificio delle Pietre Dure), experts of stone materials (University of Siena), and EL.EN. Spa, laser systems producer. The third project OP-TOCANTIERI (2002-2004) was a regional network with 24 partners, aimed to transfer the technology from research centres to high-tech producers and to validate them in the activities of running restoration yards (Porta della Mandorla in Florence, Fonte Gaia in Siena, Porta del Paradiso in Florence, Porta di San Ranieri in Pisa), demonstrating the ability of the newly developed lasers to remove the alteration layers while preserving the historical patinas, without yellowing or other side effects.

This experience was brought at European level by IFAC-CNR mainly in the COST Action G7 "Artworks Conservation by Laser" and in Culture 2000 projects. The COST Action G7 (2000-2006) had a fundamental role setting around the same table 36 European organisations, represented by laser physicists, chemists, art historians, restorers, conservators. This multisciplinary group was able to take advantage of the networking benefits, promoting new ideas and raising the overall level of comprehension about how to use properly lasers in conservation[3].

4. Technical factors

While the multidisciplinary involvement of the three pillars (research, safeguard, private enterprise) was present in the majority of European projects on laser cleaning, some crucial factors were peculiar in the Tuscany experience:

Focussing on open conservation problems considered still unresolved or unsatisfactorily resolved.

Thorough studies about the specific laser-material interaction for determining optimum laser parameters.

Laser systems engineered and produced by a laser firm previously active on the laser products market.

The first point is definitely strategic in order that the project answers a real problem, with the consequence that when a viable solution is found (breakthrough), it will necessarily attract the attention of the conservation community.

The physical model was a second crucial factor of our approach, optimising the laser parameters and avoiding unacceptable side effects.

The third factor was the contribution by the EL.EN. company, producing their laser models as finalised and low-cost products along their on-line production (about 500 laser per year) for the biomedics.

On the economic side these products have been a success in the market niche of laser cleaning systems, reaching in a few years sales in the order of some hundred units to public institutions and private restorers. Only in Florence about 25 laser units are everyday in use for masterpiece restoration.

5. Organisation factors

Other factors concerning the governance of innovation were absolutely crucial. The cog wheel of the sequence "Original Research-Innovative Technology-Know-how Transfer-Sustainable Product" could not work properly without a strong interaction between : 1) national (Italy) research programs; 2) local (Tuscany) technology transfer programs and finally 3) European cooperative (COST G7) programs.

An additional consideration has to be made about Florence and the concentration of public institutions and private stakeholders working in this city on the tasks of conservation..

6. Economic modelling of innovation in the CH sector

Economic studies carried out recently[4] extend to cultural districts the rational of industrial districts, finding similar conditions for an overall growth when a necessary concentration of cultural activities (High Culture Local System, HCLS) is able to generate unexpected interactions between each independent component and produce economic enhancement.

The city of Florence fits perfectly the HCLS model as a Cluster of Art Restoration, CAR, hosting, besides a renowned collection of historical palaces and a museums cluster, a prestigious restoration centre as Opificio delle Pietre Dure and the Soprintendenze for Arts, Architecture and Archaeology. In the Scientific Pole of Florence several research institutes of the CNR, of the National Institute for Nuclear Physics (INFN) and of the University are engaged in this field and constitute a scientific resource that integrate the CAR. Other public and private organisations exploit the fruition around this immense cultural patrimony host in the city. Some high-tech producers are available with expertise in photonics, ICT, materials.

7. Conclusions

The model of a City of Art as a HCLS explains the conditions for a successful translation of research into a sustainable innovation in the field of preservation and conservation of CH.

A HCLS may express an innovation demand that is real and asks for immediate solution.

Its economy machine (high-tech producers, marketing etc.) penetrates easily the potential market, not only on the basis of a simple improvement, but also of radical innovation (laser cleaning is an example).

The rate of utilisation of such new product diffuses easily from most prominent HCLS to the outer circle of followers at national level.

If European networking or other international links provide cooperative/competitive interchange of experiences, the best practice selection process spreads their use from HCLS throughout the entire world.

Other projects have benefited of the Florence HCLS: our institute could also contribute to Light Dosimeter, LiDo, one of the few European projects that completed the path towards technology transfer, and to AUTHENTICO, another FP6 project proceeding on the same way. The FP6 research infrastructure EU-ARTECH had in Florence a pillar of its activity, and the FP7 research infrastructure CHARISMA also will involve the Florence cluster in the forthcoming years.

In conclusion, according to our experience a more effective exploitation of the research projects results may be achieved by the involvement of HCLS. The open competition of research proposals in FP calls provides best approach to attract new ideas in research but is much less prone to translate the results into sustainable products. This task may be favoured in a HCLS. The case of Laser Cleaning is the first example of a radical innovation that could come out only because in COST Action G7 several European HCLSs produced a strong synergy between national, regional and European programs. This is an example to be followed in the future.

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APPLICATION OF LASER INDUCED PLASMA SPECTROSCOPY IN THE AUTHENTICATION OF METAL ARTEFACTS

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1. Introduction

The illegal market of objects of art and historical interest is experiencing a significant increase. Besides the illicit traffic of genuine artefacts, which is favoured by the removal of the borders and more generally by globalisation, the commercial demand of this sector is also stimulating a massive production of fraudulent imitations. Conversely, from the other side, a consequent demand for reliable authentication methodologies comes from law enforcements agencies, conservation institutions, no-profit organisations, and other stakeholders involved in the management and legal market of the cultural heritage.

Up until recent times, authentication studies were mostly based on historical-stylistic criteria (i.e. on standalone human science analyses), which involved the material concerns only at a very qualitative level. The introduction and development of archaeometric techniques carried out by the natural sciences during the last decades, is gradually changing the approach to the knowledge of the material heritage. Dating, composition, structural, and technological analysis techniques can provide useful objective data for determining the age and the production context of the artefact. On the other hand, still too often independent sets of instrumental data are achieved and interpreted within single disciplinary contexts, which can easily produce controversial and questionable interpretations. The need for genuine multidisciplinary and integrated studies is widely recognised, but unfortunately it has not a straight correspondence in the practice of knowledge in the field of cultural heritage.

One of the objectives of the project AUTHENTICO (FP6, STReP, c.n. 044480), which focuses on the authentication of metal artefacts, is the statement and application of integrated analytical methodologies in which the various competencies interact during the whole authentication process and contribute to the final multidisciplinary conclusions. At the same time, the project aims at developing portable and low-cost instrumentations for non-invasive and reliable analyses to be employed in simplified authentication procedures derived from the general systematic approach just mentioned. The main goal is to develop a first-level authenticity screening to support the work of law enforcements agencies, museum institutions, and other legal stakeholders against the illicit circulation of a large number of genuine artefacts and counterfeits. Here, we report on the state of development of a dedicated laser induced plasma spectroscopy (LIPS) system and its first use in authentication studies of copper alloy objects. The experimental work carried out on prepared samples, forged figurines, genuine findings, Florentine antiquarian collections, and celebrated Renaissance and Mannerist masterpieces is revealing a significant potential of such an elemental analysis, not only for achieving the chemical composition of the alloys but also for discriminating between natural and artificial (or accelerated) corrosion, as well as between aged and fresh patinations. The reliability of such recognition capabilities is expected to be improved in the next future by combining the results of LIPS with those provided by two other dedicated devices, which are under development in AUTHENTICO: laser-assisted electronic nose and 3D micro-topographer.

2. LIPS in the investigation of the cultural heritage: the state of the art and the present developments

The technique, whose introduction dates backs to the origin of the laser technology, has been proposed as a versatile elemental analytical tool in the field of cultural heritage along the last fifteen years for characterising pigments[1-3], metal alloys[4-5] and glasses[6], as well as for monitoring the laser cleaning processes[7-9]. It can provide qualitative and quantitative compositions through the laser ablation of a micro-scale volume (10-100 µm spot size, 0.1-10 µm single pulse-ablation depth), which usually does not involve any relevant invasiveness issue for most of the objects. Non-invasiveness along with the potentials for portability and low cost are attracting a growing interest in LIPS, according to the increasing number of works reported in the proceedings of the main conferences on the topic: Laser in the Conservation of Artworks (LACONA, since 1995) and Laser Induced Breakdown Spectroscopy (LIBS, since 2000). However, only a few of the published investigations deal with case studies of concrete archaeometrical interest and in particular, no one approaches overall archaeometallugical characterisation of museum collections, figurines, jewels, and large bronzes.

Since some years ago, the market is offering several LIPS systems at indicative costs between 40-200 k€. At the lower edge the typical setup includes an air-cooled passively Q-switched (QS) Nd:YAG laser emitting at the fundamental wavelength (1064 nm) and single or multiple compact spectrometers equipped with CCD array detectors, whereas the most sophisticated and expensive systems are based on electro-optically QS Nd:YAG lasers working at the fundamental wavelength or/and higher order harmonics, échelle spectrometer, and intensified CCD camera. However, none of these commercial devices was specifically designed to be used for investigating art and historical objects, according to the present low level of application in the field. The unsatisfactory performances of the former and the high cost and the relatively large sizes of the latter, along with the need to achieve an efficient optical collection allowing for easy alignments on the very variable surface shapes of the metal artefacts, led us to design and assemble a dedicated device. It employs: 1) stable and compact (17 cm head-length) electro-optically QS Nd:YAG laser (1064 nm, 50 mJ/pulse), 2) four compact fibre-optic spectrometers equipped with CCDs, which cover the spectral range between 200-630 nm with a resolution of 0.06 nm, 3) high numerical aperture optical collector, 4) inspection CCD camera, 5) analysis code. The novel apparatus was carefully calibrated for achieving quantitative chemical analyses of binary, ternary and quaternary copper alloys (Cu, Sn, Zn, Pb) using homemade sets of samples and commercial standards. The reliability of the quantification was verified in several crossed tests where the LIPS results were compared with those provided by ICP-OES, AAS, SEM-EDX, and TOF-ND.

3. Case studies

The LIPS-based approach to the characterisation and authentication of bronze and brass artefacts was tested and validated in a number of case studies. The technique was applied within thorough authentication investigations in combination with the whole set of traditional techniques along with TOF-ND, according to the developments foreseen in AUTHENTICO. We are carrying out a complex integrated pilot study on the antiquary collections of Florence's National Museum of Archaeology which include some hundreds of copper alloy figurines of Etruscan and Roman styles from private collections and are hence of unknown origin (Figure 1). Besides genuine parts, they include reconstructions on some of them, pastiches, and fakes all together, which make their authentication a very difficult task. The investigation is putting in evidences the significant discrimination potential associated with the comparative analysis of elemental depth profiles measured using LIPS. Thus in particular, in several cases it can allow distinguishing natural corrosion and segregation phenomena of archaeological findings from fraudulent aging and patination. Here, this feature and its application perspective in authentication studies is critically discussed. Furthermore, considering the crucial importance of the validation and promotion for a successful dissemination, we are also working on the integration of LIPS in the characterisation of large bronze masterpieces. In this presentation, example case studies such as those of the David by Donatello (dated around 1440), the *Predica del Battista* (Sermon of St. John the Baptist) by Giovan Francesco Rustici (1506-11), and the *Decollazione del Battista* (Beheading of Saint John the Baptist, 1571, Figure 2 and 3) by Vincenzo Danti will be briefly presented. Besides the fundamental information on the alloy compositions and the presence of chlorides and sulphates, these measurement campaigns significantly enriched our database on compositional depth profiles of genuine artefacts, which is being exploited together with alloy composition data for developing LIPS-based authentication assays.

4. Acknowledgments

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Sample	Sn	Pb	Zn
P1	13.01	8.06	0.76
P2	11.23	8.35	0.66
P3	14.27	13.14	0.69
P4	12.61	14.08	0.69
P5	11.98	6.77	0.62
P6	10.65	10.39	0.61
P7	11.33	8.88	0.65
P8	5.84	2.91	2.40
P9	5.41	2.04	3.04
P10	5.01	2.92	2.13
P11	5.09	4.16	2.68
P12	5.10	4.30	2.70
P14	3.93	2.91	2.22
P15	3.77	1.80	2.40
P16	14.76	17.22	0.64

Figure 1: Mapping the elemental composition of bronze figurines using LIPS.

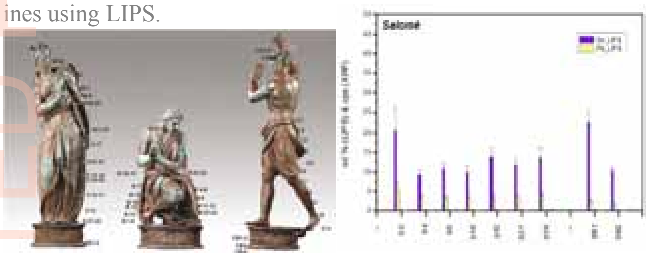

Figure 2: Mapping the elemental composition of large bronzes using LIPS: the case study of the decollazione del Battista by Vincenzo Danti (1571).

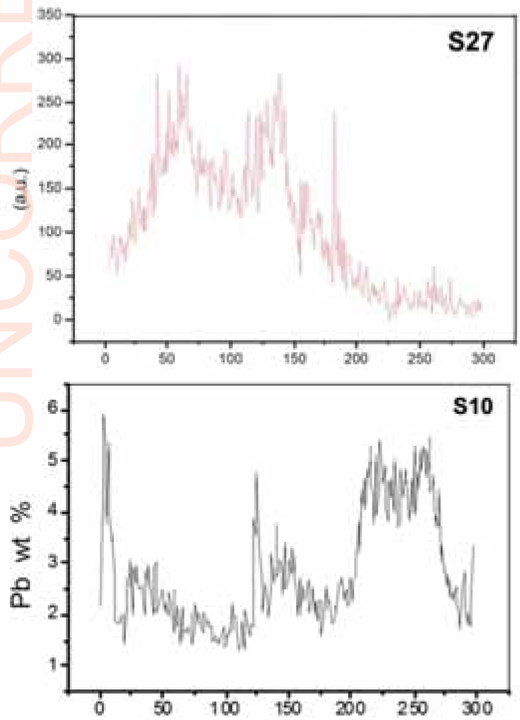

Figure 3: Examples of bronze elemental depth profiles as a function of the number of pulses provided by LIPS.

KNOWLEDGE TRANSFER FROM A STAKEHOLDER PERSPECTIVE – RESEARCH ON ORGANIC VOLATILES IN ARCHIVAL COLLECTIONS MEETS PRACTICE

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1. Introduction

At the Dutch National Archives, research has been identified as one of the main drives in what defines a leading heritage institution. As a national archive, it is our primary aim to keep the collections accessible for the posterity, and we are part of the international debate on the most optimal ways to do so. The quality of long-term storage environment is among the most essential research issues.

Our intensive engagement in a number of European collaborations has led to on-going improvements in preservation practice. In particular, the PaperVOC project is focussed on volatile organic compounds that are emitted by paper itself. This research has shown that paper may be its own worst enemy – not only due to inherent acids but also due to the volatile products of paper degradation. Their mobility enhances the spread of degradation throughout the collection and their removal from the archival environment is important. A variety of options are considered, from VOC scavengers for storage of individual objects to large-scale air purification systems.

Through international associations such as the International Council on Archives, we actively participate in dissemination of research results. As a national knowledge centre, our education activities complete the essential information flow: end-user - researcher - stakeholder - end-user.

2. Volatile Organic Compounds in Archival and Library Collections

A number of factors are known to influence degradation of historical paper, among which the environment undoubtedly plays a crucial role, along with paper composition. During paper degradation, a variety of low molecular weight products are formed, several of which are volatile and thus have an increased mobility not only within the material, but also within a collection. In Figure 1, we summarise the numerous exogenous and endogenous factors influencing cellulose degradation – among which volatile degradation products (VOCs) can be both emitted but also absorbed by paper.

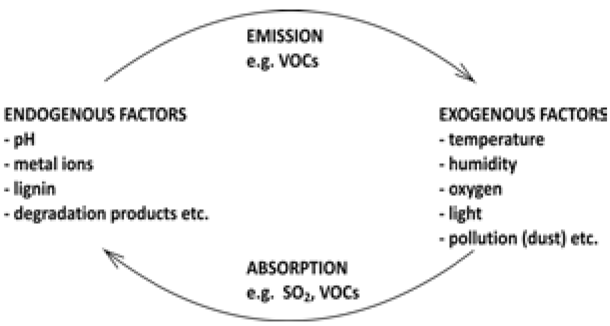

Figure 1: Endogeneous and exogeneous factors affecting paper degradation.[1]

Lately, the interest in determination of VOCs emitted from paper has increased, however, there are only limited studies available on the information which can be extracted from VOCs and on their effect on cellulose degradation.

There are a number of examples found in archives and libraries on the detrimental effect of VOCs (Figure 2). However, the importance of their removal and the relative importance of various different VOCs on in degradation processes have not yet been established

Figure 2: The transfer and trapping of volatile degradation products of the book cover materials lead to formation of the negative image on the first page of the book above.

3. Results and Discussion

Volatile organic compounds (VOCs) formed during paper degradation are numerous and varied,[2] and their identity and quantity depends on paper composition.[3] We have shown that the quantity of furfural, a volatile degradation product of cellulose, is indicative of paper acidity. [3] Thus, VOCs may be regarded as a source of information on paper quality.

On the other hand, many simple organic acids, aldehydes and even aromatic compounds, which have been shown to form during degradation, may also initiate or accelerate degradation of cellulose. Studies of the impact of several identified VOCs on degradation of paper can easily be performed in closed vessels at elevated temperatures. We evaluated the impact of the following: furfural, iso-butylbenzol, 1,4-diethylbenzen, acetic acid, formic acid, toluene, hexanal, 2-pentylfuran, formaldehyde and vanillin, on papers of three different qualities. Apart from volatile acids, a statistically significant negative effect of all compounds with a carbonyl group in the structure was noticed.

In the course of the PaperVOC project, we have also shown that:
- Groundwood containing cellulose stored in the vicinity of good quality cellulosic materials can accelerate the degradation of the latter by 100%.
- Iron gall ink containing documents have a measurable negative influence on the stability of paper through the emission of VOCs.
- The cross-infection effect (i.e. the negative influence of one object on the degradation of another object stored in the vicinity) can be minimised by trapping the VOCs by absorbents of VOC scavenging materials. In our study, we included several commercially available products and compared their effect on

degradation of cellulose and real historic samples in a closed vessel at an elevated temperature.

In the final phase of the project, it is our aim to establish the typical concentrations in repositories and to evaluate the potential harmful effect of VOCs on human health during long-term exposure.

4. Conclusions

The complex role of volatile degradation products in mixed paper collections should not be underestimated. Our research shows that the effect of cross-infection due to emission and re-absorption of these compounds is significant and strategies for removal of VOCs from storage facilities should be given due consideration.

The PaperVOC research project is the result of a long-term and exemplary collaboration between academic partners and the Dutch National Archives. A good understanding of the needs and requirements is essential in such collaborations, especially in order for the results to be readily fed into the preservation strategies of end-users.

5. Acknowledgement

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FIRE SAFETY OF NINETEENTH CENTURY CAST-IRON STRUCTURES THROUGH A COMPUTATIONAL FLUID DYNAMICS BASED ANALYSIS OF A WATER MIST FIRE SUPPRESSION SYSTEM.

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An iconic historic building nestled in the very heart of Madrid, in the Cibeles square, was seriously compromised by the strict requirements of fire safety regulations.

The building, a 250,000 m^2 and seven floors high, is being renewed to house the Spanish capital town hall. A nineteenth century castiron riveted structure, sometimes massive, sometimes in delicate trusses, was in the way to disappear under a thick sturdy layer of intumescing protection required for a ninety minutes resistance to ISO fire.

Figure 1: A general view of the building of study.

Madrid town council architects implore heaven (and techncians) for an alternative safe solution which might fulfil regula tory requirements without destroying structural harmony.

Labein was asked to do a complete "research meets practice" work identifying, defining and validating an integrated solution based on fire suppression systems. A zone-detection-activation-water mist system was proposed. Unfortunately, the integration of water mist effects in the thermodynamics of a fire was a non-sufficiently explored issue, so an innovative research project was on the way combining experimental tests and numerical simulations.

Due to the reasons mentioned, the project required a basic stage which fire load must be modelized and characterized with the incorporation of water mist fire suppression system. Moreover, temperature measurements related to a real large-scale fire test were given. Through this data, the model and characterization of the design fire and water mist system were built with an iterative process, hence after each CFD (Computational Fluid Dynamics) simulation many parameters related to fire load and water mist system should have been modified. In this basic stage, mathematical curve was created, which represented the effect of the water on the fire load.

Complex numerical models co-related with experimental data were built for a performance based justification of safety objectives through a computational fluid dynamics thermal analysis and advanced integrated structural analysis.

Firstly, a risk analysis of the study enclosure was made, in which four fire scenarios were identified as the most extremely dangerous because of their serious consequences that they could provoke to the structural stability and people's safety. After that, the geometry of enclosure was created and every protection system in case fire was introduced in fluid dynamic model, such as smoke detection system, smoke control system or water mist system.

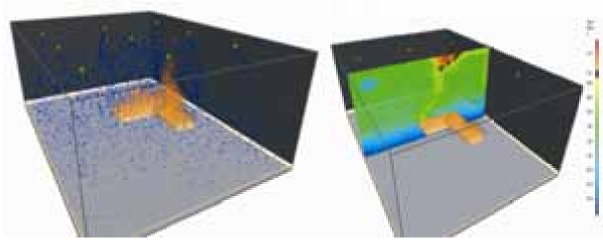

Figure 2: CFD simulations of the large-scale fire tests.

By means of the fluid dynamic analysis, lots of results related to fire situation were got, such as: temperature slices, radiative and convective boundaries, visibility maps, heat fluxes, smoke transport or concentrations of dangerous substances. Some of these magnitudes will have been used in structural analysis and others in advanced egress analysis.

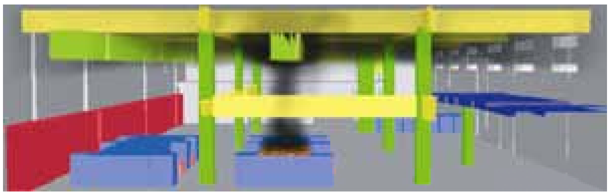

Figure 3: Smoke transport inside of the enclosure.

In the structural analysis, all cross-sections of columns and beams of the structure were characterized, and through a element finite method, the evolution of the temperature inside the structural elements was calculated. Then, resistance calculation was made including the previous temperature evolution and the material properties´ lost.

With structural study of isolated elements and sub-structures, the critical temperatures and failure modes of elements could have been calculated, in case natural fire and ISO fire.

On the other hand, the project was completed with the study of advanced egress analysis for the most critical fire scenario. As it is said before, the results got in the fluid dynamic analysis were introduced in it. Moreover, population was estimated inside the office distinguishing general public from workers, who know the geometry of the enclosure. In the same way, physiological and psychological features were defined for each person, taking into account the age and the genus. Among these characteristics, they deserve to be emphasized the following ones: height, weight, breadth capacity, orientation, extreme behaviour, impatience…

Only in this way, it could be possible to notice how the people evacuate the enclosure through emergency exits and if any queues were produced.

Finally, the level of fire safety provided by the water mist system was validated and verified for the people safety and structural stability, avoiding the application of prescriptive rules of the standard. However, the level of safety was the same, putting in practise a performance based solution.

In conclusion, the majority of cast-iron structure does not require any additional protection, demonstrating that heritage can survive to fire scenarios without jeopardizing its beauty and splendour.

Methodology, data, numerical models, tests, and results will be explained in detail in a full paper and oral presentation supported by powerpoint and video format.

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MONITORING OF HISTORIC SURFACES IN HIGH DEFINITION

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1. Introduction

Two of the problems with recording historic interiors are the time and space within which you have to work. The time factor is introduced by the use of the building, whether it is a service in a working church or restoration that is about to begin and needs recording immediately. Space to maneuver may seem not to be a problem in cathedrals but access to the objects is often restricted by the furnishings within the building.

Reaching Recording Standards (RRS) Project, Department of Building Preservation Sciences at the University of Bamberg, Germany, was borne out of these problems. A remotely controlled multipurpose platform has been developed to enable high definition 2D and 3D imaging up to a height of 25 m. This platform we believe is the smallest unit possible to go to such a height for high definition recording.

This patent pending project is based on a former EC funded project. This Research Project was carried out in cooperation with the University of Erlangen-Nuremberg, Chair of Engineering Design, Germany.

2. Technology

One of the overriding principals of this project was to incorporate any and all devices that have been developed, in other fields of expertise that would match our needs. The project was cooperation between two universities. In the project the world's smallest mini crane (Furukawa Co Ltd, Japan / model UNIC 094, Figure 1) was adapted with a newly designed 25 m boom (Figure 2). A remote controlled 3D- head from the Film industry (MovieTech Munich, Germany- ABC Remote head PeleXL) allows the use of a high definition digital camera with an adaptation which enables a professional flash system to be attached. This light produces consistent colour balanced images for monitoring. Due to its high payload of 30 kg, the multipurpose platform can also be used with further recording devices, such as a 3D Laser scanner or an IR Thermography camera increasing the data spectra. A newly constructed end piece for the connection of the remote head to the 25 m boom can be attached in two positions to allow not only the rotation of 360˚ but is now able to be placed in a vertical position for recording floors and ceilings.

The usability and user friendliness were two main goals during the research project. The system should be small in dimensions and not exceed a certain mass weight. The dimensions of the unit to be small enough to go through standard sized doors and have the ability to be maneuvered within restricted interiors, it would also allow the unit to be transported in a standard van. The 25 m Aluminum boom is retracted in 8 elements, the steering is electrical but has the capability of a petrol engine if required, the important stabilization of the carrier is controlled by the built in safety system. This flexible unit can eliminate the use of scaffolding, which would be less cost effective. The RRS system would also be less intrusive for the historic environment, because it can be set up in less than an hour and therefore the can be done on a day by day basis.

Figure 1: The Unic Minicrane is the base for the RRS system. It is adapted with a newly designed 25 m boom. On the end of the boom a remote controlled 3D head can hold either the digital camera with two flash heads or other recording systems. The image shows the system while in construction, here up to 15 m without the strengthening guides and the head.

The boom can be moved on the base to ease access and maneuvering. Drawing: Lars Wittko, University of Erlangen.

For the recording of surfaces in historic buildings, the high resolution images give a true representation of all surface properties such as fine craquele, flaking and cracks. Choosing the highest resolution single shot camera on the market (Hasselblad H2D -39 Mp) we have the ability to produce extremely detailed images enabling damage assessment of the object remotely.

The 3D recording is produced by a high resolution scanner (Leica Scan station) enabling either comparison to the 2D images or to combine two data sets together for a virtual view.

With the digital high resolution camera it is possible to enlarge parts of the image and see all the surface damages, for instance, blistering and flaking of the paint layer.

3. Evaluation of the technology

Initial lab testing shows that the goals of the project can be fulfilled with this newly created system.

The true advantage of this apparatus is in its flexibility. Scaffolding is traditionally used as the best method to gain access to areas within monuments to record and monitor any damages. Hydraulic lifts, or cherry pickers, have also been used in larger areas but these can be extremely difficult to maneuver even in a large cathedral. This unique system is able to pass through a standard doorway, turn in relatively small areas and be ready for use quickly, thus not being a disruptive force within the historic environment. The use of the Minicrane systems is cost effective, over traditional scaffolding; this allows a higher monitoring frequency or monitoring of more objects.[1]

The professional digital camera systems allow high resolution digital images that are comparable to professional analogue images. The digital system has clear advantages in practical terms on location, colour control, image access and distribution.

4.Exploitation

Location tests will take place after the CE certification beginning 2009 on selected historic objects.

The historic locations provide different challenges for monitoring, such as stained glass windows, wall paintings and painted stone sculptures up to height of 25 m in restricted spaces.

The exploitation of the results and the practical application is carried out by a start-up SME, promoted by the Bavarian State Ministry of Sciences, Research and the Arts.

The new founded start up company beckett&beckett photography (www.beckettphotography.com) will provide the use of the RRS along with further recording services.

5. References

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Figure 2: Construction drawing of the new developed adaptation plate for the 25 m boom.

Figure 3: High resolution image of a medieval age wall painting (overpainted in the 19th century) in the St. Stephanus Chapel of Cologne Cathedral.

I-SSB TECHNIQUES TOWARDS PRESERVATION OF HISTORIC BUILDINGS

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I-SSB (Integrated Safe & Smart Built Concept) is a collaborative research project co-funded by the European Commission, under the 6th Framework Programme – Priority III – NMP4 (Nano-technologies and nano-sciences, knowledge-based multifunctional materials and new production processes and devices). It started in January 2007 with 4 years' duration.

The main goals of the I-SSB project are to elaborate a system of modular construction for smart buildings, based on steel skeletons with lightweight drywalls, that will meet special requirements related to dynamic loads, fire and flood security, faster and safer construction process, high acoustic comfort. The advantages of the system such as: high resistance to dynamic loads, meeting anti-seismic regulations, high fire resistance properties and reduction of the construction weight can contribute in a significant way to cultural heritage needs. The system can be an excellent solution to support a damaged construction of historical monuments and protect them in case of earthquake or fire. The innovative nano-materials for self-repair in drywall structures could be part of the emerging technologies that will be applied in the historical buildings. Important aspect is a monitoring system based on non destructive techniques that can benefit to the monitoring of the historical building during natural hazards. Developed within the project plasterboard with improved properties for indoor air-quality and self cleaning can be adopted to better preservation of historical buildings. The culture of Europe is based on the culture of ancient Greece, the Roman Empire and people living before the Empire in the Mediterranean region as Persian, Egyptian, Mesopotamian and other. It is good to remember that Mediterranean region is especially subjected to seismic load and fire and must be exceptionally protected against such catastrophic events. In 2007 in the region more than 9000 earthquakes have been registered by European Mediterranean Seismological Centre.

The potential of the I-SSB techniques on the cultural heritage market can be observed by so far renovation of historical buildings. Good example of application of the drywall system in the cultural heritage area, was the comprehensive renewal of one of the most famous theatres – La Scala in Milan. These works have shown that plasterboard can find it application in many different cases. During the restoration 3500 m^2 of plasterboards were used. Another restoration works, where fire resistance plasterboards were used is Teatro la Fenice in Venezia and Teatro Giovanni Mestica. Recent advances in nanotechnologies opens up the possibility of creating gypsum based plasterboard products that are lighter, stronger, with self-healing properties. Nano-materials concepts form biomedicine and from advanced electronics materials processes are suitable for engineering into high-added value construction materials. These concepts will be used in the I-SSB project, and the final product will surely be a great solution in restoration works.

Apart from the idea of construction weight reduction by using lightweight drywall partitions I-SSB will also produce a system that will actively reduce vibrations arising during an earthquake. Such a system could be installed in an existing historical monument and protect it in the situation of earthquake. In the process of designing earthquake-resistant building reinforcements it is necessary to assume different types of damages that could be caused by the earthquake. The structure must be design for a frequent event, when the damage limitation requirement must be met and for a rare event, when the collapse has to be prevented. During project researches different types of vibration control systems have been considered: passive, semi-active and active vibration control systems. Although vibration reduction is better using active reduction system, semi-active and passive systems are much easier and cheaper to implement in mass production of construction materials, thus these systems will be used to control the deformation during an earthquake. To reduce vibrations that are transferred from the shaking ground, magnetorheological (MR) fluids will be used. MR fluids are liquid smart materials, the consistency of which can be controlled by a magnetic field within some milliseconds. They basically consist of small magnetically polarisable particles that are dispersed in a carrier liquid and stabilized by chemical additives. If a magnetic field is applied, the particles will attract each other and connect to chains. This change of viscosity is used to design a damper with adjustable stiffness to control important lifelines like switchgear cabinets in the house. Depending on the size of the building, there could hundreds of dampers attached to the construction. There is a building in Japan that uses such dampers to eliminate vibration-Japan's National Museum of Emerging Science and Innovation.

Another I-SSB purpose, that will help to preserve Cultural Heritage goods, is the idea of improving materials as gypsum, mortar, cement in respect of its refractory and self-repairing properties. To achieve these purposes superplasticizers, rock enhanced fireproof materials and alkali-activated magnesia cements will be used. These materials will be used during renovation of a historical monument and when an earthquake appears, they will repair themselves. What is more they will be much more resistant to fire, because of modifying theirs structure. It is aimed to develop and characterize gypsum/cement based materials as well as advanced coating both with improved fire-safety properties, as for instance reduced flame spread, low shrinkage behaviour under fire conditions, increased fire endurance due to high mechanical stability etc.

Objective of the project is to develop plasterboards with improved properties for indoor air-quality and self-cleaning. Plasterboard will be provided with modified photo TiO_2 powders that degrade NO_X under the influence of visible light. First method of the application will be with a use of inorganic transparent coating. The second method is a mixing-in of the powders, which are from nano to micro scale, in the fresh plaster. Plasterboards with photo catalytic powders will improve the indoor air quality substantially, and will also have a self-cleaning ability.

PROTECTION AND CONSERVATION OF CULTURAL ARTEFACTS BY IRRADIATION. CROATIAN EXPERIENCE

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Cultural artefacts of organic origin are susceptible to biological destruction by the action of bacteria, fungi, molds, yeasts, insects, algae, etc. This destruction is a pronounced problem in the conservation and protection of objects made of wood, paper, leather, textiles, etc.

Traditional method of inactivation of harmful organisms has been the treatment of objects with poisonous gases, known as fumigation. However, the most extensively used gases methyl bromide and ethylene oxide have either been phased out or their use has been limited. A successful substitute of fumigation gaining significance is disinfestations and decontamination by treatment with ionizing radiation. Biocidal effect of radiation is based on its ability to cause chemical damage of DNA, the genetic material of all biological contaminants, no matter in which form of their life cycle they are irradiated. Infested objects are exposed to highly penetrating high energy photons from radioactive 60Co in an irradiation chamber. Low doses of radiation applied for inactivation of contaminating organisms do not cause significant chemical changes of treated materials. The most important parameter of radiation method is the dose of irradiation. It depends on the scope of irradiation, initial level of contamination and radiosensitivity of contaminating flora. Radiosensitivity is determined as a D10, the dose which reduces the level of contaminants by an order of magnitude. For insect control 0.5 - 1 kGy, for fungi control 2 - 3 kGy and for microbial decontamination 2 - 10 kGy are used.

The method of irradiation for the protection of cultural heritage objects became widely public in 1978 upon the presentation of gamma irradiation of Ramses II mummy, performed by the Nucleart Laboratory, Grenoble, France, during the 5th Triennial Meeting of the International Council of Museums (ICOM), which took place in Zagreb. The activities of the Nuclear Laboratory Grenoble, as well as of the Conservation Radiation Facility, Museum of Central Bohemia, Roztoky, Praha, Czech Republic, were leading the way in the application of irradiation for the protection of cultural objects for 30 years.

Ruđer Bošković Institute (RBI) in Zagreb also owns a suitable multipurpose panoramic ^{60}Co irradiation facility operated by its Radiation Chemistry and Dosimetry Laboratory (RCDL) (Figure 1). RCDL is covering basic and applied research in the fields of radiation chemistry, radiation protection, radiation dosimetry and radiation processing. After significantly upgrading of the gamma source to 50kCi of 60Co in 1983, it became possible to perform research as well as decontamination and disinfestation of various materials.[1]

During the past twenty-five years we took an active part in the protection and conservation of cultural heritage objects by irradiation. The participation of and cooperation with the Croatian Conservation Institute (CCI), Department of Restoration, Academy of Fine Arts, University of Zagreb, and other interested parties were essential for those activities. Long lasting cooperation between the CCI and several laboratories of the RBI resulted in the formal Cooperation Agreement, the Memorandum of Understanding between the Ministry of Science and Ministry of Culture.

Figure 1: ^{60}Co irradiation facility of the Radiation Chemistry and Dosimetry Laboratory, Ruđer Bošković Institute.

Joint activities of CCI and RCDL were devoted to preventive and curative treatments of a number of polychromic sculptures, altars and other wooden objects. Significant number of those sculptures and objects were displaced and damaged during the Patriotic War in Croatia (1991-1995).[2] After irradiation at the RBI irradiation facility the objects underwent immediate restoration or were stored at the storage room for polychromic sculptures of CCI in Ludbreg, prior to the further conservation and restoration treatment.

An example of an emergency treatment was joint action of the salvation of nine polychromic wooden sculptures found buried for 10 years in the crypt of the destroyed St. Mary church in Gora, near Petrinja (Figure 2). The sculptures were processed by cleaning, drying, climate stabilisation and repeated irradiation for decontamination and disinsection purposes. Identification of contaminating microflora, moulds and bacteria was performed in the process.[3] Some of the sculptures are still under restoration.

Irradiation of all sculptures treated in cooperation with the CCI was recorded in the treatment evidence of the CCI database (BREUH).

Our activities in radiation treatment were acknowledged at several exhibitions of restored polychromic sculptures. The last one was held in the Town Museum and Gallery, Jastrebarsko in 2007, on the occasion of the completion of the conservation-restoration work performed on the altar of Our Lady of Loretto in the parish church of St. George in Plešivica.

In the RCDL irradiation facility, during the last 25 years, more than 5000 wooden sculptures, parts of altars, pieces of furniture, musical instruments and other wooden, paper, textile and leather items were treated.

The dissemination of knowledge and education on the radiation method are continuously performed at all levels, both at professional seminars, such as Microbial Destruction of Cultural Monuments held in 2000 in Zagreb, and lecturing at the Bachelors level course with a demonstration at our irradiation facility for 10 years since the beginnings of the Department of Restoration of the Academy of Fine Arts. We are also taking part in the organization of doctoral studies in restoration at the University of Dubrovnik. We continue to offer consulting services to all interested parties.

At the international level we are currently participating in the cooperation through the International Atomic Energy Agency (IAEA) regional project: RER/1/006: Nuclear Techniques for the Protection of Cultural Heritage Artefacts in the Mediterranean Region.

At the training course in Grenoble in 2007 under that project (Training Course on the use of Gamma Rays for the Preservation of Cultural Heritage and Disinfection of Art Objects), the case study presentation of the Croatian experience received a pronounced attention.

Presently Croatia is taking part as an alternate leading country to Romania in launching a new regional project for the period 2009 to 2011: NuclearTechniques for Characterisation and Preservation of Cultural Heritage Artefacts in Europe Region.

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Figure 2: The church of St. Mary, Gora near Petrinja and the polychromic wooden sculptures.

USING DIGITAL MODELS TO MAKE EXACT 3D LAYOUTS OF INTERESTING CULTURAL HERITAGE PLACES

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Abstract
The conservative inertia of the cultural heritage sector causes that the graphical information handled by their professionals continues being bidimensional (fundamentally elevations and cross-sections). However, the increasing demand of detailing meticulously the complexity of the relevant places, with increasing reliability, implies that it is necessary to obtain accurate data and managing three-dimensional information with novel equipment and software. Before the change this supposes becomes obligatory, the SMEs on which the sector is based all over Europe must carry out innovative actions in conjunction with the R&D organizations.

Therefore a new process is presented, improving exactitude, fidelity and time with regards to the traditional methodology for getting planimetries used to guide the architectural interventions, which significantly increases the competitiveness of the companies that execute these works. To facilitate it, special software has been developed, compatible with *AutoCad*, that allows the automatic and manual delineation on digital models built on the geometric and colour information given by laser scanners.

These models allow the cataloguing and diffusion of the original place to be achieved, and facilitate conservation and restoration works as simple functional variants. On the other hand, the conventional processes require watertight specific operations for each one of these tasks.

1. Introduction
In practice, before 2003, laser scanners for long range 3D measurement were tools reserved to the research centres. However, at present, they constitute an alternative and, in any case, a complement to the classic photogrammetric and topographical methods.[1,2,3]

The optimised equipment for architecture and heritage applications is based on the 'time of flight' technology. Depending on the predetermined resolution on a target spot, by means of an automatic sweeping of the place to study with a laser beam, the geometric coordinates (X, Y, Z) of each point are obtained with respect to the position of the scanner.[4] Optionally, if the equipment allows it, the colour coordinates (R, G, B) of these points can also be obtained by means of the association between the Cartesian coordinates and the photographs corresponding to the measurement perspective.[5] These are taken with a digital camera associated to the scanner (either internally or externally).

The alignment and registration of the resulting point clouds, lead to a global one. It faithfully describes the reality not only in shape, but also dimensionally. This does not happen with the colour data, because it varies depending on the fixed geometrical resolution, and, moreover, on the conditions of the environmental illumination, that could be very variable outdoors.[6,7] The digitalisation of five representative locations[i] has demonstrated that these problems are diminished combining an optimal exposure of the scanner camera with a suitable geometrical resolution.

This leads to the generation of three-dimensional digital models of great utility in the cataloguing, conservation, restoration and diffusion of the cultural heritage.[8,9] Concretely, once oriented and referenced with respect to a zero-level in height, they will serve as a basis for the accomplishment of the layouts derived from the surveying of an interesting site.[10]

For this application the point cloud with the position and colour coordinates is not enough. A polygonal model have to be used, which is a triangle mesh that keeps the same amount of information on the object and better defines its geometrical features. Furthermore, the triangulation allows the easiest manipulation from the mathematical point of view, with a smaller computational processing effort.[11]

In consequence, in order to obtain the exact three-dimensional plans, two computer tools have to be used:[12,13]

1. A computer program to make any type of dimensional characterization (distances, angles, radios, geometrical approaches, areas and volumes), together with sections in any plane with respect to the selected reference system.[14]

2. A particular software, developed to permit the automatic extraction of the contours of all the structural elements of the site through curvature analysis, based on the studies of Decarlo et al., Rusinkiewicz and Ohtake et al..[15-17] The layouts will be completed manually by means of the direct delineation on the polygonal model, which displays the average colour of the three points that compose each triangle of the mesh. This information allows a trustworthy definition of the lines and edges to be drawn.

For the operations indicated on point (1), different free use software's could be downloaded by Internet from the web pages of the market leaders of solutions for processing 3D measured data.

Regarding point 2, the manual completion has to be diminished. It is obvious that the time dedicated to the edition of the planimetries with that software should be less in comparison with the typical equivalent fully manual delineation, that does not describe properly the real geometry.

The results of the new proposed methodology, and the related technology, to perform a computer assisted delineation of interesting cultural places using 3D digital models are detailed in the present paper, and, especially the software created to automate the process as much as possible. The derived conclusions, as opposed to the methods still in use, are also described.

2. Experimental
The traditional procedure to make a fast and low cost surveying is carried out in two steps. The fieldwork comes first, and mainly consists in obtaining the individual coordinates of each one of the selected control points that are considered of interest under experienced people criteria. Referencing a few hundreds of points takes several weeks of work, which is a reason why it is not applied to the small details present in almost all the sites of cultural interest. In order to leverage this drawback, complementary, different photos of the place in a frontal point of view are taken. As second phase, already in office, their perspective is corrected by computer and the measured points are joined properly to each other forming guidelines onto which the photos are fitted. The outcome is a centimetre accurate 2D template to manually carry out the delineation. However, the need to detail the reality itself, that is, in three dimensions, has given rise to alternative techniques whose cost-effectiveness must be proved to guarantee their usability.

The photogrammetry is a very widespread procedure to obtain three-dimensional digital models upon a group of photographs, right to delineation purposes. There are many references in relation to this technique, but, in general, it is worth to point out that is primary oriented to solve geometrically well defined shapes (planes, cones, cylinders, etc.), whereas laser scanners are mostly used for complex ones.[18]

The majority of the interesting places have very complicated geometries. By this reason, the cultural heritage is potentially an important field to extend the use of laser scanners. The amount of captured information is a thousand times greater than the general well-known techniques. Also the working time in field is reduced radically keeping a suitable exactitude (mm) within a range of hundreds of meters for data acquisition. Besides, the basic aspects relative to the use of conventional measurement equipment (total stations or laser distance meters), are conserved:[19] physical contact with the object to study is not required; the adaptation to the local orography is allowed; and it is possible to georreference the site.

First of all, it is thought about making the drawing in three dimensions using only the information that directly provides the scanner. There are commercial plug-ins that allow the manual delineation on the point clouds in the AutoCad environment, but proving anyone of them, certain basic difficulties are found: managing large volumes of data is not easy; a clear differentiation of the features to be drawn is not allowed when a big density of points is handled; and the complete automation of the process is not viable.

Because the low quality of the point clouds colour, an alternative consists of taking photographs of the site with a separate camera. This way, the camera could be freely chosen and the images could be captured with the best perspective angle and lightning conditions. Therefore a direct relation between the 3D information and the respective photographs would be made. The tools available in the market for this operation proceed both on point clouds or meshes, but are not suitable unless the obtained images are orthophotos, or the camera whereupon they have been taken presents is calibrated. This photographic superposition would mean a huge advantage for the delineation, but currently it implies a so elevated temporary cost that is not effective in practice.

Hence it is needed to give rise to a digital model that truthfully describes the original place to be utilized to make rigorous layouts. The aspects which have to be controlled in order to obtain such kinds of models, are:

The exposure of the camera associated to the scanner in function of the environmental illumination conditions, if the equipment that does not do it automatically.[ii] If the sun affects the optics directly, shading its components is essential.

- The geometrical resolution in the acquisition of points. A value between 0.01 m and 0.015 m is strongly recommended. Below this value the size of the corresponding file becomes unmanageable.

- Considering these two premises, the data acquired by the scanner are exported to a 3D data processing software, where a coloured triangle mesh is built. Each triangle will display the average tonality of the coordinates (R, G, B) in its vertices (Fig. 1).

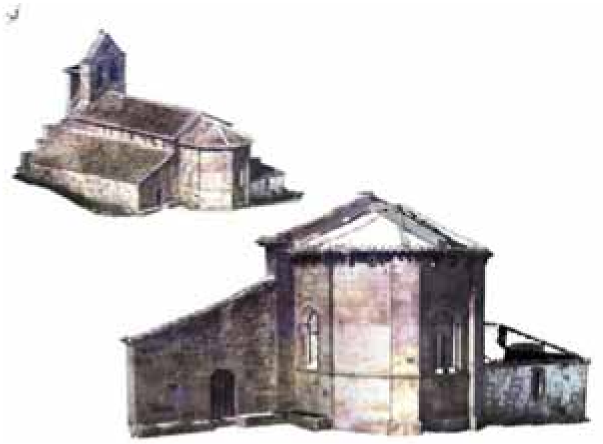

Figure 1: Left upper part: point cloud of the outside of the romanesque church of Valberzoso (Palencia); Right lower part: detail of the mesh derived from that point cloud corresponding to the apse.

Two tools are detailed next in order to obtain the exact three-dimensional planimetries of a place through digital models.

Utility of the applications of 3D data processing

The application used just to create the mesh has still the interest of referencing and bearing the digital model in the space. Also it is useful for making any type of calculation and dimensional characterization (distances, angles, radios, geometrical approaches, areas and volumes), along with sections in any plane with respect to the preferred system of reference (Fig. 2). The colour information is not necessary to do these operations.

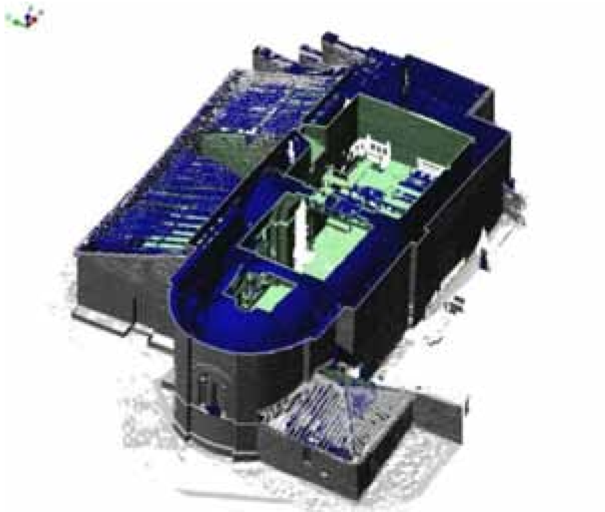

Figure 2: Cross-section of the digital model of the church of Valberzoso (Palencia) using PolyWorks v10.

The definition of rows and the outlining of all structural elements necessary to come to the reading of walls and decoration on a layout are not feasible in such applications at the required level of detail. From a practical point of view, its utility resides in the automatically extraction of the lines that delimit and define the entire digital model. The time inverted in the process is long and the result is incomplete when treating with so complex elements. At the same time, the number of extracted lines is so high that their edition is not practicable.

Necessity of the development of complementary software for 3D delineation

Software that allows the exact and automatically detection of the lines that comprise the graphical representation of interesting historical-artistic sites is required. Therefore the edition of the layouts with respect to the conventional delineation can be improved substantially. Besides, this software has to be able to achieve the manual delineation when the direct extraction has not been possible or is incomplete.

Since well referenced algorithms and free use programming libraries have been used to this aim, the model is turned into the format PLY within the application used for meshing and so on. This format, created by the University of Stanford (http://graphics.stanford.edu/data/3Dscanrep/), is standardized and optimised from the computational point of view (it is transcribed as a binary file).

The software code has been developed in Microsoft Visual C++ 2005, and conserves not only the geometrical and colour information of the digital model, but also the referencing and the spatial orientation previously established. Also lets the interactive manipulation of this model: horizontal and vertical displacement, rotation and zoom, as well as orthographic views according to the coordinate system.

The automatic detection of the lines that give rise to the three-dimensional planimetry is based on the calculation of curvature gradients. Taking in consideration the work of Decarlo el al.,[15] as well as the algorithms of Rusinkiewicz,[16] this is exclusively done by means of the geometric information of the model. The triangles are indexed and travelled across analysing its vicinity. Using the formulae of Ohtake, Belyaev and Seidel,[17] the two possibilities required for an exhaustive delineation are workable: (1) crests calculation, that define the most external part of a contour (profiles) and aid to detail the model; (2) valleys calculation, that define the most internal part (joints) and aid to specify the volume of the model. Crest and valleys are displayed with different colours to facilitate their interpretation. In both cases, a threshold can be selected to extract those lines that the architect considers more representative (Fig. 3).

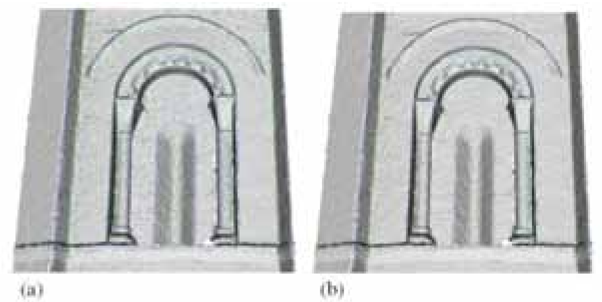

Figure 3: Threshold choice for the extraction of crests (blue) and valleys (green) to make the East elevation of the church of Valberzoso (Palencia). (a): Low threshold; (b): High threshold.

For all the described operations, the 'trimesh2' C++ library has been used, which is a set of utilities for input, output, and basic manipulation of 3D triangle meshes, whose author is Rusinkiewicz again (http://www.cs.princeton.edu/gfx/proj/trimesh2/). That is distributed under General Public License (GNU) and provided jointly with the 'miniball' code; the 'freeglut' library (an open source GLUT - the OpenGL Utility Toolkit - replacement); and the GLUI user interface library, that sits on top of OpenGL, hence is portable to many different systems.

3. Results

The described automated extraction leads to a set of polylines according to the geometry, the dimensions, the orientation and the reference level of the original place. They all will be exported to DXF format, native of AutoCad and the most widespread in the architectural delineation. The crests will be stored in a DXF file splitted into two layers: the crest extraction itself and the level taken as reference for the vertical of the place. The case of the valleys is analogous, and their reference level is equivalent. This direct tracing of valleys and crests, slightly retouched, is already suitable to present the plans that integrate a project of intervention to an Architects' College, which is enough to justify its utility.

When the automatic extraction of contours does not offer the expected results, it becomes necessary to draw manually onto the model, which is interactively manipulated to visually accentuate the details that are needed in order to finish the delineation. For this reason, these possibilities are considered: the variation of the lighting to display the model (type and direction); its curvature mapping; and its colour information. It has to be emphasized the utilization of the colour information of the mesh, so much for usefulness, as for its innovative nature (Fig. 4).

Figure 4: Manual completion of the delineation using the intrinsic colour of the mesh corresponding to the church of Valberzoso (Palencia).

Consequently, new polylines will be created directly on the model, also exportable to DXF together to the same referencing than the crests and the valleys (Fig. 5). Both automatically and manual delineation could be saved and in the developed software to be reused in so many working sessions as necessary.

Hence, complete 3D layouts of the location are carried out, whose 2D ones from any position and direction will be immediate (not only of the four basic elevations). This supposes a great added value to the conventional procedures in a smaller time. The table 1 summarizes the orders of magnitude obtained after the validation of the proposed methodology in the five digitised locations.

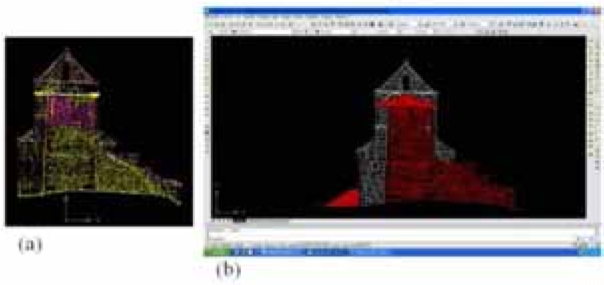

Figure 5: Visualization in AutoCad of the automatic and manual delineation with the developed software, corresponding to the West elevation of the church of Valberzoso (Palencia); (a): Direct loading; (b): Final result after editing.

Table 1: Comparative between the conventional and the new procedure.

	Work in Field		Delineation	
	No. of Points	Time (Weeks)	Accuracy	Time[iii] (Weeks)
Conventional Methodology	Hundreds	1.5	cm	5.0
New Methodology	Millions	0.4	mm	3.8

Obviously, the greater is the number of triangles of which the models are made up, the greater is their loading time into a computer. In addition, its manipulation slows down more and more. At the moment, the software has been tested in a typical PC,[iv] and no incidences occurred when loading the meshes and editing of lines on them. Thus, the use of workstations to operate with the developed software is not mandatory.

4. Conclusions

The layouts built upon the data derived from the use of conventional equipment continues being utilized in the documentation and the elaboration of cultural heritage intervention projects, but are not highly accurate and display only bidimensional information. However, the use of laser scanners for surveying the interesting places leads to an amount of captured information about thousands of times higher with respect to that captured by conventional equipment. All at once, the fieldwork time is reduced around a 75%.

A millimetre accurate three dimensional digital model that faithfully describes the site is obtained. The associated planimetries could be made upon this model. The delineation that it implies has to gather with three basic aspects: marks and measurements; longitudinal and transversal cross-sections; and the elements to reflect clearly outlined.

The operations associated to the first two aspects can be executed in a free use 3D data processing application. The last one requires the development of specific software that allows to the manipulation of the geometric and chromatic information linked to the digital model to be carried out. This software runs on common PCs and has two complementary ways of operation: automatic, for direct extraction of the necessary lines (crests and valleys); and manual, for completing or better defining that extraction. Using these procedures, different AutoCad files are generated, and the complete layouts are obtained with a saving of time of around a 25% with respect to the conventional process.

Hence, a new methodology emerges, which at the same time is applicable to digital models created with alternative techniques (such us photogrammetry). Accordingly, a wide audience for the presented approach is guaranteed.

As added value, the digital model generated with the new methodology could be used in further tasks such as: multimedia editions; to put it into context in a computer scenario; and recreate of the history of the object studied. It is even suitable for building physical copies directly coloured, in different scales, through 3D printing techniques.

5. Acknowledgement

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7. Endnotes

i. By chronological order (2005-2007): church of Santiago, at Cezura (Palencia); church of Sta. Mª. la Real, at Valberzoso (Palencia); hermitage of Sta. Cecilia, at Vallespinoso de Aguilar (Palencia); church of Ntra. Sra. de la Asunción, at S. Martín del Rojo (Burgos); church of S. Miguel Arcángel, at S. Miguel de Cornezuelo (Burgos).

ii. This is the case of the LEICA HDS-3000 equipment.

iii. Including the data manipulation to obtain the template and the mesh, respectively.

iv. Pentium IV microprocessor; 1GB of RAM; and 128MB DDR graphical board memory.

ADVANCES IN MATERIALS RESEARCH TO ASSURE COMPATIBILITY IN PROTECTION OF MONUMENTS: FROM RESEARCH TO DEVELOPMENT AND APPLICATION

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1. Abstract

At the Laboratory of Materials Science and Engineering of the National Technical University of Athens, several syntheses of restoration mortars were performed according to the reverse engineering process through the evaluation of the characteristics and production technology of the historic ones. The methodology for the production of restoration mortars is articulated by various steps, aiming to determine the criteria for evaluation and their relation to certain materials and characteristics of the mortars. The methodology includes characterization and selection of raw materials and the preparation of various syntheses with different ratios of binder / aggregates / additives and gradations. The technical characteristics of the pastes were measured after optimization. The various mortars were evaluated during setting and hardening using thermal analysis (DTA-TG), porosimetric analysis and mechanical tests (compressive, flexural). The results indicate relation between the properties of the mortars and certain materials and technology of production. Moreover, multivariate statistics and especially Principal Component Analysis (PCA) is performed for classifying restoration mortars in separate groups, depending on their synthesis and physicochemical characteristics. Different syntheses of restoration mortars were studied using traditional techniques and materials such as binders (aerial and natural hydraulic lime), pozzolanic additives (natural and artificial pozzolanas) and aggregates (sand and crushed brick). The results give us a very useful and illustrative tool for understanding the correlation between mortar properties and raw materials and the manufacturing process.

Now that the research on the characteristics of the mortars and their correlation with certain materials, ratios between them and the production technology process has concluded, the implementation of in the industrial production of restoration mortars for the protection of Cultural Heritage is planned. Moreover a database from all the results obtained will be a critical tool for the strategic planning of more production activities.

2. Introduction

The performance of historic and restoration mortars have been studied comparatively to judge their longevity in relation to the other wall constituents as far as:

- the physico-mechanical and physico-chemical properties are concerned. They control the main function of the mortar - to bind the building units together and to provide a durable masonry. The adhesion between building units and mortar in all these complex systems can be very different, depending on the interaction between a binder and load bearing units under various operating conditions, regarding the environment and the structure[1,2] It allows the structure to absorb energy without affecting its material properties irreversibly, which is not encountered in most modern masonry or concrete structures.[3] Modern mortars and adhesives are less porous than building stones and bricks, with higher values of hardness, mechanical resistance and thermal expansion coefficient attributing to them a performance rather incompatible to the original materials.[4]

- the microstructural properties and the capillary systems are concerned. They control the behavior of the masonry to the percolation and evaporation of the salt solutions within it.[5] The very dense pore structure, very small pore radii and the low porosity of the modern cement restoration mortars preferentially induce the percolation of the salt solutions to the original, more porous material of wider pore structures towards larger pore radii, building units, triggering their intense corrosion by salt decay.[6]

3. Characterization and evaluation of historic composites[3,7-9]

The following properties were evaluated: mechanical properties, physical properties (gradation, microstructural characteristics), mineralogical and chemical characteristics (X-ray diffraction analysis, optical microscopy, scanning electron microscopy (SEM) assisted by energy dispersive analysis (EDX), spectroscopy, e.g FT-IR and, when possible, Nuclear Magnetic Resonance when possible (NMR), differential thermal analysis (DTA), and thermogravimetry (TG), determination of the total soluble salts). Tables 1 and 2 report the data obtained from the tests performed, as mentioned above, allowing the identification of physico-chemical and mechanical characteristics of the most typical mortars encountered in ancient structures.

4. Criteria and Methodology for the selection of raw materials and the production of restoration mortar[10-13]

The selection of raw materials is the determining step in the development of restoration mortars with the task to meet the criteria arising from the knowledge of the historic composites.

The raw materials that are more common to use for the production process are:
- Binding materials: lime putty, hydraulic lime and cement. - Aggregate materials: sand of silicate composition and crushed tile.
- Additive materials: natural and artificial pozzolanic materials.

The techniques and the tests of investigation employed for the physico-chemical characterization of the raw materials are the following:
- Thermal analysis (Differential Thermal along with - Thermogravimetric Analysis)
- X-Ray Difraction (XRD)
- X-Ray Fluoresence (XRF)
- Porosimetric analysis
- Pozzolanicity test
- Determination of soluble silica (Reactive silica) (EN 196-2)
- Granulometric analysis (ISO 565)
- Specific weight measurement

The selection of the raw materials results from the research of the locally available materials in relation to the technical characteristics and the production technology of the materials.

Table 1. Chemical characteristics of historic mortars as deriving from thermo gravimetric analysis.

Mortar type	Physically bound water (%)	Structurally bound water (%)	CO_2%	CO_2/structurally bound water
Lime mortars	<1	<3	>32	10, 7.5 – 10
Lime mortars with unaltered portlandite	>1	4 – 12	18 – 34	1.5 – 9
Hydraulic lime mortars	>1	3.5 – 6.5	24 – 34	4.5 – 9.5
Natural pozzolanic mortars	4.5 – 5.5	5 – 14	12 – 20	<3
Artificial pozzolanic mortars	1 – 4	3.5 – 8.5	22 – 29, 10 – 19	3 – 6

Table 2. Physico – mechanical characteristics of historic mortars.

Mortar type	Cum. Volume (mm^3/g)	Bulk Density (g/cm^3)	Average Pore Radius (μm)	Specific Surface Area (m^2/g)	Total Porosity (%)	Tensile Strength (MPa)	Binder: Aggreg. ratio
Lime mortars	170-230	1.5-1.8	0.8-3.3	1.3-3.3	30-45	<0.35	1:4-1:1
Lime mortars with unaltered Portland.	105-241	1.8-1.9	0.03-6.5	1.7-10.6	20-43	0.6-0.7	1:2-1:1
Hydraulic lime mortars	90-230	1.7-2.1	0.1-3.5	2.5-13.5	18-40	0.35-0.55	1:4-1:1
Natural pozzol. Mortars	160-265	1.6-1.9	0.1-1.5	3-14	30-42	>0.60	1:5-1:1
Artificial pozzol. mortars	170-280	1.5-1.9	0.1-0.8	3.5-9	30-40	>0.55	1:3

5. Criteria and Procedure for the Evaluation of restoration mortars[10-13]

The optimization of the mortar pastes on the base of the water requirement and the proper workability should be carried out. The reproducibility of the preparation process should be evaluated by tests in order to estimate the technical characteristics of the fresh mortars. The optimum workmanship should be decided on the basis of a low water request, a good workability of the mixture, an appropriate cohesion of the paste and an efficient applicability in a pilot masonry structure.

For the measurement of the technical characteristics of the optimum paste, in order to have an appropriate reproducibility, an International Standard should be used and the following tests should be performed:
- Determination of air content
- Determination of bulk density
- Determination of consistence
- Determination of retained water
- Determination of volume change upon setting

The pastes syntheses produced after the above optimization should be moulded and stored under controlled conditions, appropriate for the setting and hardening of the mortars.

In order to evaluate the various syntheses during the setting and hardening of the mortars, the following measurements should be performed:
- Differential Thermal Analysis - Thermogravimetry (DTA - TG) in order to estimate the kinetics of mortars hardening through the study of carbonation of the binder and the development of the hydraulic phases,
- Porosimetry in order to estimate the change of the microstructure during hardening, and
- Mechanical strength tests in order to estimate the strength of the mortar developed during hardening.

It is proved that historic masonries could be disturbed by the differential transport behavior of the material components and deteriorated by the consequently developed tensions at the interfaces. The compatibility of various repair mortars with the porous building materials must be also evaluated by their performance in transport and evaporation, in terms of ionic/moisture/vapor transport, which is shown in relation to their microstructure. The acceptability limits, defined by the original materials, indicate the microstructural requirements that repair mortars have to fulfill, in order to be compatible and to extend the longevity of the masonry structures. All the different categories of restoration mortars must be evaluated against these requirements. Microstructural parameters during hardening are determined by intrusion mercury porosimetry and transport phenomena are studied (in terms of vapor/moisture permeability), in order to assess the compatibility of the various cement-based systems with the porous building materials of the original structures.

It is proved that the relationships between transport phenomena and microstructure, as well as transport phenomena and long-term durability control the behavior of the stones and respectively the behavior of the masonries exposed to weathering process. Total porosity and pore size distribution effect transport phenomena coefficients and patterns such as diffusion coefficient, water absorption coefficient and water/vapor permeability. Monuments act as pilots of long term durability assessment and evaluation. The main requirement for long term durability for complex systems like masonry of sandstones with mortars as bearing elements is the compatibility of the microstructure, so that the transport phenomena will proceed as homogeneously as possible. The results from microstructure studies in parallel with the results from the non-destructive techniques (IR-Thermography)[14] prove the compatible to the historic ones restoration mortars.

6. Conclusions

A principal component analysis can be performed gathering all the data from the measurements performed, in order to find out the relation between the special characteristics and the materials used for the production of the mortars. These results can be used for the industrial production of restoration mortars. Furthermore, the database with the results can be expanded in order to be verified, or to test new materials used for restoration.

Finally, the Reverse Engineering Methodology is the proper one for the production of compatible restoration mortars

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THE EC-PHAROS PROJECT: A SUCCESSFUL TRANSFER OF KNOWLEDGE FOR THE PROTECTION OF STONE LIGHTHOUSES

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1. Abstract

Old stone Lighthouses are unique monuments of the industrial heritage, which testify the history of navigation and technological evolution of European civilization. They are the most exposed in the corroding marine environment and their materials are destroyed because of the synergy of time and sea. They belong to the National Lighthouse Services which are responsible for their maintenance. Nowadays the use of the Global Positioning system in determining naval position has depreciated the functional role of Lighthouses and they are abandoned. Therefore, it is very possible that the old Lighthouses and their myths become forgotten.

In the frame of EC-PHAROS Project a net of activities resulted in concrete deliverables coming from original research work.
- The recitation and high lightening of the values involved in old Lighthouses.
- The systematic record and diagnosis of the damages.
- The suggestion of process materials and techniques for repairing Lighthouses.
- Training of technicians of Lighthouse Services in cooperation with the Lighthouse Authorities.
- Organization of an exhibition entitled "Stone Lighthouses: from the past to the future".
- A pilot study of restoration and upgrading one Lighthouse, using a prototype. The aim was to protect Lighthouses and incorporate them properly in modern societies, to avoid ineffective repair, so as they continue enlightening human history.

2. Profile of EC-Pharos Project

Title: The EC-PHAROS PROJECT "Holistic strategy for the Preservation, Restoration and Integration in the life of the modern societies of Old European Masonry Lighthouses"

Project homepage: http://www.ec-pharos.net

Coordinator: Aristotle University of Thessaloniki, Dept of Civil Engineering, Prof. Ioanna Papayianni

Partners: Associazione Trames (Italy): Dr. Virginia Ravaioli, University of Lincoln (UK): Dr Belinda Colston, Frederick Institute of Technology (Cyprus): Dr George Konsantinou, Riksantikvaren (Norway): Kari Opsvik Vartdal

3. Objectives

- Development of a Holistic Strategy for the Preservation, Restoration and Integration in the life of the modern societies of Old European Masonry Lighthouses.
- Raising awareness and interest, enhancing preservation and exploitation activities and increase public access.
- Networking of consortium and management of the project.

4. Description of Activities

The website was set up in order to be an easy method of communication between partners and people who are interested in Lighthouses. The website presents a high visitability and remains to be one of the few websites dedicated to Lighthouses.

Through the scientific systematic analysis of the Lighthouses that were selected as the case studies of the Project presented (Greece: Lighthouse of Megalo Envolo, Norway: Lighthouse Utsira, Great Britain: Lighthouse Happisburg, Italy: Lighthouse Cervia and Rimini, Cyprus: Paphos Lighthouse), precious informative material regarding the history of the European Lighthouses, their role in navigation, the problems they confront today and social and literary aspects was selected.

During the EC-PHAROS project a holistic methodology was applied, for the study of old European Lighthouses considering them as monuments of industrial heritage. The study of all case studies started with a thorough documentation of their preservation state, with the creation of architectural designs and mapping of their pathology and basic structural elements. This stage was thought to be a most important one, since the proposals of restoration and rehabilitation of each case study were based on these data. It includes historic and architectural survey of the case studies, in situ measurements and diagnosis of the main pathology problems.

According to the results from the analysis of the structure of the case studies, a series of proposals were made regarding the restoration and rehabilitation of the lighthouses. These proposals were based on the compatibility of materials and methods of restoration applied to each case study. The basic principles of all proposals were the maintenance of the authentic physiognomy of each case study, as well as the integration of the surrounding area.

All results from the analysis of the case studies were put in practice into a data base, entitled: "Expert system for recording the pathology and the repair methods of structures of stone lighthouses". This study aims to create a practical tool for the localization of the different types of damage encountered in lighthouses and for the recognition of the relevant degradation processes.

Several activities regarding the dissemination of the methodology created during EC-PHAROS took place by the Greek and Norwegian Partners. Seminars were organized for schools and Lighthouse Authorities, while the internal participation of the partners in local meetings regarding the case studies and their surrounding area was significant.

The first International Conference on Historic Lighthouses was held in Cyprus (Pafos, Nicosia) 13-6-18 November 2007, entitled "European Lighthouses: Holistic strategy for the Preservation, Restoration and Integration in the life of the modern societies of Old European Masonry Lighthouses". The main purpose of the symposium was to present the most significant results of the Pharos-project as well as the presentation of the five pilot studies for the restoration and revitalization/new use of five lighthouses, one from each of the partners.

One of the most important activities during EC-PHAROS Project was the Organization of a movable exhibition in Thessaloniki (Depot C', harbor of Thessaloniki) during the period 13-26/10/2007. The Exhibition, entitled "European Lighthouses: from the past to the future" came to be a great success and was considered to be one of the most important cultural events of the town of Thessaloniki at that period. In the period of 15 days, 4500 people visited it, while many schools of all levels of education attended the educational programs that were organized. The exhibition was divided in 8 thematic units in which the evolution of lighthouses regarding their architectural, structural, technological characteristics, and the relation of lighthouses to art (literature, figurative arts, music) was analyzed.

The interaction of the subject of lighthouses with young people was great during the program. All partners came in conduct with young people and the results of this conduct were really enthusiastic, since lighthouses are always a theme that attracts teenagers. Also, the impact that lighthouses had on the media (newspapers, magazines, radio, TV channels) was very interesting. During the exhibition in Thessaloniki all newspapers were talking about the activities of EC-PHAROS Project and the importance of Lighthouses as historic landmarks.

5. Innovative topics resulting from EC-Pharos Project

Some innovative research regarding lighthouses took place during EC-PHAROS Project. In the international scientific world, for the first time the following was achieved:

1. Creation of the "Expert system for recording the pathology and the repair methods of structures of stone lighthouses".

2. Earthquake investigation of two case studies: The Lighthouse of Megalo Emvolo (Greek partner) and the Lighthouse of Pafos (Cypriot partner.) An extensive investigation was developed in order to evaluate the seismic response of the lighthouses during earthquake. For this purpose, numerical simulation of the lighthouse with finite elements and two-dimensional failure criteria were utilized to evaluate the numerical results.

6. Follow up Activities

Despite the end of EC-PHAROS, some activities regarding its achievements, still take place:

The study of the Lighthouse of Megalo Emvolo (Greek Partner) is already accepted by the Lighthouse Authority and the Ephorate of Contemporary Monuments of Central Macedonia to be realized. The funding will be made by the State.

The rehabilitation proposals of the Greek Lighthouse that were made during the program were all included in the general master plan entitled "Greek marine world", made by the Municipality of N. Michaniona for the rehabilitation of the seaside area between Aggelochori and Michaniona.

The exhibition entitled: "European Lighthouses: from the past to the future" (WP8) took place in many Greek cities.

The Seminar for the technicians and lighthouses keepers of the Greek Lighthouse Authority that was organized in Thessaloniki during the exhibition has been repeated at the Head Office of the Lighthouse Authority in Athens.

THE PRODUCTION OF POLYMER BASED AGGLOMERATES WITH RECOVERED SLATE POWDER

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Abstract

In this paper we report the results of our experiments concerning the preparation of composites made by slate powder and polymeric binders (acrylic and epoxy resins). The technique applied to make the products, in particular tiles, is frontal polymerisation; during the reaction, the heat released by the exothermal reaction of monomer or oligomer to give the polymer is exploited to promote the formation of a hot travelling front able to propagate and self-sustain the reaction. The characterisation of the products is herein discussed, looking at the good performances especially reached with the epoxy resins as binders. Namely, the tiles show values of water absorption repellence and chemical, thermal and mechanical resistance equivalent or better than those of the raw slate.

1. Introduction

The Italian slate called "Ardesia" is the most traditional roofing product in Liguria (Italy), employed for its durability (at least 40 years under the conditions of the Liguria climate). The use of slate as roofing and cladding product is diffused all over Europe, and many European countries are also producers; however, strong petrographic, and therefore technical, differences among slates types occur, as consequence of the age and the geologic environment of formation.

The slate is a metamorphic stone characterised by high fissility; this structural quality is at the base of the possibility to cut along parallel direction the stone itself obtaining plates with different thickness. Besides the production of plates for roofing and floor, in the last years the Italian slate is widely used to build the billiards tables, especially for the US market.

The mining and the manufacturing of slate imply the production of a huge amount of discarding (powders, small pieces, and mud), that for their disposal are transferred and collected in dismissed quarries. It is evident that this is not a never-ending solution, keeping into account the large quantity of discarding. It is for this reason that many enterprises working in the field of slate mining and manufacturing are involved in studies with academic institutions focused to the investigation of new way of discarding recycling giving both economical and environmental advantages. Also our group, in collaboration with some enterprises of the Liguria region, developed in 2004-2005 a research project financed by the Scientific and Technological Park of Liguria, to prepare composites made by the slate powder (constituting the discarding) and polymeric binders (i.e. acrylic and epoxy resins). With our proposed methodology it is possible to obtain either end-products or intermediate materials useful for successive applications and for a wide range of manufactured objects. Particularly our technology is addressed to the production of tiles for roofs and floors.

The technology applied to obtain the products is the frontal polymerisation, in which the heat released by the exothermal reaction of monomer or oligomer into polymer is exploited to promote the formation of a hot travelling front able to propagate and self-sustain. This polymerisation route occurs with high rate and reaches almost the 100% of conversion in a very short time. Frontal polymerisation can be considered as environmental friendly and with low cost, indeed:

- No organic solvents are required,
- No unreacted monomers remain in the system thanks to the high conversion,
- No external energy must be provided since the polymerisation is self-sustained.

The set up of frontal polymerisation is due to J. A. Pojman;[1-6] our research group applied this reaction to several systems monomer/inert (stone, textile, marble powder).[7,8] The presence of an inert material could hamper the polymerisation, because it could absorbs a fraction of the energy developed during the reaction; nevertheless, the obtained results demonstrated that frontal polymerisation occurs and with good results also in the presence of inert materials.

To assess the performances of tiles, studies of resistance to water, climate, acids, alkalis and mechanical tests were carried out in order to verify is these products can be considered a an alternative to the raw slate.

2. Experimental

A large number of experiments were performed to optimise the ratio between the inert (slate discarding) and the polymeric binder, the amount of initiators and/or catalysts, the granulometry of discarding, the initiation temperature of the frontal polymerisation, the reaction times.

Monomers chosen as binders, leading to cross-linked polymers, were:

- 1,6 hexanediolediacrylate (HDDA), polymerised in the presence of AIBN as initiator (3% wt),
- Epoxy resin deriving from bisphenol A and diglycidil ether, cross-linked with diethylentriamine.

The best results in terms of performance of the agglomerates have been obtained with 16.6% wt of acrylic binder and 30% wt of epoxy resin (due to its higher viscosity). Clearly, the amount of binder must be less than that of the inert that, being a recovered product, is cheaper than the polymers. However, the epoxy resin is cheaper than the acrylic monomer.

Concerning the inert material, two types were available: mud (wet and dry) and chips (sizes: 3.5 mm, 1 mm, 0.7 mm). After several experiments using different ratios between chips and mud (90/10, 80/20, 70/30, 60/40) it was possible to establish that to obtain self consistent products mixtures chips/mud equal to 70/30 had to be chosen.

Experimentally, at the beginning the inert material was mixed with the polymeric binders and the initiator and after transferred in the mould (available sizes: 5x5x2 cm; 30x40x1 cm). Here the polymerisation started by thermal initiation at about 150 °C; in 5-10 min the reaction was completed. During the process monomers or oligomers are converted into polymers that embedded the inorganic powder. During the synthetic process the mixture "slate powder and binders" can be modelled and shaped in order to obtain final products with desirable size and shape.

All the products were firstly characterised by SEM coupled with EDS to have information of their inner morphology.

After, many tests to assess the final performances were carried out, as reported in the following.

The Capillary Water Absorption test was carried out using the gravimetric sorption technique, according to the Normal test 11/85.[9] The stone specimen is laid on a filter paper pad around 1 cm thick, partially immersed in deionised water, with the treated surface in contact with the pad. The amount of water absorbed by capillarity forces is determined by weighing the specimen after 10’, 20’, 30’ and 1, 2, 4, 6, 24, 48, 72 and 96 hours, to obtain the wet specimen mass M_i ($M \pm 0.0001$ g). The amount of absorbed water Q_i, at the time t_i per surface unit, is defined as follows:

$$Q_i = (M_i - M_0) / S,$$

where M_i is the specimen mass (g) at the time t_i (second), M_0 is the dry specimen mass (g) and S: contact surface (cm^2). The Q_i values (g/cm^2) are plotted against the square root of time ($s^{1/2}$), to give the capillarity absorption curve.

The apparent density B in g/cm^3 was determined following the UNI EN ISO 10545-3:2000 standard; it is given by the ration between the dry mass of the sample and its volume.

The resistance to thermal excursion was evaluated looking at the standard UNI EN ISO 10545-9:2000; firstly the samples were soaked in cold water at 15 ± 5 °C; after 15 min they were placed in oven at 105 °C for 40 min. This cycle was repeated 10 times. The resistance to freezing cold was performer following the standard

UNI EN ISO 10545-12:2000; firstly, the samples were soaked in cold water for 15 min; after drying, they were placed at -5 °C for 15 min, then they were stored at 5 °C for 15 min. This cycle was repeated 10 times. In both cases, the resistance of composites to heating and freezing was assessed looking at the eventual modifications of samples.

The resistance to the chemical attack was determined following the standard

UNI EN ISO 10545-13:2000, by soaking the samples at room temperature in solution of several chemical agents: ammonium chloride (100g/l), sodium hypochlorite (20 g/l), HCl (3% and 18% v/v), citric acid (100 g/l), KOH (30 and 100 g/l). Any modifications were detected after 12 days.

The soil resistance was evaluated following the standard UNI EN ISO 10545-14:2000, by applying on the samples surface some substances, as: hot water (55 °C), cleaning agent (pH 6.5-7.5 and pH 9-10), HCl 3% v/v, KOH (200 g/l), acetone, olive oil, and looking at the eventual modifications occurring on them.

The abrasion test was performed with an instrument set up in our laboratories, as described elsewhere.[8] The impact resistance Charpy was evaluated following the standard UNI ISO 179.

3. Results

In figure 1 the curves of capillary water absorption for the produced agglomerates are collected together with that of a carbonatic stone as reference; the raw slate absorbs less water than the acrylic based composites, but the epoxy based products are more hydrophobic of the raw one.

The apparent density of the composites is on average 1.6-2.0 g/cm^3, whilst for the slate is higher (2.5-3.0 g/cm^3).

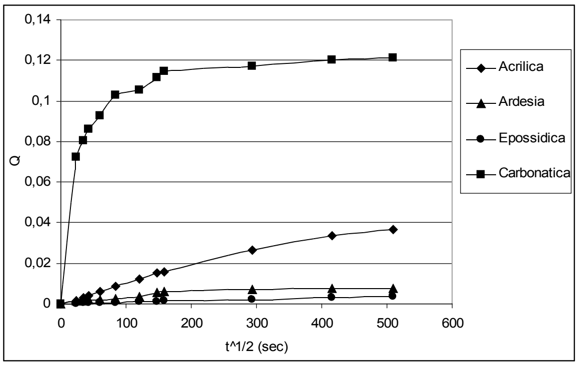
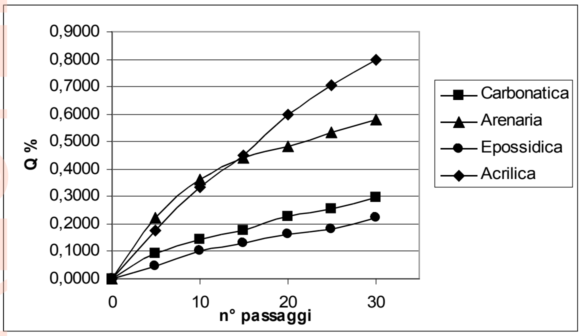


Figure 1: Capillary Water Absorption.

Both the acrylic and the epoxy based products show resistance to the thermal excursion, to the freezing cold, to the soil and to the chemical attack.

Considering the abrasion test (Fig. 2), the epoxy based agglomerates are more resistant of those made by acrylic and of the raw slate (also in this case the curve related to a carbonatic slate is shown).

The impact test shows that the acrylic based composites have a resistance equal to 1.67 KJ/m^2, whilst for the epoxy based is 1.45 KJ/m^2.



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igure 2: Abrasion test.

4. Conclusions

Tiles produced with the slate powder constituting the discarding and polymeric binders (i.e. acrylic and epoxy resins) show values of the water absorption repellence and the chemical, thermal and mechanical resistance equivalent or better than those of the raw slate.

5. Acknowledgement

Authors thank the Scientific and Technological Park of Liguria for the funding and INSTM for the administrative support.

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DEVELOPMENT OF AN INNOVATIVE DIAGNOSTIC STRATEGY TO EVALUATE THE DETERIORATION DEGREE OF PAPER ITEMS OF HISTORICAL, ARTISTIC AND ARCHAEOLOGICAL VALUE

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The PAPERTECH project funded by the 6FP (ref INCO CT-2004-509095) was carried out with the aim to develop/use innovative materials and technologies for the conservation of paper of historical, artistic and archaeological value. This contribution presents the conclusions reached at in the field of diagnosis. The Innovative diagnostic strategy to evaluate the deterioration degree of paper items of historical, artistic and archaeological value make use of a multi-analytical approach analysing the same point (spot) with EDXRF, FTIR, NMR, Raman and SEM-EDS instrumental techniques. Then chemometric analysis and chemical modelling are conducted to explain the results. The coupling of these techniques allows us to unequivocally define the pigments and binders used in the manufacture of the paper items. Applying those techniques to the cellulosic support we can evaluate its state of conservation (oxidations due to chemical or biological attack) as well as the presence of impurities, even the paramagnetic ones and metallic chips.

Selected examples are be presented to illustrate the potentiality of the innovative approach: (a) biological attack to cellulose and copper carbonate pigments, (b) the presence of the unsuspected lead tin yellow type II pigment in an artwork of the XIX century, (c) detection of hazardous pigments/chemicals, (d) analysis of binders and (e) degradation of brochantite by SOx attack. Moreover, almost all of the techniques used in the analysis were portable, non-destructive and non-invasive, which is very desirable when analysing objects belonging to Cultural Heritage.

1. Pigment analysis

The methodology that has been followed in this project consists in a screening of the elements present in the different parts and colours on the specimen by using a mobile non-invasive micro X-Ray Fluorescence system. In this way it is possible to determine which kind of materials and type of pigments are present (iron pigments, cobalt pigments, copper pigments, etc). Afterwards, the specimen is analysed by non-invasive micro Raman spectroscopy in order to know the molecular composition, that is, how the elements determined by XRF are linked among them. As the elemental and molecular composition is known, it is possible to set a tentative list of original pigments that could be present together with possible degradation products.

For example, if in a green colour area arsenic, iron and copper are determined, the scientist knows that iron yellow oxide, Prussian blue, Scheele's green, emerald green, azurite, malachite, verdigris or other copper green pigment could be present, whereas for example, no cobalt, lead or manganese pigment would be present. This is very useful at the time of interpreting the Raman spectra because the assignment of Raman signals is more reliable and we ensure that all elements are related to a pigment or material. Thus, all pigments are determined in an elemental and molecular way. For this purpose, FTIR [1] and Raman [2] spectra databases of materials (e-VISARCH and e-VISART) were built. Sometimes it is not possible to obtain any Raman signal (fluorescence from the matrix, low scattering of the molecule, degradation of the original compound, …). In this case, only XRF data can give us the information of the original elements.

The use of Raman spectroscopy in combination with X-Ray fluorescence made possible to determine the chemical composition of almost all pigments and inks used in the polychromed ancient paper artworks selected and involved in the Papertech project [3-5]. During the characterisation of some of the samples, several hazardous pigments were found. For example, in some wallpapers the green colour was a mixture of Prussian blue, a yellow pigments, Scheele's green and emerald green. Scheele's green was available from the end of 18th century, but it was used only until the beginning of 19th century because of its high toxicity. In the same way, emerald green was extensively used during the 19th century with very adverse consequences in the health of people and wallpaper manufacturing industry workers. In the same way, lead white and red vermilion found in many of the samples can be considered as hazardous pigments. In one of the samples analysed lead tin yellow type II ($PbSn_{1-x}Si_xO_3$) was determined in a sample from the 19th century [6]. It is supposed that by that time this pigment was not used anymore. According to the XRF spectrum (Figure 1), it was clear the presence of a high signal of lead and tin. Raman spectrum of that shade showed a band at 323 cm^{-1}, that corresponded to that yellow pigment.

By using this methodology, it was also possible to demonstrate the degradation of pigment brochantite ($Cu_4(SO_4)(OH)_6$) into mineral antlerite ($Cu_3(SO_4)(OH)_4$) [6]. These compounds not only matched the position of the most intense Raman bands (Figure 2), but also their relative intensities in the other minor bands. On the one hand, the bands centred at 1069, 986 (strong shoulder), 636 (shoulder), 343 (shoulder), 296, 261 and 239 cm^{-1} could correspond to antlerite. On the other hand, bands at 976, 611, 398 and 313 cm^{-1} were consistent with the presence of brochantite. This sample was found in a house that had been inhabited and without a roof for years. Besides, close to the house there was a heavy industry (steel makers) that had been dumping SO_x into the atmosphere for the last 120 years. The combination of this pollutant gas and humidity could have promoted a partial decay of brochantite to antlerite according to the reaction:

$$3Cu_4(SO_4)(OH)_6 + H_2SO_4 \rightarrow 4Cu_3(SO_4)(OH)_4 + 2H_2O$$

Finally, during the analysis of a Dutch map [5], in the XRF analysis of the green areas, it could be seen that only copper (Cu) was present. With the help of the TV camera of the Raman microprobe, it was possible to see that the colour was not a mixture of pigments but a simple green pigment. Four Raman bands were detected at 1516, 614, 586 and 559cm^{-1}. After an intense search in the literature, the compound was identified as moolooite (copper oxalate, $CuC_2O_4 \cdot nH_2O$, $n < 1$). This compound has a very scant occurrence and it was first reported in 1985 in Australia. Due to its rareness, it was not possible to state that moolooite was the original pigment. Thus, it should be a degradation product of other copper pigment. The presence of oxalate in the cultural heritage has been related to the biochemical activity of lichens and bacteria, which produces oxalic acid and reacts with the original components of the artwork. However, the presence of only calcium oxalate had been reported. In fact, we found also in several areas of the map calcium oxalate. Lichens species containing moolooite in the thallus have been identified growing in areas of high copper mineralization. It seems that micro-organisms use organic chelators, such as oxalic acid, to dissolve poisonous heavy metal minerals, promoting their transformation into more stable, less soluble and less hazardous oxalate compounds.

2. Binder analysis

For the analysis of binder, varnishes and other related materials FTIR spectroscopy was used in combination with chemometric tools. The chemometric model was developed based on Principal Component Analysis (PCA), selecting those parts of the FTIR spectra where valuable information is found for this kind of materials. Several authors have been working in the determination of binders by FT-IR. However, chemometric techniques haven not been used before in order to treat the data. Prior to the analysis, a step of extraction is performed with the use of cotton wet in the selected solvent (water and dicloromethane). In the aqueous phase proteinaceous and polysaccharides compounds are extracted while lipidic and resinous substances are taking out in the organic one.

The PCA model was built by using the spectra of standard contained in our database. The database contains FTIR spectra of 130 organic materials. There are several kinds of binders according to their nature: lipid, proteinaceous, polysaccharides and resinous binders. In our case, the chemometric analysis of the spectra let differentiate among the five families of binders under study as can be seen in Figure 3. PCA can often be so effective and efficient in reducing the dimensionality of analytical data that it can provide immediate visual indication of patterns within data and is commonly employed as exploratory technique. In fact, the FTIR spectrum of the binder extracted from the artwork is introduced in the PCA model and depending on the place or group where the sample appeared, it is easy to know the nature of the binder.

4. Acknowledgement

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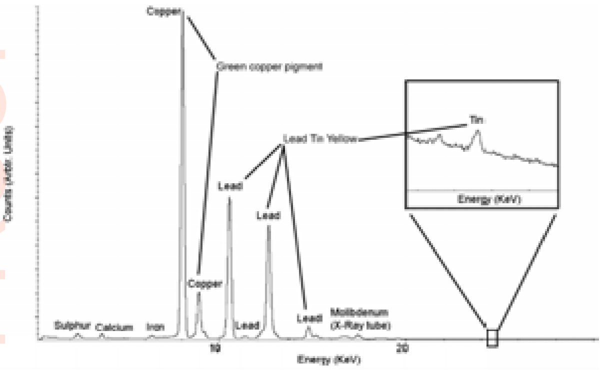

Figure 1. XRF spectrum of a green colour where lead tin yellow was found mixed with a green copper pigment.

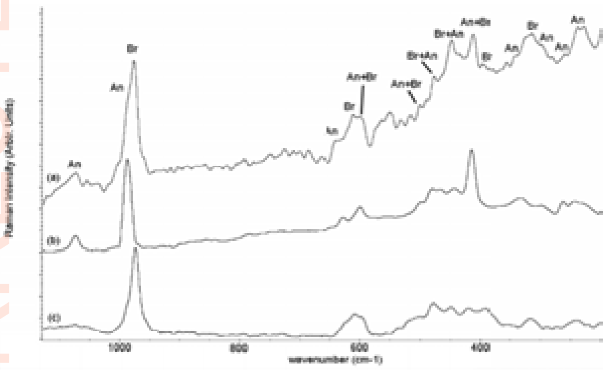

Figure 2. Raman spectra of a) green area in a wallpaper b) antlerite standard and c) brochantite standard.

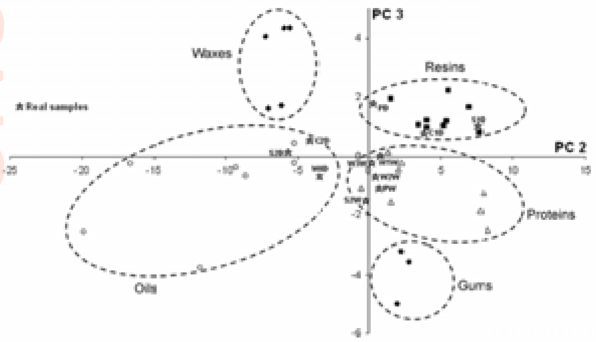

Figure 3. PCA model with the five groups. Several results of real samples can be seen grouped with their corresponding binder type.

METAKAOLIN MODIFIED LIME MORTARS IN CZECH RESTORATION PRACTICE

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An increasing tendency to limit or eliminate the use of Portland cement in repair and restoration of mortars in the Czech Republic has led to the need to develop new and sufficiently strong lime mortars. The author designed a new binder based on a mixture of air lime and metakaolin. This material has been introduced into restoration practice under the trade mark VAPO, and is produced by a small Czech company, AQUA s.r.o. VAPO is typically used for plastering and rendering. However, it has also been successfully applied in restoration of ancient pavement mixtures.

1. Metakaolin modified lime mortars

The use of metakaolin in restoration and other construction activities has been investigated quite intensively in recent years. Its application in restoration is supported namely by its pozzolanic characteristics, which were used from antique times through medieval times.[1] Natural and anthropogenic pozzolanic materials were added into lime mortar mixtures as a latent hydraulic component. Thanks to pozzolans, highly durable and strong mortars were produced long before the industrial revolution. Lime mortars modified by burned kaolin are therefore historic materials that are being re-invented after a temporary decline due to the production of new hydraulic binders, namely Portland cement.

2. Characteristics of metakaolin

This study of the addition of metakaolin into a lime binder is based on a tradition of using pozzolanic additives. The Czech Republic has considerable kaolinitic clay resources, which have been also exploited in recent years for the production of metakaolin. At the present time, some companies in the Czech Republic produce metakaolin by means of kaolin and flint clay calcination in a rotary furnace at 750 °C, followed by milling to various levels of fineness. However, the price of metakaolin produced in this way (around 0.5 Euro/kg) has limited the utilization of this material. For this reason we have undertaken a study of the dust outlet as possible sources of reasonably-priced metakaolin. Dust outlet is trapped while burning kaolin or flint clay and stored in the textile fabric screen after escaping from the rotary kiln. Dust originating in the process of flint clay calcination has a trade name RON CH. Its chemical composition is shown in Table 1. The elemental composition of RON CH is almost the same as that of metakaolin produced in the standard way by calcination and grinding. As far as the mineralogical composition is concerned, not all the kaolin is transformed to metakaolin, because most of the dust is removed from the furnace before the dehydroxidation process of the clay is complete. Part of the dust remains in the kaolinite phase. The level of dehydroxidation can be checked by determining the loss by ignition measured on the RON CH product. The grain size of the RON CH is similar to or finer than that of the metakaolin produced in the standard way. The specific surface of RON CH is 13.7 m^2/g.

Table 1: Chemical composition of RON CH.(% wt).

	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	K_2O	CaO	MgO
%	54.81	39.15	2.34	1.56	1.30	0.53	0.28

3. Lime – metakaolin binder

The research work aimed to compare the performance of mortars mixed from lime hydrate and RON CH in various ratios with the performance of pure lime mortar. The highest mechanical characteristics were obtained for a mix of lime hydrate: RON CH with a ratio of 7:3. The strength and also the frost resistance of this mixture increased with additions of white Portland cement CEM I 52.5 (10% wt. to binder), but the total porosity fell (from 21 to 17%).[2]

A modified lime binder based on a mixture of air lime hydrate and RON CH in the ratio of 7:3 was introduced into restoration practice under the trade name VAPO. A comparison of the characteristics of mortars prepared from VAPO binder and from lime putty is shown in Tables 2 and 3. The quality of the RON CH for producing the VAPO binder was regularly checked by testing the following material characteristics: loss by ignition (should be below 1.5% wt.), grain fineness (90% < 10μm) and pozzolanic activity.

Table 2: Mechanical characteristics and total porosity of the mortars studied.

Characteristics (28 day)	L mortar	VAPO mortar	VAPO + OPC mortar
Flexural strength	0.09 MPa	0.93 MPa	1.08 MPa
Compressive strength	0.6 MPa	3.8 MPa	4.9 MPa
Total porosity	21.8%	22.8%	17.1%

L mortar, the reference lime mortar, was prepared from lime putty and standard silicate sand in the ratio of 1:3 vol. (1:4 wt.). VAPO mortar was prepared from VAPO binder and standard silicate sand in the ratio of 1:1.5 vol. (1:5 wt.). VAPO + OPC mortar was prepared by adding 10% wt. of Portland cement CEM I 52.5 to VAPO, and the binder was mixed with standard silicate sand in the ratio of 1:1.5 vol. (1:4.8 wt.).

The workability of the fresh mortars was adjusted to be almost similar (flow table: 150 mm). The mortars were stored before testing in laboratory conditions (20 °C, 60% RH).

The salt solution for the salt resistance test consisted of 100 ml deionised H_2O, 3.5 g NaCl , 0.5 g Na_2SO_4 and 1.5 g $NaNO_3$.

In order to avoid any contamination of a historic structure by salts, the amount of ions was checked in a water extract from the VAPO binder with the use of ion chromatography. The sulphate anion content was 0.14% wt. due to contamination of RON CH by fuel, but the sulphate level was considered acceptable (for comparison: 0.6% wt. of sulphate anion was determined in a water extract from Portland cement).

4. Conclusion

Mortars prepared from VAPO binder were used as repair mortar or as mortar for rendering and plastering Czech historic structures during conservation works in 2005-2006 (monasteries at Skalka by Mníšek pod Brdy, at Velehrad, at Teplice, at a church in Horní Slavkov, at Roudnice nad Labem castle, at Mníšek pod Brdy castle, at the synagogue in Žatec). A grouting variation was used in conserving the Romanesque portal at Záboří near Týnec nad Labem. VAPO with the addition of Portland cement was used to replace the ancient exterior plaster floor at Karlštejn Castle. In a few cases, the properties of lime-metakaolin mortar are monitored by testing selected characteristics on mortar specimens taken from structures after a period of time.[3]

RON CH metakaolin product provided a reasonable compromise in economic and technical terms. However, due to the need to check that the RON CH was of the required quality, in 2007 the AQUA s.r.o. management changed strategy and started to produce VAPO from standard metakaolin, despite the higher price. Future research work will investigate the influence of maturation and curing conditions during the setting period, the influence of the water content in fresh mortar, and the long-term characteristics of matured lime-metakaolin mortars.

5. Acknowledgment

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Table 3: Mechanical characteristics of the mortars after tests of frost and salt resistance.

	L mortar	VAPO mortar	VAPO + OPC mortar
Flexure strength of fully wet specimens	0.02 MPa	0.68 MPa	0.88 MPa
Flexure strength of fully wet specimens after x frost cycles	after 1 cycle 0.00 MPa	after 5 cycles 0.55 MPa	after 5 cycles 0.69 MPa
Compression strength of fully wet specimens	0.20 MPa	3.0 MPa	4.8 MPa
Compression strength of fully wet specimens after x frost cycles	after 1 cycle 0.10 MPa	after 5 cycles 2.2 MPa	after 5 cycles 3.4 MPa
Visible disintegration of specimens after frost cycles	after 1 cycle	after 11 cycles	after 15 cycles
Flexural strength of dry specimens after 15 salt cycles	0.30 MPa	0.52 MPa	0.41 MPa
Compressive strength of dry specimens after 15 salt cycles	0.50 MPa	2.3 MPa	3.2 MPa

Table 4:
Amount of ions of water soluble salts in VAPO binder

cations	% wt	anions	% wt
Ca^{2+}	9.73	Br^-	0
K^+	0.09	Cl^-	0.1
Li^+	0	F^-	0.01
Mg^{2+}	0.03	NO_2^-	0.02
Na^+	0.08	NO_3^-	0.01
$NH4^+$	0.04	PO_4^{3-}	0.01
		SO_4^{2-}	0.14

PRACTICES OF MONITORING AND MAINTENANCE OF ARCHITECTURAL HERITAGE IN EUROPE: EXAMPLES OF "MONUMENTENWACHT" TYPE OF INITIATIVES AND THEIR ORGANISATIONAL CONTEXTS

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Abstract
The paper deals with the topical issue of preventive care and maintenance of built heritage in Europe. As a reaction to arising requirements for developing the field, advanced by European and international bodies, we outline some conditions needed to establish organized practices of monitoring and maintenance as a conservation strategy. Starting from the presentation of the organisation "Monumentenwacht" dealing with inspections for the maintenance of built heritage, we investigate its activity and framework by comparison of some implemented practices in Europe: the Netherlands, where the first organisation comes from, Flanders-Belgium, Denmark, England and Hungary. The main parameter of assessment is the organisational and legal framework, a prerequisite for implementing preventive maintenance on an official and sustainable basis.

1. Introduction
Preventive conservation is generally considered to imply measures to minimize the deterioration and damage of heritage, thus avoiding major restoration interventions so to retain the authentic material and integrity as long as possible. Although preventing decay has been advocated already by the Athens charter in 1931 and formalized with the Venice Charter (1964, art.4), preventive conservation has only gained importance in the last decade. Regular monitoring, control of major causes and routine preventive maintenance with small repair are its core activities.

In a European context, it contributes to the conservation of different dimensions of authenticity:[1] material, technique and spirit and feeling, as it is based on small timely repair, use of local traditional crafts and community involvement. Preventive conservation in heritage has been more comprehensively developed in the framework of museum conversation practices, from where several definitions derive. On the other hand, preventive actions have been promoted in relation to risk-preparedness and disaster mitigation where – again – continuous preventive maintenance[2] is underlined.[3] However, preventive care only has sense and impact when it is established as a comprehensive and permanent strategy. An example of such continuous preventive approach in built heritage exists since the 1970s in Europe as an inspection-for-maintenance service. It is called "Monumentenwacht" (MW) or "Monument watch"[4] and it is the focus of the present contribution.

Building upon the existing researches, carried out by the Legislative Support Task Force at the Cultural heritage Department of the Council of Europe[5] and research at the University of the West of England,[6] the investigation addresses the latest requirements by the European Commission (COST Action C5,[7] SPRECOMAH[8]) as well as by UNESCO and the World Monument Fund to promote proactive attitude in conservation of cultural heritage. Looking at the legal and organisational contexts of five implemented practices, we try to outline some of the conditions for its establishment. The investigation is part of an on-going doctoral research at the RLICC, thus the results are temporary.

2. Analysis: Inspection for maintenance and Monumentenwacht
The Netherlands - The first "Monumentenwacht"[9] organisation started in 1973 in the Netherlands on by two individuals working in heritage protection and with the support of the Dutch Minister of Culture. It is since 1990 a federal umbrella non-profit organisation with twelve independent organisations. While the federal is in charge of coordination, training and PR, the provincial ones are in charge of the building inspections. The work is carried out by teams of two inspectors-craftsmen, experienced in restoration projects, who perform yearly inspections of buildings, from roof to basement, using climbing techniques, in order to provide to the owner a thorough report on the condition of the building, with specific advice and a time-line of actions and maintenance works to be undertaken. Building owners or managers can subscribe for its service for an annual fee 50€, while the inspection fee amounts to 40€ per team per hour of inspection. The wachters' main and only duty is to inspect, and not intervene, by spotting all the work to be done they steered activity in the sector.[10] Only in cases of small urgent works, such as cleaning of gutters or replacing a broken tile, can be carried out by the wachter himself. Financial support derives mainly from provincial subsidies (85%) and collected fees (10%). The relevance of such a service is proven by the increase in membership and related inspection work. The number of member buildings grew from 9800 in 1993 to 21.000 in 2007, while the number of teams increased from 37 to 100.

The successful figures mirror the national strategy. In fact, maintenance of monuments is a requirement of Dutch Monuments and Historic Building Act of 1988, and it is enabled by several financial incentives.[11] There are subsidies for restoration as well as for maintenance of listed buildings, aiming at making the building "wind and water proof, cover from 25 to 65% of costs and are often ascribed according to the presented report by MW. The National Restoration Fund offers a revolving fund system. Recently, the VAT tax for maintenance of work such as painting, decorating and plasterwork has been reduced to 6%. As MW is a non-profit organisation they are exempt of VAT.[12]

Belgium - The Belgian non-profit organisation[13] started in 1991, following the example of the Dutch model, yet it slightly varies. It was started from the regional level[14] where an umbrella organisation – Monumentenwacht Vlaanderen (MWV) was created to take over the coordination and training activities of five separate independent provincial organisations. Starting funds were provided by the King Baudouin Trust and from the different provincial authorities. Today the organisation's income is manifold, 70% of budget comes from the Provinces, 20% comes from the Flemish Region and 10% comes from fees (membership 40€ annually, 24.32€ (incl.VAT) per person/hour on building). The service is offered to members of the organisation who are owners or managers of listed monuments or of valuable historic buildings. Belgian teams are composed of one architect with specialisation in restoration and a craftsman with practical experience. Since 1997, the special profile of "interior inspector" was introduced for inspections of interiors and movable objects. Another core activity and objective of MWV is awareness rising that is achieved through the communication with building owners and seminars and information campaigns addressing a wider audience. The meaning and success of MWV is proven by the increasing number of its members; the 4700 in 2006 grew to 5130 in 2007.[15] The rise in awareness and involvement of owners can be traced also in the increase of the number of non-listed buildings: in 2006 these represented 44% of all owners, whilst in 2007 it grew to 48%.

The Flemish legislation on cultural heritage contributes greatly to the increase of the maintenance attitudes. The Flemish region is in fact the only one in Belgium that set forth the clear obligation for maintenance with the "implementing order" of November 1993. It primarily refers to exteriors, interiors, as well as vegetation within a perimeter of a protected group. In the case of "church fabric" or *kerkfabriek* it does encompasses also some elements of the movable elements (chimneys, clocks, bells, etc.). Consequently, the Flemish Ministry foresees specific grants for the maintenance of monuments and tax reduction.[16] A requirement for a maintenance grant application is a complete condition assessment of the building, for which vary often MWV reports are used. The grants vary according to the category of the owner (public, private, religious, association, etc.) and shares are distributed as follows: Region 25-60%, Province 7.5-30%, Municipality 7.5-15%. A total subsidy coming from all the three levels will cover from 40-90% of costs, while incentives are calculated with a coefficient on a sliding scale from 40 to 25% of work-costs. Nevertheless, MWV is charged for VAT that is included in the final service fee. However, since the Flemish legislation only includes national monuments and an inventory of valuable buildings, three Flemish provinces (Antwerp, Limburg, Vlaams Brabant) instituted special granting systems for the maintenance also of non listed but valuable buildings. The grants are appointed provided that they become MWV members for ten years so to ensure the continuity of maintenance works. Yet, at the moment these grants are activated only in Vlaams Brabant.

One more institutional aspects needs to recalled. Since MW activities spot the minor repair to be done, the demand for specialised craftsmen increased and steered the activity of craft training organisations, such as ECR[17] and EUCORA[18] in Flanders. Similar was the effect of promoting maintenance in the Walloon region of Belgium. Since 2006 the cultural heritage authority *Institute de Patrimoine Wallon* instituted the *Cellule de maintenance*, a body that helps monument owners carrying out maintenance work and that derives from the activities of an independent organisation started in 1994 on the example of MW. The Cellule collaborated closely with the governmental institute for training traditional crafts *Centre La Paix Dieu*[19] that provides the necessary skilled labour force. However, while the Wallonian centre is subsidised by the Region, the Flemish organisations get funding through projects.

Denmark[20] - A "monumentenwacht" organisation was implemented in Denmark in 2000, within the at-the-time Raadvad centre for Crafts and restoration, a partly-governmental organisation. It was integrated as one of the action fields, named "House Examination System". After organisational changes in 2001, the core activities of the Centre, together with the MW service were integrated in the new institute Center for building care (Bygningsbevaring). The name Raadvad remained to a new structure that also partially deals with preventive conservation by offering brief inspection services. The Centre for Building Care continued with its former activities, primarily training of craftsmen and inspections for maintenance, following the Dutch example. Despite the privatization due to loss of financial support, the inspection service continued. Due to the profit nature, the clients pay every working hour as well as the travel of the inspectors. During the first, subsidised period around 2000, the subscription fee was equal to 200DKK (ca. 26€) and inspection fee per hour was 100DKK (13€), so that an average inspection cost around 280€. Today inspection costs per building vary with the size of the building from 700-1000€ and there is no membership subscription.

As to the legal aspects, in the first phase, a major obstacle regarded the safety regulations, thus the inspectors could not use the climbing techniques, but used cherry-pickers and cranes. However, today the lack of state subsidy for the MW activities weighs heavily on their work, but primarily on the owners through high fees.

As to legislative tools, the protection of immovable heritage is administered by Heritage Agency of Denmark, belonging to the Ministry of Environment.[21] The *Consolidated Act No. 1088 of 28 August 2007 on Listed Buildings and Preservation of Buildings and Urban Environments* requires the buildings to be kept "in good condition" and with "roofs and windows free of leaks" and it sets maintenance as mandatory. For proper maintenance, the laws foresee the advice of an architect restorer from the National Forrest and Nature Agency. Subsidies or loans are offered for works on listed buildings, yet the Agency grants only for private buildings, not for public. Although the support can cover up to 100% of costs, it is calculated in proportion with the expenses and the nature of the work; hence for example the conservation of sandstone carvings will get more support than the replacement of tiles. There exist tax allowances within the "Annual decay scheme" within which the annual tax allowance is calculated on the basis of repairs found to be required to avoid decay.[22]

Similarly to the Belgian case, also the Danish example stresses the fundamental connection between maintenance and traditional crafts, with the very fact that the inspection service was established in a centre for traditional crafts, so that the skilled labour can be trained according to the demand and directly involved in small repair works.

England[23] - A first maintenance inspection service for historic buildings, based on the Dutch MW model, was carried out as a pilot project in the Bath area in 2002-2003 by the non-profit voluntary group "Maintain our Heritage" (MoH), with the aid of £64.000, or 80% of all costs, from Bath Preservation Trust, Esmée Fairbairn Foundation and English Heritage. With the aim to test all aspects – practical, organisational, legal, financial – inspection was carried out on exteriors of 72 listed buildings, after having invited building owners or managers to participate. The average cost of inspection fee amounted to £1,100, while only the marketing costs reached £100 per inspection. Three teams with an experienced inspector and a selected assistant, carried out the work on voluntary basis. The pilot had no continuation due to the financial non-feasibility in the existing framework. Valuable feedback was provided by questionnaires filled by participating owners. Despite a generally positive final reaction, the major obstacles consisted in a slow first response and a lack of proneness toward preventive actions.

Preventive care and maintenance is required and promoted by the heritage authorities, where the essential role of traditional crafts is stressed.[24] Nevertheless, there are no taxation relief for maintaining properties. The financial aid for preventive care exists within in the National Lottery Fund and the Heritage Lottery fund.[25] The main conclusions of the research by MoH primarily pointed out to a lack of advice and information to the owners as well as a lack in advice and support. Further, the lack of leadership and of coherence in coordinating activities and goals should be improved through a national maintenance strategy, together with financial assistance with VAT, tax reductions and grants.

Hungary - The most recent implementation of MW took place in Hungary, where in 2006 the Maméq non-profit NGO was started based on the Dutch model. There are 8 inspectors, with the background of "monument maintaining technician".[26] The starting funds were provided by private sponsors. In three years the number of members grew from 8 to 32, of which 24 are listed buildings, both private and public. At present the budget is enabled by membership fees (3000-4000HUF or 13-17€) which represents 60% of whole budget, while 40% is still provided by private sponsors. As in the model MW, the inspectors do not perform major maintenance work, they inspect only, so to contribute to job creation by involving skilled labour.

The National Cultural Fund, operating under the Ministry of Education and Culture, does not foresee specific grants for maintenance work. Grants for restoration projects are sporadic, mainly directed to major monuments. However, the sponsorship is stimulated with the Non-profit Act that foresees up to a 100% tax reduction for private donations to Public Benefit Organisations, and can channel up to 50% of tax payers (2006).[27]

3. Observations up to date

Up to date observations lead to five temporary conclusions:

1. At the legal level, preventative care can be required only if accompanied by supporting tools such a financial mechanisms through tax reliefs and reductions, grants as well through structured sponsorship to both, owners and inspection services. Support is needed also in terms of professional assistance and advice to building owners. Hence, national preventive conservation strategies play a key role.
2. MW type of organisations showed to be a valuable medium in achieving the above goal, by providing a continuous monitoring tool to the owner as well as a management tool to the state.
3. As a free and independent body their objective and non-interfering task of identifying needs automatically contributes to the development of a maintenance market in a sustainable way.
4. However, comprehensive and coherent MW work is ensured only if organisational factors are met, such as a two-level structure, with an umbrella coordinating body supporting the national strategy, and independent bodies in charge of implementing strategies and actions on regional/provincial level. This way funding for inspection and maintenance activities is structured.[28]
5. Division of tasks and provision of skilled labour is significant. Inspectors have to be properly trained in theory and practice so to provide comprehensive condition reports, at the same time, traditional crafts are essential for executing maintenance work. Examples stressed the importance of supporting local craft training centres and linking them to the activities of MW.

Preventive conservation through organised regular monitoring and maintenance can have a threefold impact. On the level of values, it contributes to the retention of not only authentic material, but also techniques, thus to the integrity. On economic level, it contributes to a long-term cost-efficient strategy as to investment.[29] Integrity of the place adds to the value of historic places as economic assets in tourism, where investment in maintenance pays off.[30] On a larger social level, it extends the participation of the local community by transferring the responsibility of first caretakers onto owners.

4. Conclusion

The contribution presented the topic of preventive care and maintenance by introducing five examples of organized practices of inspection service for the maintenance of built heritage in Europe, on the example of "Monumentenwacht", and their frameworks. In the attempt to respond to a raising demand for a general framework to preventive conservation, the temporary results outline the following conditions to be met : a comprehensive national strategy including financial and professional assistance to building owners, the set-up of an independent body in charge of inspection, and the provision of skilled traditional craftsmen. Finally, up to date results show that MW practices can steer a general raise of awareness on heritage, an improved condition of buildings and a sustainable economy.

5. Acknowledgements

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6. References

1. We refer here to the "Nara-grid", a tool developed at the Raymond Lemaire Centre for Conservation, for identifying the the different dimensions of values in heritage. Cfr. Koenraad Van Balen, *Experimenting with the »NARA-grid«, an evaluation scheme based on the Nara Document on Authenticity*, APT Bullettin, No. 2-3, XXXIX, 2008, 39-46.

2. Bernard Feilden defined the two approaches in planned maintenance: "preventive" and "corrective" (cf. B. Feilden, *Conservation of historic Buildings*, ICCROM, Rome, 1982, p.221). The division has been widely researched at the Department BEST of the Politecnico di Milano, where both approaches are developed within the "Planned conservation strategy" or "conservazione programmata" (cf. S. Della Torre, ed., *La conservazione programmata del patrimonio storico architettonico, Linee guida per il piano di manutenzione e consuntivo scientifico,* Regione Lombardia, Guerrini e associati, 2003).

3. Pierre Pichard stressed the fundamental role of preventive maintenance in seismic areas already in the early 1980s. Cf. P.Pichard, *Emergency measures and damage assessment after an earthquake*, UNESCO Paris, 1984, p.38.

4. Not to be confused with the International Monument Watch organization based in N.Y.

5. R. Pickard, Ed., *Policy and law in heritage conservation,* Council of Europe, Glasgow, New York, 2000.

6. N. Dann, *European Maintenance initiatives*, University of the West of England, Bristol, 2005.

7. Building maintenance in urban heritage was the subject of the EC project COST Action C5, carried out between 1993/1994 and 2001. Within the final focus on lime technology, the general observations and suggestions stressed the need for further comprehensive insights into the different European practices especially as to the assessment of physical conditions of buildings, legislative restraints and economic impacts of maintenance. F.G. Hofmann, ed., *Urban heritage – Building maintenance, final report, COST Action C5*, European Comission, April 2001.

8. The recent EC FP6 SPRECOMAH project produces Guidelines for the implementation and further research on Preventive conservation, maintenance and monitoring of the architectural heritage. Two international and interdisciplinary

seminars attempted to provide a framework of preventive conservation, through definitions and identification of the fields involved. Cf. www.sprecomah.eu.

9. www.monumentenwacht.nl, accessed 15/10/2008.

10. The clear delimitation of inspection work to observation and independent advice conveys a general demand for maintenance work in the sector. Cf. A. Stulens, *Monument Watch in Flanders : an outline*, in: A. Stulens, ed., *First International Monumentenwacht Conference 2000*, Amsterdam 2002, p. 15.

11. S. Richel-Bottinga, *The Netherlands*, in R. Pickard. ed., *Policy and law in heritage Conservation*, Council of Europe, Glasgow-New York, 2001.pp.251-264.

12. B. Goes, *Conservation in the Netherlands, facts and figures on Dutch conservation (monuments and archaeology)*, ICOMOS Netherlands, 2005.

13. www.monumentenwachtvlaanderen.be, accessed 29/10/2008.

14. We notice here that Belgium has a federal system, where the two regions, Vlaanderen and Wallonie, work separately and independently. Thus the regional level here is an equivalent for national level. Cf. http://www.culturalpolicies.net/web/belgium.

15. Statistics from Monumentenwacht Vlaanderen vzw, *Jaarverslag 2007*, Antwerpen 2007, p. 27.

16. Cfr. M.Goblet et al., *Belgium*, in R. Pickard, Ed., *Policy and law in heritage Conservation*, Council of Europe, Glasgow-New York, 2001, pp. 12-40.

17. www.ecrvzw.be, accessed 10/10/2008.

18. www.eucora.be, accessed 10/10/2008.

19. www.paixdieu.be, accessed 12/10/2008.

20. J. Andreasen, *Experience with the Danish monumentenwacht*, in A. Stulens, ed., *First International Monumentenwacht Conference 2000*, Amsterdam, 2002, pp. 41-43; S. Vadstrup, *Addendum Denmark*, *Raadvads Bygningssyn – progress in 2000 and 2001*, in A. Stulens, ed., *First International Monumentenwacht Conference 2000*, Amsterdam, 2002, pp.43-44. Information for 2008 were collected through interviews with Robert Lau (Raadvad Centre) and Søren Vadstrup (Centre for Bygningsbevaring), results can be obtained from the authors.

21. Exceptions are the buildings belonging to the Danish Evangelical Lutheran Church that are under the protection of the Ministry of Ecclesiastical Affairs.

22. U. Lunn, C. Lund, *Denmark*, in R. Pickard. ed., *Policy and law in heritage Conservation*, Council of Europe, Glasgow-New York, 2001, pp. 73-91. We note here that the most updated source, the on-line compendium on cultural policies of the European Council, provides no information as to built cultural policies and related legal issues.

23. www.maintainourheritage.co.uk, accessed 29/10/2008.

24. Clear requirements of Government policy about the maintenance as protection of the historic environment in England is found in the *Planning Policy Guidance 15 (PPG15): Planning and the historic environment,* while guidance on “everyday husbandry on a five-year cycle” is given in the British Standard 7913. Since 2000, the heritage English Heritage in the report “*Power of Place*” has promoting regular systematic condition surveys and routine maintenance. Cf. D.S. Watt, B.J. Colston, *Maintenance Education and Training for Listed Buildings*, Final report Research Module 6, Maintain our Heritage, Leicester, 2003, pp. 6-11. Cf. Also N. Dann, D. Worthing, *Heritage organisations and condition surveys*, in: *Structural survey*, 23, n.2, 2005, pp.91-100.

25. R. Pickard, *Conservation finance 2: area-based initiatives and the role of foundations, funds and non-profit agencies*, in: *Structural Survey*, **20**, 2002,112-116.

26. www.mameg.hu, accessed 02/07/2008.

27. Cf. P. Inkei, *Tax Laws*, in: P. Inkei, ed., *Cultural policies on-line: Hungary*, www.culturalpolicies.net, accessed 05/07/2008.

28. Suggestions on the primary role of area-based initiatives have been promoted also by R. Pickard, *Conservation finance 2: area-based initiatives and the role of foundations, funds and non-profit agencies*, in: *Structural Survey*, **20**, 2002, 112-116.

29. The Finance department RWO of the Flemish ministry carried out a statistical research on cost of maintenance vs. restoration between 1983 and 2007, where a clear decrease in investment is discernible accompanying an increase of support to preventive maintenance. Cf. The report *Rekenhof Stuk 37-A 2007-2208* on the “regional investment in restoration and maintenance grants for immovable heritage 1983-2007”. Http://aps.vlaanderen.be/statistiek/cijfers/stat_cijfers_monument.htm#top, accessed 04/11/2008.

30. The concept the turnovers of CH in tourism economy and pay off by the investment in continuous care has been explored by Terje Nypan, Directorate of Cultural Heritage (Norway). Cf. T. Nypan, *The Economics of Built Heritage: Findings and Challenges*, in: *Cultural heritage and tourism: Potential, Impact, Partnership and Governance*, Vilnius, 2007.

MARITIME CULTURAL HERITAGE OF THE MEDITERRANEAN

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1. Introduction

The ArcheoMed Consortium was formed in 2002 following the initiative of some European regions (Toscana, Campania, Catalunya, Andalucía, Provence-Alpes-Côte d'Azur), Culture Ministries (Italia, España, Portugal, Maroc, Algérie) and centres for research (CNRS Provence, University of Malta) participating to transnational European projects with a significant group of associated partners (among them Italian CNR and the Universities of Barcelona, Pisa and Cádiz). The main purpose of this consortium is to develop and share knowledge aimed at the protection and valorisation of maritime cultural heritage coherent with a sustainable development of the environment. The Consortium activities are based on the complementary fields of expertise of the various partners as well as on bilateral and multilateral cooperation between regions and countries. Furthermore, public authorities are also involved together with research centres in the formation of specialized teams in the field based on the new technologies that can be applied to underwater cultural heritage research and protection and that fit the specific problems of the organizations in charge of them.

The Consortium supports the policies which have an impact on the protection of maritime cultural heritage, such as the *Convention on the Protection of the Underwater Cultural Heritage*, adopted by the UNESCO General Conference in 2001,[1] and the innovative approach of the *Green paper for a future maritime policy for the European Union* integrating maritime activity and coordinated actions concerning all European maritime territories and their relations with the hinterland by means of cultural heritage, environment and sustainable development.

The initiatives of the Consortium follow the principle of integration of the engagement of European, national, and regional authorities which have a direct bearing on innovative best practices improving sustainable development and maritime cultural heritage, especially underwater archaeology, "as an integral part of the cultural heritage of humanity and a particularly important element in the history of peoples, nations, and their relations with each other concerning their common heritage" (UNESCO, 2001).

Over 70% of the Earth's surface is covered in water. The maritime surface areas under the jurisdiction of the EU's Member States are larger than the total land area of the European Union, facing a coastline of 68,000 km. Nowadays, almost 90% of the EU's external trade and over 40% of its internal trade are transported by sea.[2] In the past, maritime routes offered the principal, if not the only possibility of connecting ancient cultures and economies. A huge amount of material documents have been preserved underwater practically intact though centuries and millennia. They are mostly concentrated in the Mediterranean and in its outflow in the Atlantic ocean, where exchanges always occurred, in ancient as well in modern times.

Due to physical, historical and legal constraints these archaeological resources have been considered in a completely different way compared with the land sites: "It was necessary to gain acceptance of the idea that the underwater cultural heritage is part of the universal heritage of humanity, just as significant and deserving the same protection as the cultural heritage found on dry land, and that it was necessary to liberate this heritage from the age-old tradition of "first-come, first-served" salvaging practice… The risks endangering underwater cultural heritage sites are multiplied by the widespread absence of protective legislation, which has, on the other hand, been generally enacted for dry land sites in most countries".[3] Underwater cultural heritage is still considered, in many cases, in the same (if not a worst) way that has been practiced in the nineteenth century by the major European countries in the first exploitation campaigns of the great ancient civilizations. "If you applied these principles to on-land archaeology it would drive a coach and horses through hard-won foundations of responsible heritage management".[4] The big business of treasure hunting is selling off the world's maritime heritage – and it's perfectly legal.[5]

The treasure hunters enterprises are earning millions of Euros in revenues selling thousands of gold and silver coins[6] and other artefacts that permitted to develop their business on an industrial scale and organization: collecting documentation on scientific basis for programmed investigations on site, investing in the most advanced technologies available on well equipped ships, when not small fleet, endorsing their activities with marketing and legal assistance on an international scale. Also the media support tends to create a favourable attitude of the general public toward romantic and challenging adventures against the forces of nature and time, avoiding to inform on the destructive impact of the exploitation of these irreplaceable monuments and of their historical context. "An inventory of all the wrecks who have been subject to excavation or salvage since the invention of the aqualung (autonomous deep-sea diving suit) half a century ago demonstrates that no historic wreck has ever been saved by commercial contractors or treasure hunters; only archaeologists have succeeded in this task".[3]

Underwater cultural heritage is then increasingly threatened by the impact of the indiscriminate use of effective techniques permitting to identify and reach ships lying far below the surface (Figure 1). In addition, it has been estimated that the monthly budget of a large private company is more then the annual budget of an outstanding research centre in the field of nautical archaeology.[5]

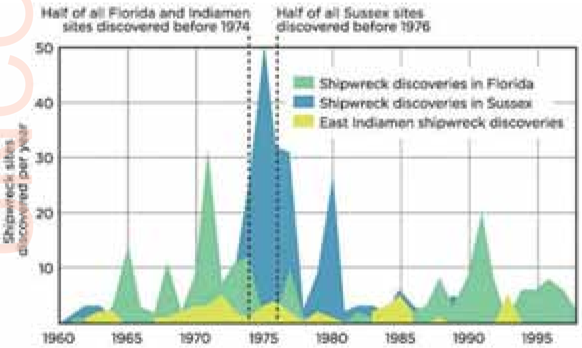

Figure 1: A study on shipwrecks in three parts of the world published by *Archaeology Magazine* that suggests that shipwrecks are a rapidly declining resource.[5]

A strong common effort is particularly necessary for countering the risks of destruction of this irreplaceable part of our cultural heritage. The European strategies of Lisbon, Barcelona, Bologna and the policy of integration of the efforts that is supported by various EU funded projects can provide the solid platform and the institutional support that is necessary for the

protection of European maritime cultural heritage by creating synergies and economies of scale by putting together results, expertise and equipments. The ArcheoMed consortium developed some pilot projects that can be implemented still further following this approach:
1.The integration of knowledge using new ICT advanced open source software solutions[7] for the sharing and the exploitation of digital cultural resources, especially with the databases *Maritime Archaeological Map of the Mediterranean*[8] and *Base de données épigraphiques sur amphores romaines.*[9]
2. The application to the archaeological research of advanced technologies and methodologies, usually developed in other scientific domains:
a) *The Paleoenvironment of Littoral Zones of the Mediterranean*[10]
b) *Monitoring and Protecting Underwater Archaeological Sites* that applies new technologies to the ship wrecks sites of the Battle of Trafalgar (Andalucía) and of the Golfo di Napoli.[11]
c) *3D Modelling* carried on ancient statues from the National Museum of Archaeology of Athens, the island of Delos and the Museo di Baia (Napoli).[12]
3. The *International School in Mediterranean Maritime Archaeology* (2007-2008) organized by the ArcheoMed Consortium with the involvement of various European universities, focused on the investment in human resources so as to train a new generation of specialists in the field based on new techniques.

In particular acoustics and robotics technologies offer some important opportunities for monitoring and protection of underwater archaeological sites. "Area security and surveillance at sea is a priority not only in a military scenario, but also in several civilian applications, ranging from situations in which access to the area is always forbidden to unauthorized personnel (marine protected areas, fish farming installations, archaeological sites), to situations in which access maybe temporarily forbidden or monitored (as in dock yards, harbours, etc.). The increasing interest of responsible authorities or private companies toward ways of detecting and monitoring unauthorized area access, together with obvious budget constraints, has led to the investigation and prototypal development of a low cost passive acoustic system for detection and tracking of surface crafts entering into unauthorized areas".[13]

Figure 2 The ROV (Remote Operating Vehicle) that has been upgraded by ISME (Interuniversity Ctr. Integrated Systems for the Marine Environment, Italy) with the new technical devices targeted for archaeological investigations (©Catarsi).

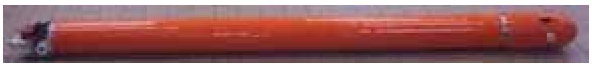

Figure 3 The low cost AUV (Autonomous Underwater Vehicles) "Folaga" built by the ISME moves on the surface and dives at pre-set points for collecting data. Typically an ideal vehicle on which to mount a side-scan sonar (©ISME).

Thanks to some good practices results is now possible to develop technical equipments designed for maritime archaeology, often as fallout of other application sectors (military or civilian), that fit the specific needs of archaeologists according two fundamental criteria: (i) The economic sustainability of their use and related services; (ii) The possibility of an effective use directly by archaeologists. The basic underwater research and monitoring should be a normal routine. The added contributions of technical experts (geologists, engineers, etc.) should be necessary only in particularly complex cases. The requirements of this approach will reduce the multipurpose performances of the most advanced and expensive apparatuses actually used for industrial use in maritime infrastructures (ports, pipelines, cables, etc. usually based on large international investments) to more specific functions, directly connected to the specific and targeted needs of underwater archaeology. In this perspective, ready to use apparatuses incorporating an advanced know how can be developed by innovative SMEs.

The public access to *in situ* underwater cultural heritage has to be promoted, except where such access is incompatible with protection and management.[14] Nowadays there are millions of divers in the world more and more interested in the underwater environment and cultural heritage. This phenomenon has important cultural and economic effects. The pioneer experience of the Louisbourg Underwater Museum (Canada) is very eloquent: "Outside the port, where the law of maritime salvage rules, there can be no diving because everything has been taken away and a desert is of no interest to divers; on the contrary, we see the continued arrival of plane loads of tourists from all over the world, divers who want to visit the famous underwater wrecks from the new European world, inside the port, where the Park has always guaranteed a sustainable scientific, patrimonial and tourist means of management…
All this happens inside the port; no one wants to dive outside the port. The evidence is striking: in the waters outside the port, the "goose that lay the golden eggs is dead" (R. Grenier).

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ENERGY EFFICIENCY RESEARCH IN HISTORIC AND PROTECTED BUILDINGS. A REVIEW OF EXISTING NORWEGIAN RESEARCH AND RESULTS

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Energy use in buildings constitutes a major part of the energy consumption. EU directives Energy Efficiency 93/76/EEC and Energy Performance in Buildings 2002/91/EC demands energy certification and enforces mandatory energy efficiency measures. But often measures to reduce energy loss are detrimental to the historic values of buildings.

We cannot in the future expect that historically interesting or even protected buildings all become exceptional cases, exempt from energy regulations and with high energy consumption.

But it is a fact that frequently applied energy saving measures – such as extra added insulation of the facades – may damage the cultural historic value of the building. This may again lead to demolition or major rebuilding projects which is also not advisable in a resource retaining perspective. Focus must therefore be on measures that do not demand major changes or interventions in the building. Such measures will also be more economical and easier to implement while achieving the wanted effects.

To develop and document alternative measures for improved energy efficiency is a task for the cultural heritage authorities and the scientific community to support sustainable development strategies.

This paper sums up research projects on energy efficiency in historic buildings carried out over the last years and gives some results.

Due to a ban on log construction in buildings proposed because this construction did not conform to the U-values demanded a study was commissioned to do a life cycle study of a traditional log house and a modern wood-frame house. The study "Energy consumption and environmental impact of buildings" (NBI 1995) demonstrated that the traditional building was not less energy efficient when analysed in a life-cycle perspective which included constituent materials. For this reason the clause in question was removed from the new building regulations in the beginning of the 1990-ies.

After some 20 years of government subsidies for changing windows in older houses a research project looked at the actual energy savings achieved. The study "Windows in existing buildings – maintenance, upgrading or replacement? Windows in existing buildings in a sustainable perspective" (NBI 1996) showed that changing windows in historic buildings resulted in net energy savings lower than the theoretical calculations. The main reason for this was that the new frame for the replacement windows was less tight than the original and that sub-quality work and materials went into insulating the new frame for the windows. Even with tight window frames the energy savings would be negative for a long period if the energy costs of producing the new windows were included.

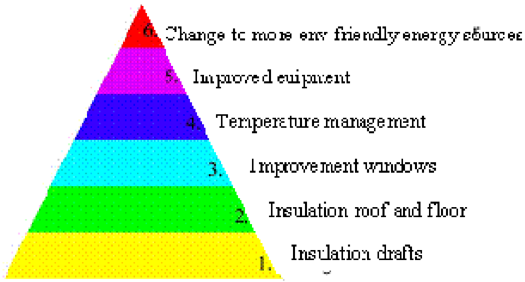

Figure 1: The steps and effects of different measures to increase energy efficiency in historic buildings.

Results from studies done by SINTEF on energy efficiency in older buildings (Energy saving in historic buildings, 2000-2004) by calculating effects from different non destructive measures proved that we may achieve a total and accumulated energy reduction of almost 80% by using such methods. A description of measures and achieved energy savings will be presented. We may through these step by step measures far exceed the demands of modern regulations without damaging the visible historic structures or changing the façade of the house.

Measure 1, Closing and insulating draft- Energy demand for heating reduced from 68 200 kWh/yr. to 63.900 kWh/yr.

Measure 2a, Insulation of beams between floor and cold loft: Energy demand for heating reduced from 63,900 kWh/yr. to 58,800 kWh/yr.

Measure 2b: Insulation of floor against a cold basement: Energy demand for heating reduced from 58,800 kWh/yr. to 46,400 kWh/ yr.

Measure 3: Installation of 1 layer windows with LE coating: Energy demand for heating reduced from 46,400 kWh/ yr. to 30,600 kWh/ yr.

Measure 4: Installation of new technology management of electric heating ovens (temperature control): Energy demand for heating reduced from 30,600 kWh/yr to 26,800 kWh/yr.

Measure 5 and 6 entails adding alternative energy sources and technology for covering the still missing energy demand of the house for obtaining the demands given by public regulations.

With all measures implemented the energy demand may be reduced from 68 200 kWh/yr to 26.800 kWh/yr

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ENERGY EFFICIENCY IN CULTURAL HERITAGE BUILDINGS – NORDIC APPROACH

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1. European and national legislation for energy efficiency

Climate change is considered to be the major threat to the welfare of mankind and the environment. European Commission has stated, that "...our buildings account for some 40% of European energy consumption. Our demands for lighting, heating and cooling, and hot water in our homes, workplaces and leisure facilities, consume more energy than either transport or industry."[1]

Under current rules, energy efficiency standards for new and renovated buildings have been set by national governments. In Finland the energy efficiency of new building constructions is nationally controlled by the National Building Code.[2] However, Commission could propose EU-wide minimum efficiency requirements, or overall limits on energy use, or establish performance requirements for individual building components. EU Directive of Energy Performance in Buildings 2002/91/EC has been a disappointment for the Commission due to the limited impacts and slow application in Member States. It is highly probable that the scope of the Directive will be broadened to concern existing building stock in addition to new building.

2. Objectives for building conservation

The most common means to improve the energy performance in existing buildings in cold climate is to add the thermal insulation of the building envelope and to build a heat recovery system. The accurate challenge for the building conservation sector is to find out, how it should be made without compromising traditional constructions, materials and the architecture of cultural heritage buildings and monuments.

The objectives for successful building conservation has been presented for instance in Venice Charter 1964, by ICOMOS and DoCoMoMo.[3] In short, the preservation of integrity and authenticity of design, setting, material and workmanship are the essential aims of building conservation.

3. Improving energy efficiency – the impact on built heritage

I have chosen cases showing the options and challenges to improve the energy efficiency without compromising the architectural and historical values of listed and existing buildings. The most typical building types are wooden log or timber buildings, blocks-of-flat of either solid brick walls or prefabricated, reinforced concrete elements.

3.1 Improving the energy efficiency of external walls

Under current rules the U-value for outer walls required in National Thermal Insulation Regulations from 2007 should meet the U-value 0.24 W/m^2K. According to the new requirements coming into force in 2010, it will be tightened to 0.14 W/m^2K. To build a new massive timber wall, in theory, you would need 840 mm wood!

According to the principles of building physics the thermal insulation should be added outside of the wall.[5] Architectural consequences would be detrimental: external boarding has to be replaced, windows and doors will stay into holes or they have to be changed and the building will loose its eaves used to safeguard the wooden wall structure from rain water. Looking after physically sustainable construction maximum 50 mm thermal insulation can be added inner side of the wall to prevent humidity condensation into the wall structure.[6]

30% of Finnish people live in suburban areas, in blocks-of-flats built in 1970' and 80', being now under heavy renovation. In many cases the external prefabricated wall elements are either covered (architectural change!) or replaced with new ones causing remarkable material loss.

3.2 Improving the energy efficiency of upper floors

Energy loss from upper floor is estimated 10% of the total energy loss. An easy way to improve the energy performance of heritage buildings is to add thermal insulation to the attic floor. Traditional sawdust can be added with cellulose insulation - both are more permeable to water vapour than mineral fibre wool. However, it will never meet the rules of National Regulations new draft: upper floor U-value should be 0.09 W/m^2K (meaning 760 mm mineral wool) instead of former 0.15 W/m^2K (450 mm).

3.3 Energy efficiency of windows

Windows are the most important architectural element in buildings. In Nordic countries double glazed windows were introduced already in 18th century. Air space between two window frames, one opening outwards and the other inwards, supplies a U-value 2.8 W/m^2K.[7] In the period of central heating, radiators are always placed under the window to pre-heat the incoming air.

Maintenance, sealing and fitting adjustment are recommended for improving energy efficiency of windows. Curtains and blinds are easy and cheap way to reduce energy loss. The most efficient way is to add a new third glass in a new separate frame.[8] Triple glazing or energy glass should be removable for summer to prevent the need for cooling. Comparisons where life-cycle, economic costs and energy costs are counted should be made. Wooden windows should not be replaced with aluminium and plastic ones. Loss of material is one type of energy loss!

3.4 Front doors

Front doors should be preserved for architectural reasons. Panel doors used as outer doors are typical for older buildings; nevertheless, they do not keep heat in cold climate. The new draft for National Thermal Requirements C3 states U-value to 0.7 W/m^2K (former 1.4 W/m^2K) can be achieved only by modern multi-layer doors with special thermal insulation. Adding a new door to the hall to form an additional "air lock" catch the wind and minimize draught.[9] In blocks-of-flats the room temperature of the staircase should be lowered.

3.5 Foundations - outdoor air ventilated crawl space

In cold climate the crawl space foundation is very common. New laboratory studies[10] show that to keep the crawl space dry, we need to pump the water out, and dry and ventilate the space with electrical fans nearly whole year round. I think building structures should function without electricity to really save energy. Traditionally crawl space was outdoor air ventilated through "cat locks" which were opened for summer and closed for winter. For winter snow was shovelled around the foundations to improve air tightness and thermal comfort of the house.

3.6 City and house lighting

The energy efficiency of lighting in houses can be improved by using the modern innovation "low-energy light-bulb" compact fluorescent lamp with E27 Edison screw. These lamps are designed to replace an incandescent lamp and can fit in the existing light fixtures. Electric power used for streets and façade lighting should be reduced to limit energy use. Light pollution has several harmful effects on biology of human beings, plants and animals.[11]

3.7 Heating and renewable energy resources

Heating systems remained decentralised until 1880' when the first central heating systems were introduced. In Finland district heating CHP (combined heat and power) has been the main means for energy production from 1950'. CHP is ecological and economical way to produce hot water and heating energy as a joint production from the electricity production. In building conservation CHP can take advantage of existing heating devises and radiators.

Finland's most important renewable sources of energy are bio energy, wood in particular, hydropower, wind power, ground heat and solar energy.[12] Traditionally each room had its individual wood burning stove. Stoves were designed as an integral part of the interior and architectural style. Wood burning stoves are still common and they should be preserved in use.

Other renewable energy recourses such as wind, sun, earth and air in old buildings need numerous new devices, installations and careful design. Wind mills in coastal areas have an effect on archipelago landscape. Earth pumps can take the heat from the sea,[13] but they might have an unknown effect on micro climate and the vicinity. Air heat pumps can be a disaster for the façade architecture.

3.8 Heating, cooling, natural ventilation and air conditioning

As a result of restoration works started in 1970', all listed public buildings in Finland are mechanically ventilated. Well designed and adjusted the HVAC devices can have a significant ability to energy performance in existing building stock. On the other hand, systems are short-lived due to the developing technology and increasing demands. Therefore, the installations should be reversible. Additional devices should be designed specifically to minimize their visual impact upon the building and the loss of historic building material. Historic and innovative installations should be identified and preserved as valuable examples of the history of technology and design history. Guidance for achieving the objectives of conservation of mechanical and electrical installations is given by Finnish Association of Museums[14], SPAB[15] or Secretary of the Interior's Standards of National Park Service.[16]

Natural ventilation is free and usually works well enough. Natural ventilation buildings have smaller amount of complaints than mechanically ventilated buildings.[17]

It is paradoxical that in cold climate cooling is actually needed because of the energy efficient windows and building envelope. In spring and summer time the Sun raises the room temperature. Therefore windows with good thermal isolation ability should be removable. If the windows are covered with solar coating, sun energy cannot be used for heating.

3.9 Heat recovery and the quality of indoor air

Heat recovery works only in buildings equipped with mechanical ventilation or air-conditioning. As an unintended side effect, heat recovery results to a remarkable material loss of a building. Traditionally horizontal floors of blocks were filled with natural substances peat, moss, turf, straw, sawdust etc. Low air pressure caused by mechanical ventilation equipments sucks the fresh air through structures contaminating the indoor air with microbes and bacteria; therefore nearly 100 per cent of implied renovations end up to remove all natural insulation material from whole building.

4. Recommendations

EU legislation is based on economical, juridical and technical aims. Authorities compiling legislation in European level are not in contact with the cultural heritage authorities in their home countries. So we need to compare the means applied in various European countries in order to improve the energy performance of listed and existing buildings, to preserve our built heritage.

CHALLENGES AND POSSIBILITIES FOR THE CULTURAL HERITAGE SECTOR; WITH EMPHASIS ON DEVELOPMENT IN THE FIELD OF POLICY, MANAGEMENT AND RESEARCH

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Change happens. To what extent have social changes of the last 50-years affected our work or our mindset? Have our policies and methods adjusted to the change in the European economy? To the growth of the leisure society and the increased number of cultural heritage consumers? To the need to preserve and appropriately reuse historic environments? To new definitions of historic valuable environments? or to EU policies for energy efficiency? etc. We would emphasise the developments, since 1964, as formative for the new situation in which we find ourselves.

There are 3 major trends. Trend 1. From destruction to valuable asset. Trend 2. From quaint to a non renewable environmental resource; sustainable development and sustainable management practices. Trend 3. Proliferation of valued objects and changed conservation focus; Charters and practices.

The 'new' trends that touch us most are:

1. The need for radical changes in environmental policies and resource use, forcing historic buildings to conform to demands developed and set for new modern buildings.

2. Widening of the concept of built cultural heritage and the proliferations of heritage objects, leading to an impasse when we try to manage these as monuments instead of use-objects.

3. The growing concern for development of the urban environment and destruction of historic buildings and ensembles. Even through politician say the urban historic centres must be preserved (the Leipzig Charter) the reality is the opposite. The instrumental use of cultural heritage to create a European.

4. Increased economic and employment importance due to the leisure economy and tourism.

5. The melting together of nature and culture conservation making cultural heritage a scarce and valuable common good which must be sustainably managed.

6. Qualitative technological jump in building construction, modernism and the insistence that modernistic is the only contemporary building style.

7. The lowered acceptance among the general public – increasingly touched by bullet 3 – for the government to protect their house without paying for the additional costs this brings.

We see these trends as important parameter for the need to develop new approaches and new types of projects. We will give some examples of case studies, best case practice, policy development, management, protection, town planning, enhancement, economics, etc. which we think point to future oriented solutions.

1. Participation and subsidiarity are accepted principles. But to what extent are the 'systems' open for people to be actively involved in the protection, preservation and the taking care of their (built) heritage? Cultural heritage buildings and environments as economic goods. To have economic studies and to be able to, as all other public policy sector to give economic statements and rationale (in addition to other valuable factors) for cultural heritage policies is a necessity. Economic figures are sometimes demanded by law.

2. Sustainability, climate crisis. Do we develop active and contributing policies? Do we develop policies that make rehabilitation competitive with new buildings when rehabilitation is a better environmental sustainability option?

3. Legislation. Building and energy regulations, amongst others, are threatening to make restoration and even rehabilitation of historic houses problematic, sometimes impossible.

4. Diversified conservation policies – mindset - Integrated management. The professional approach to conservation needs to be diversified for different types of buildings. The authorities need a more service minded attitude.

5. Urban policies. How may we more actively exploit the policy statements affecting our working environment? What rules govern upgrading historic buildings to keep them in use? How do we handle the potential conflict between conservation and the need for re-use and adaptation? What do we do about volumes and heights for new buildings in historic areas?

6. We might need to see cultural heritage protection and conservation as part of a larger Change Management Policy and to confront the challenges this brings with it.

1. Projects / Case studies 1. Participation and subsidiarity in heritage policies

The Norwegian project "Creating Assets in the Cultural heritage sphere" and the project in Radovljica in Slovenia ear examples pointing forward are examples of projects opening for more participation.

2. Projects / Case studies 2. Economic studies. Cultural heritage buildings & environments as economic goods

Here we will look at the Stonehenge example and others illustrating the need for and the benefit of economic studies.

Economy is the 'language' of our times. Economic figures, cost-benefit analysis etc. are now demanded by users / practitioners and the politicians. Cases: Stonehenge, Borgund, The electro centrals in Berlin. The maintenance and presentation costs of all these sites have tremendously increased the pressure on the State's budget while tourism has turned heritage into a market commodity. Market economics tools are showing to be more adapted and more efficient in preparing management and business plans of heritage sites. Without such tools the Stonehenge would today be crossed by a highway.

3. Projects / Case studies 3. Energy studies, environmental studies

We have known since 1972 - that this question will become more and more important. Great savings can be achieved without destroying historic authenticity. We need to move from a defensive position and become active in developing and proposing alternative solutions. We lack a strategy that includes cooperation with the private sectors. For example developing good substitution windows for historic windows in cooperation with the industry are such projects. Outreach to ownrs and managers is important to assist them avoid industrially promoted solutions.

4. Projects / Case studies 4. Working with legislation at the supranational level

The cultural heritage sector has a problem with the new legislation from the EU as this legislation makes prescriptive standards mandatory. Cultural heritage actors are traditionally focused on the national level and on national issues. We do not engage actively in legislative processes outside our domain; i.e. the heritage legislation. This leaves us little room for alternative solutions to achieve the same objective. We again suffer from our defensive or passive attitude; we are not proactive but react after a problem has become apparent. That is too late and leaves us no room to influence the legislation or the lawmakers. Cases: We have none. That is in itself interesting.

5. Projects / Case studies 5. The heritage mindset, development & use of legal frameworks, integrated management

Policies and legal frameworks are, in general, focused on Monuments. Less emphasis is on change and re-use oriented conservation. Protection orders are often seen a nightmare for the owners. Why? We are convinced it is to the benefit of the population. Research priorities are focused on technical questions of materials and their conservation, social and economical topics are hardly breached. Are our policies, attitudes and mindsets a danger to our legitimacy in the population and a reason for not being considered in political discourses? Why is there such a pressure on the administrations becoming more service minded, becoming partners rather than old fashion bureaucrats? Little research on our position and acceptance in society. Some opinion pools in certain countries.

6. Projects / Case studies 6. Change use projects - Urban policies.

The protection, enforcement and the sustainable development of historical Old Towns is an objective at European level.

Definition and use of historic urban landscapes (HUL) still not clear. There are 2 main dimensions to this challenging work and they are often in opposition to each other. One aspect is the wish to conserve the historic environment, the other aspects is the need to adopt this environment to contemporary use needs. How do we reconcile them?

Transformation projects and conservation / preservation of historic centres are becoming one of the main working areas of the cultural heritage administrations today. The challenge lies not only the projects internal multiple goals of conservation and use, it includes such issues as: which buildings to preserve, how to integrate new buildings, deciding retrofitting of existing and preserved historic buildings, (re)creating mixed living environments.

But cultural heritage is in demand! A number of new possibilities are open to the cultural heritage sector. We will look at some of these (urban development & the Leipzig Charter, the EU tourism policies, value and asset creation aspect, labour creation asset, environmental and energy questions). But to be partners in these processes the sector needs some shifts in working methods, mindsets and capacity building.

ECTP FOCUS AREA CULTURAL HERITAGE AND ITS ROLE FOR IMPROVED COORDINATION OF THE BUILT CULTURAL HERITAGE AT EU LEVEL

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1. Introduction

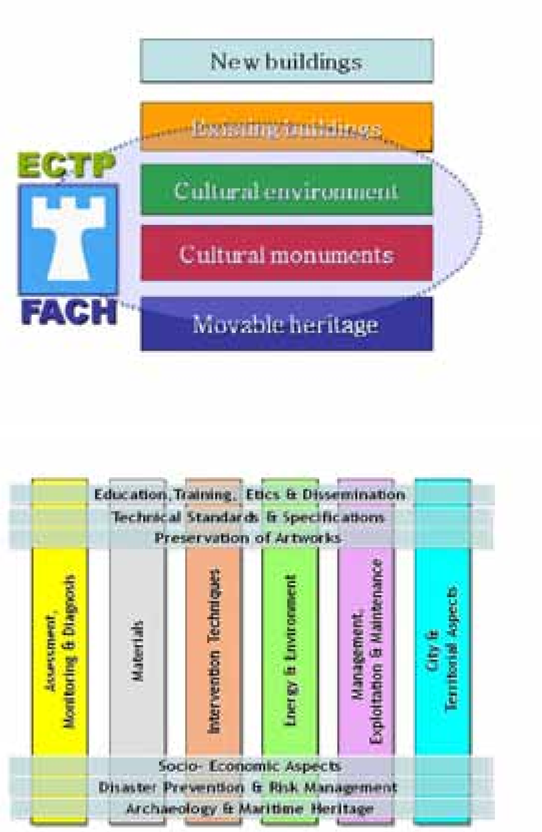
A general objective of the European care for heritage protection is to promote new sustainable and preventive strategies, concepts, methodologies and techniques for conversation and restoration of the cultural heritage in order to improve the quality of life of citizens and the attractiveness of Europe, particularly its cities, buildings and landscapes. The importance of this cultural wealth can be measured in economic and social terms, in employment, job creation and has considerable impact in many areas such as the environment, construction, tourism, regional development to enhance the European competitiveness and skills.

An important role in coordination of EU research policy in the field of cultural heritage research since 2004 has been the development of the Focus Area Cultural Heritage (FACH) as one of the seven Focus Areas of the European Construction Technology Platform (ECTP, www.ectp.org). FACH activities are carried out through cooperation of nearly 250 members. A major document that influences the EU research policy in cultural heritage is the FACH Strategic Research Agenda that is also integrated in the Strategic Research Agenda of ECTP and its Implementation Plan. The ideas of FACH were further developed and delivered through a number of documents of the FP6 project CHRAF – "Priorities and strategies to support Cultural Heritage Research Activities within ECTP and future FP7 activities". Documents of CHRAF have helped to identify priorities and develop strategies regarding CH Research as input to the ECTP and its SRA as well as to future FP7. This may also contribute to the exchange of information and dissemination of results of FP5-FP6 projects in CH research.

2. The research priorities as identified by FACH

Cultural Heritage is a clear priority for the construction sector in order to found a development of the sector based on knowledge and sustainability. At least two other ECTP Focus Areas "Quality of life" and "Cities and Buildings" are concerned by cultural heritage as regards the "discerned-quality" for a territory or a city, but also the Focus Areas "Materials and Processes" &" Information Communication Technologies" can interact with cultural heritage.

Research activities aim to establish systems for an integrated management of cultural heritage in Europe. These would ensure the safeguarding, regeneration and development of the Historic European Urbanized and Vernacular Environment, based on research-supported development and implementation of standardized modular "hard "and "soft" tools. These include strategies, technologies and systems for rational management, monitoring, surveying, documentation, evaluation, sustainable maintenance, public participation, communication and networking of units with cultural and natural heritage territorial values. Six main research topics of FACH must be developed to support this aim. In the short and medium term, the research has to focus on new assessment and management tools, new safeguarding and maintenance projects.



Napaka: vira sklicevanja ni mogoče najtiFigure 1: ECTP FACH targeted areas of interest and matrix showing the FACH fields of activities.

In the long term, new applications should ensure implementation of the research results. The research efforts should help to achieve the following targets:
- Make cultural heritage accessible for all;
- The service life of cultural Heritage assets, structures and materials can be predicted with 20% error and is the base of predictive maintenance plans;
- Reducing the decay of most significant Cultural Heritage by 95%;
- Improved safeguarding and consolidation of Cultural Heritage values in risk territories.
- All information generated during the study, restoration and maintenance process will be available and used for appropriate management;
- 25 important EU cultural heritage sites should be assessed using new specifications between 2010 and 2030;
- Cultural Heritage considered as an added-value for economical, social and environmental aspects and not only because of tourism impact;
- The safeguarding of Cultural Heritage as a solid pillar of sustainable development.
- Application of technologies and materials that do not impose the conflict between the various disciplines engaged in heritage preservation.
- Application of technologies and materials that are compatible with the physical and cultural nature of monument and that do not contribute to its long term deterioration

FACH members consider that the above listed targets can be achieved within several groups of interlinked projects. Not only researchers and professionals but also all European citizens can be well engaged in heritage safeguarding. This can be reached through development of awareness of need for constant maintenance of natural and man-made heritage and consequently through undertaking of variety of activities. It leads to the improvement of quality of life for all and to creation of a sustainable balance between the cultural heritage and economic benefits.

The changes of cultural heritage can be foreseen and managed through:
- Prediction of long-term behaviour of structures and materials in order to establish reliable maintenance plans.
- Development of understanding of mechanisms of degradation and deterioration of materials.
- Development of models for disaster prevention and risk management in historic materials and structures (climatic changes, earthquakes, fire, strong wind, landslides, flood, pollution, urban development, terrorist attack …)
- Introduction of the principles of rational use of energy in planning and execution of interventions as well as in management of heritage sites and buildings.

Assessment and control of the heritage can be achieved by:
- Development of an integrated quality control system based on the criteria of compatibility, sustainability and authenticity;
- Developing the science of monitoring from on-site applied technologies to the satellite technologies to assess harming processes and their consequences.
- Developing new predictive behaviour models for periodic maintenance
- Innovating in the creation of materials and structural components for cultural heritage:
- Development of materials adapted to better preservation of historic materials applying nano and other emerging technologies.
- Understanding the historic materials and technologies

The innovative and low intrusive intervention techniques should be developed and introduced in practice. The introduction of the replaceable additional or supplemental structural components is a substantial part of new intervention strategies. Special attention should be paid to preserving urban and built environment. Therefore, understanding of thematic and spatial governance interactions in cities is essential.

An innovative integrated analysis and planning mechanism taking into account climate and demographic changes should be also developed beside the holistic rational management and dissemination strategies. It will enable flexible use of Cultural Heritage for living cities.

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CHARACTERISING HISTORIC LANDSCAPES IN EUROPE

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Historic Landscape Characterisation (HLC) is a GIS- (Geographical Information System-) based form of landscape archaeology for understanding and representing landscapes with particular reference to their historical development. It has been developed in the UK, though cognate approaches are becoming increasingly common in other parts of Europe in the wake of the European Landscape Convention. HLC was developed at broadly the same time as the Convention, and has much in common with its aims and approaches. Perhaps most importantly, HLC recognises that landscape is ubiquitous, that it is fundamentally about perception, and that it can be seen in many different ways.[1, 2, 3, 4]

HLCs differ in important ways from traditional methods for describing the historic 'resource' such as inventories of archaeological sites or intensive field surveys. Instead of plotting individual archaeological sites as points or lines on a map, HLCs present more generalised interpretations of the whole landscape.

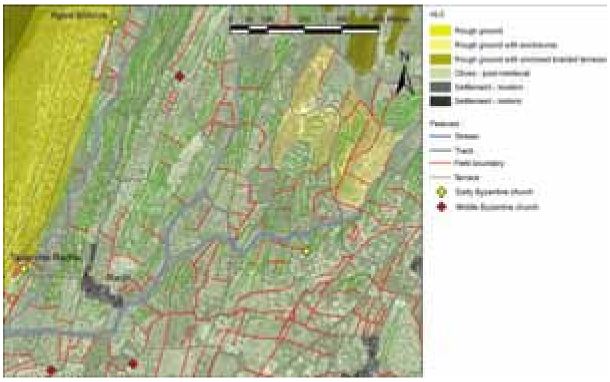

Figure 1. HLC of part of Naxos, Greece (includes IKONOS material © 2006, Space Imaging LLC. All rights reserved).[5]

Like conventional archaeological inventories, however, HLCs are rooted in an understanding of landscape as material culture and can be used to inform both landscape management and research. HLC recognises that all landscapes are historic, and that they all shape and are shaped by the people who dwell in them. In Europe, there are hardly any landscapes that have not been radically modified by people, but even the wildest places are still visited, lived in, changed and valued according to cultural meanings. It is clear that these meanings are not necessarily the same for each person, whether in the past or the present. Europe does not just consist of neutral land but instead of contested landscapes, experienced differently by different people depending on their perspectives. Even so, much of what people experience is rooted in materiality – the physical features that make up landscapes. People's perceptions of these landscapes are not completely subjective, but instead grow – at least in part – from that materiality.[6, 7] If we can accept that all the physical elements of a landscape can be appreciated as material objects with a range of different possible values for people in the past and present – whether they are buildings, ruins, earthworks, trees, hedges, plants, animals or whatever, then an 'archaeological' approach like this can give us a good framework for facilitating debate about the landscape.

In conventional archaeological representations, the depiction of sites simply as dots on maps has frequently separated them from their contexts, both past and present. No one methodology or source can summarise every aspect of a place, and neither HLC nor any other archaeological or historical techniques claim to do so. If we want a real in-depth understanding of a particular place, we need to bring together a wide range of sources and different types of data.[8] Using HLC can provide a way to present the historic context on a broader scale. In this sense, an HLC is different to conventional archaeological site-distribution maps or historic landscape surveys and analyses. New interpretations or new data can still be added to HLCs that have already been 'completed'. HLC is therefore not a monolithic approach, and different workers might choose to characterise the same area in different ways; there is no reason they should not.[9] HLCs are created in GIS, and the flexibility of GIS allows different interpretations to be added or removed easily. The aim of this is not to challenge or devalue the established methods of one discipline or another, but to facilitate exchange and communication of perspectives and perceptions. Rather than creating a definitive map of landscape features with particular values, an HLC is a presentation of a landscape's historicity, and should be open to negotiation based on different viewpoints. As archaeologists there is an urgent need for us to develop protocols and processes to bring such negotiations and debates into the public domain.

The value and implications of HLC-type approaches could therefore extend well beyond their immediate application by archaeologists: potentially, they provide a mechanism to facilitate communication, both between the various academic and professional disciplines concerned with landscape and amongst different groups of the wider public. One challenge is to develop HLC as a flexible tool to serve these purposes.

In this paper we use case-studies from recent research in Greece[5], Turkey[10] and the UK[8] to present the HLC technique and some implications for landscape management.

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ECONOMICS AND BUILT HERITAGE

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Built heritage is in an important sense 'priceless' but economic arguments are demanded frequently these days. Discussing heritage in economic terms can be seen pressuring. However, extending the discussion to the value adding potential of heritage in the regional economy can also bring us to a more fruitful debate on different values in our society and the necessary interplay between them. When different (sociocultural, economic) values get related to each other, the societal connections of heritage protection can be made visible, highlighting the significance of built heritage for both cultural, social and economic sustainability.

Among the specialists, there is a broad agreement that historic preservation is beneficial for the whole society and that it produces well-being and public good that outweigh the costs. In practise, in argumentation with the decision makers, in the langauge of budgets, more empirical evidence is expected. At the same time, a good amount of theoretical discussion on the theme already exists.

The *´public value´* of built heritage is discussed in Randall Mason's research (e.g. 2007) in a comprehensive way. The parallel evaluation of *intrinsic value, instrumental value* and *institutional value* supports the understanding of heritage as *both* public *and* private good.

Krister Olsson (2003) analyses the obstacles that the acknowledgement of built environment as a public good faces in practice. The private good characteristics of heritage are currently stressed in public planning. We need to develop new methods for valuing. The valuation scheme according to environmental economics, including *direct* and *indirect use value*, *option value* and *existence value*, is one possibility (Olsson 2008).

Is it possible to turn these values into numbers? Can all the public benefits of cultural heritage be measured in economic terms? Clearly not, and such attempts would lead us to loss or distortion of meanings. An overarching economic language is not an option. But while acknowledging the inappropriateness of money-based evaluation in certain key realms of the built heritage, in other realms it may well be relevant. Measuring the existing and potential economic benefits of cultural heritage to society, while, at the same time, clarifying the other value perspectives besides the economic one, might together lead to a better discussion on what is the "price of value" of cultural heritage. (See e.g. Mäntysalo & Schmidt-Thomé 2008.)

One possibility to find a basis for economic measurements is to apply methods that have been developed in environmental economics (see e.g. Ready & Navrud 2002; Schmidt-Thomé 2006). In these methods, heritage items are be seen as goods that are at the same public and private – and for which people might be willing to pay more than commonly expected.

The methods of environmental economics can give us knowledge on population's preferences. According to Ready & Navrud (2002) this knowledge can only improve decision making. Preservation of cultural heritage is traditionally based on profound knowledge and skilful work of experts. Many decisions concerning heritage are, however, in reality made in such a way that preservation experts themselves are treated as outsiders (see e.g. Olsson 2003). On the other hand, the changes in society can be seen demanding wider citizen participation also in questions related to heritage preservation.

The multi-disciplinary research platform "Economics and Built Heritage" (www.ebheritage.fi) wishes to shed light on the economic valuation of built heritage. One research interest is to tackle the public value of conservation, which extends from the economic to the cultural and political. On the other hand, new arrangements and forms for cooperation are needed, in order to maintain and develop heritage sites so that they can be considered succesful in terms of both economy and heritage preservation. To learn more about that, there is a demand for looking behind the scenes and studying cause-effect-relations. There is a clear need for a number of case studies, and comparisons across will be are important.

The European network aims at launching European research and development projects and wishes to make its work accessible for those that need the results.

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A RESEARCH NET FOR THE FUTURE OF CULTURAL HERITAGE

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Cultural heritage is the mirror of society. It constitutes the legacy of tangible artefacts, such as historical buildings and monuments, as well as intangible features, such as traditions, customs and practices. Tangible and intangible cultural heritage operate through a symbiotic relationship, whereby the physical symbols serve as evidence of underlying norms and values of a culture. Taking this into consideration, the importance of protecting tangible cultural heritage is significant not only in order to reflect on and to better understand the past but also to maintain identification in the future.

Figure 1: Val D'Orcia.

The cultural heritage of the European Union is crucial for establishing a shared European identification through progressive integration. The protection of cultural heritage is an extremely intricate endeavour, one which can only be accomplished by joining forces and maximising synergies. To add to this challenge, there have been no prior means to disseminate research results which applies to the protection of tangible cultural heritage. NET-HERITAGE European Network on Research Programme Applied to the Protection of Tangible Cultural Heritage) is the first significant initiative which has set out to coordinate national RTD programmes of European countries, and support European programmes in research applied to the protection of tangible cultural heritage.

NET-HERITAGE is a partnership of ministries, funding agencies and national RTD authorities from 14 European countries. It has embarked on a monumental effort to fulfil a crucial need within EU research policy: to overcome the barriers of exchanging information on coordinated research activity applied to the protection of tangible cultural heritage. Prior to the formation of this ERA-NET, information on heritage science consisted only of exchange among researchers, as well as dissemination to policy makers, end-users and professional non-researchers. This resulted in the value of heritage science remaining highly invisible and the exchange among researchers fragmented.

The existing national cultural heritage programmes, which NET-HERITAGE is building upon, indicate that this field is prepared for a European cultural heritage research network. The ultimate aim is to strengthen the foundation of scientific and technological research as it applies to the protection of cultural heritage in Europe. NET-HERITAGE will encourage a gradual unfolding and penetrating of cooperation among stakeholders. This will involve three stages: information exchange, strategic activities and joint activities.

Figure 2: Andria, Castel del Monte.

Figure 3: Tivoli, Hadrian Villa.

Within the information stage, the NET-HERITAGE Observatory, a web portal, will be developed as a response to European fragmentation. As a main access point on all issues related to European cultural heritage, it will be the only resource of its nature in the field of heritage science research providing detailed up-to-date information on European and national programmes, as well as results and research outcomes. Agreement on best practice and common methodologies will be facilitated through the development of a shared platform, which will lessen unnecessary effort and duplication. This key innovative instrument for information exchange will be active during the entire project and will provide the basis for future dissemination and collaboration activities.

Numerous strategic activities are planned. Some of these include the improved assessment of indoor and outdoor environments, environmental monitoring for pollution, climate change, and seismic risks – simple, cost-efficient measurement tools which end-users can utilise. Finally, joint activities will be possible by identifying common priorities to incorporate into national RTD programmes, strategic test cases, and common policies.

The impact of HERITAGE-NET will be vast, spanning the coordination of national activities, education, training and knowledge transfer, the inclusion of cultural heritage protection in EU legislation, and on the harmonisation and acceptability of technologies which apply to tangible cultural heritage. When it comes to cultural heritage preservation, the programmatic and operational approaches differ considerably among NET-HERITAGE partners. This is actually a strength, as it will provide a systematic exchange of information, experience and best practice for joint multilateral actions. One of the project's main outcomes will be the Advanced Training Programme which will address the needs of heritage professionals such as art conservators and conservation scientists.

NET-HERITAGE will provide an opportunity for Europe to maximise and coordinate combined efforts, which will in turn assist it with finding solutions in a global context. Furthermore, its contribution to a sustainable cultural heritage will support the European tourism industry in relation to growth, development and job creation. Essentially, NET-HERITAGE will facilitate the vision to redefine the national approach to research in the cultural heritage domain leading to a common European strategy of investment in research, thereby investing in maintaining Europe's identity in the future.

'It will be the only resource of its nature in the field of heritage science research providing detailed up-to-date information on European and national programmes, as well as results and research outcomes.

Figure 4: Tivoli, Este Villa.

Figure 5: Rome, Angelica Library.

HERITAGE CONSERVATION AND SUSTAINABLE DEVELOPMENT – INITIATIVES IN THE UNITED STATES

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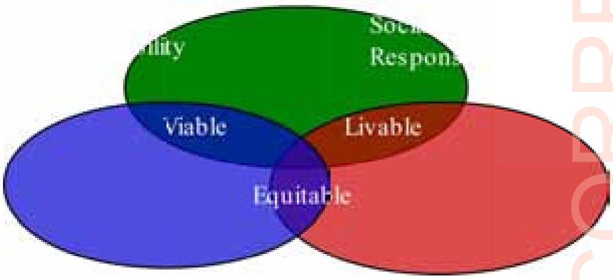
The sustainable development movement in the United States has been dominated by manufacturers of "energy efficient" building components and so-called "green architects" – two groups that have focused primarily on technological responses to energy conservation being incorporated into new buildings. This approach is extraordinarily myopic, however, on two levels. First it too narrowly defines "sustainable development" as simply environmental responsibility. To this end, the Environmental Protection Agency (EPA) has assembled and sponsored an independent NGO called the US Green Building Council (USGBC). The major accomplishment of this organization has been to establish a series of checklists to evaluate building projects. The system is called LEED, an acronym for Leadership in Energy and Environmental Design. Depending on the number of points received, a project may be rated certified, silver, gold, or platinum.

The broader concept of sustainable development which incorporates not just environmental responsibility but also economic and social/cultural responsibility is widely understood in Europe and much of the developing world, but not clearly grasped in the U.S. Internationally, principles of sustainable development recognize that for a community to be viable there has to be a link between environmental responsibility and economic responsibility; for a community to be livable there needs to be a link between environmental responsibility and social/cultural responsibility; and for a community to be equitable there needs to be a link between economic responsibility and social/cultural responsibility.



The Inter American Development Bank certainly understands the connection stating, "As the international experience has demonstrated, the protection of cultural heritage is important, especially in the context of the globalization phenomena, as an instrument to promote sustainable development strongly based on local traditions and community resources." to which the World Bank adds, "…the key economic reason for the cultural patrimony case is that a vast body of valuable assets, for which sunk costs have already been paid by prior generations, is available. It is a waste to overlook such assets."

But the 5-year Strategic Plan of the EPA doesn't even use the phrase "sustainable development". As with the EPA, there is at present a total absence of the more comprehensive understanding of sustainable development at the US Green Building Council.

Further, there is little credit given to the inherent contribution of heritage buildings even to the environmental component of comprehensive sustainable development. The latest LEED checklist to be released is LEED-ND for Neighborhood Development. Out of a possible 106 points, 1 point is given for being a historic building – the same as for adding a bike rack. But even that is an improvement. The current checklist for Existing Buildings gives no credit whatsoever for rehabilitating a heritage structure.

Numerous cities around the United States – particularly places known for environmental activism – are adopting their own "Sustainability Initiatives." Cities such as Seattle, Washington, Portland, Oregon, San Francisco and Berkley, California all have such programs. The primary focus of these efforts is the incorporation of "green gizmo" solutions to energy efficiency such as waterless toilets and back draft dampers. Frequently buildings meeting LEED certification will be given "fast track" approvals for construction or rehabilitation. But virtually none of them have anything in their sustainable development efforts beyond just environmental components. Santa Fe, New Mexico, founded in 1610 is one of the most historic cities in the United States. Recently they adopted a Sustainable Santa Fe policy. The number of times that historic preservation was mentioned as part of sustainable development in that document? Zero.

In response to this limited vision of sustainable development, three simultaneous efforts are taking place. First, the National Trust for Historic Preservation has begun a major public policy initiative to incorporate heritage conservation into broader sustainable development strategies. The National Trust is the major preservation education and advocacy organization in the United States. Their Sustainability Initiative operates on three guiding principles: 1) reuse existing buildings; 2) reinvest in older and historic communities; and 3) retrofit existing building stock. The initiative, which was begun in 2007, began by assembling the basic research that has been done to date on the relationship between heritage conservation and sustainable development. Correspondingly the Trust became active with the US Green Building Council

Second, research is being complied that demonstrates the positive environmental impact of saving historic buildings (as well as the negative impact of razing them) including such measurements as embodied energy, costs of landfill, adaptability of energy saving technologies into existing structures, and others. Among the preliminary findings are:

An estimated 1/3 of the existing building stock in the United States is anticipated to be demolished in the next 25 to 30 years

Construction and demolition debris constitutes around 25% of solid waste in municipal landfills

It takes nearly 65 years for an energy efficient new building to save the amount of energy lost in demolishing an existing building

245,000 houses are demolished each year in the US, generating 19.7 million tons of waste

Demolishing one small commercial building (two stories, 5000 to 6000 total square feet) wipes out the entire environmental benefit of recycling 1,344,000 aluminum cans

The energy embodied in the construction of a building is 15 to 30 times its annual energy use

Canada, Australia and Western Europe are far ahead of the United States in original research in this area, but that research is being identified and adapted to use in an American context.

Third, a few cities are rethinking their approach to sustainable development by consciously incorporating the redevelopment of historic buildings as a central element. While as mentioned above, the cities that have been centers of the environmental movement in the United States are creating "sustainable" strategies that deal with nothing except the environmental component of sustainable development. Even that focuses almost exclusively on annual energy use and nothing else. Meanwhile the small Midwestern town of Dubuque, Iowa (population 57,000) is far ahead of any of those places. It is in the process of designating its 28 square block warehouse district as a pilot project for a comprehensive Energy Efficiency Zone. And what does Dubuque have as a basic principle? That the adaptive reuse of those warehouse structures is key for energy conservation for Iowa's future. Likewise the even smaller community of Biddeford, Maine (population 22,000) is committed to reutilize some 2.5 million square feet of vacant textile warehouses to accommodate virtually all of the population and economic growth for the next two decades.

At most perhaps 10% of what the environmental movement does advances the cause of heritage conservation. But 100% of what the heritage conservation movement does advances the cause of the environment. Heritage conservation advocates may be late in getting to the "sustainable development" table in the United States, but today aggressive actions are being taken to make up for lost time.

CRESPI D'ADDA: PERMANENCE AND TRANSFORMATION OF A COMPANY TOWN IN THE UNESCO WORLD HERITAGE LIST

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1. Permanence and transformation of complex systems

Contribution focuses on the management tools for the built heritage, and in particular regards conservation and change at the intermediate scale. The case study refers to transformation assessment in urban planning.

Italian legislation[1], as well as the widespread awareness[2], has progressively accepted the innovatory vision, proposed since 1964 by the Franceschini Commission[3], whereby the cultural heritage is nowadays described as "any material testimony of civilisation", and matches, referring to historical architecture, with the more recent and inclusive notions of "built environment"[4]. Besides, the European Landscape Convention[5] defines the landscape as "an area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors". The general enlargement of the idea of "cultural heritage"[6] suggests a more extensive attitude and helps to overcome the traditional division between listed and non-listed buildings[7]. Afterwards, it seems useful to rethink about the traditional dichotomy between the strict conservation and the uncontrolled renovation[8].

The historic urban areas represent the multifaceted mean that heritage acquires in nowadays life: they hold a cultural value, often unevenly distributed, but also economical, usage, collective, public, social and even political assets. Our needs[9] progressively grow, and, reasonably, we often ought to prefer the most cost-effective project in order to produce physical, technical and functional changes. In this framework, we need a widespread approach for the built heritage, based on a systemic[10] and inclusive point of view, in order to adjust equally rules and degrees of freedom; the management tools allow us to measure maintenance, conservation, transformation and reuse of ancient buildings.

In a transformed context, the whole alteration is different from the addition of changes, as well as planned and methodically repeated; different levels of impact regard architectural details, edifices, complex systems, neighbourhood, and finally landscape. Therefore, it seems useful to develop definite criteria in order to deal with the global impacts, assessable at different scales.

Architectural heritage shapes environment, designates paths and frames, underlines boundaries and induces or prevents relationships and, at the same time, environmental context has a deep influence on architecture. It directs, at wide scale, the urban shape, and determines the displacement and the connection among the elements. Finally, we can describe any landscape as a unique palimpsest, continuously formed by superimposition of chance and deliberateness: environment, volumes, surfaces, patterns, match with usage and significance.

A significant context of application and improvement for this kind of investigation regard an intermediary size between the edifice and the wide scale, and particularly complex building systems, individually devoid of exceptional values but, on the whole, valuable as landmarks. At middle scale, the architecture is shaped on an exact functional program who establishes forms, connections and patterns. Nevertheless, at the present, it may be acknowledged that most of these structures seem to reflect obsolete needs. In many cases, loosing their previous role, landmarks acquire other meanings, and gradually become an independent element of identity for the local communities. In a widespread cultural context, they can constitute significant and unimaginable relationships, becoming part of thematic networks or diffused sites.

2. Case study: Crespi d'Adda.

Site on left side of Adda River, Crespi d'Adda (Figure 1) includes a large-sized textile factory and the related company town, increasingly developed between 1878 and 1927 by the factory owners[11].

The urban planning is rational and increasable: the main lane, that runs parallel to the river and leads to the graveyard, provides for a regular arrangement, and the same boulevard also divides production and dwellings. The lots, only in part completed, are distinctly discernable on maps; they are arranged in echelon formation or following a radial axel. Residences vary on a simple typology and strengthen unvarying aspect of the village.

Figure 1: Crespi d'Adda. Aerial view.

Ebenezer Howard theorises the "garden city" since 1898 and in 1903 establishes Letchworth; Crespi d'Adda, almost contemporary, presents the same ambivalence between countryside and new technology, the same spread vegetation, and even the characteristic broad boulevards, disposed on a radial axel.

ICOMOS evaluation acknowledges that "it survives remarkably intact, and part is still in industrial use, though changing economic and social conditions inevitably pose a threat to its continued survival". The UNESCO statement recognizes the authenticity of the village, and affirms that "a remarkable degree of authenticity has been preserved at Crespi d'Adda. All the Original elements - public, private, and industrial - survive intact: none has been demolished or substantially modified. There are some more recent constructions ancillary to the dwelling houses which are out of keeping with the overall appearance of the town; these will be removed when the municipal plan comes into full effect". Integrity assessment acknowledges also that "Although the evolution of economic and social conditions constituted an inevitable threat to the survival of Crespi d'Adda, its integrity is remarkable and it has partly conserved its industrial activity".

In spite of the meaning of this election, in 2003 the factory (Figure 2) has definitively stopped working, leaving Crespi d'Adda in need of new meanings and roles. This occurrence has altered the perception of the site, damaging the wholeness and the continuity of the setting[13]: the urban layout is still intact, but the factory along the river is nowadays inaccessible and decaying. Disconnected from the company town, the industrial unit became a frame between the residential area and the river.

Figure 2: Crespi d'Adda. The factory.

The company town, privatized since 1972, appears in a quite good state of conservation, but, in many cases, material genuineness is already compromised. The massive substitution of plasters and fastenings supports the maintenance of outward appearance but contradicts the authenticity of the site (Figure 3). Besides, garages and storerooms were built among the residences, altering the perception of the zone. Contemporary needs of inhabitants request a measured and conscious adaptation, that can not be deferred, and the simplistic and predictable solution of a fake return to 19 century, in order to increase the tourism, conflicts both with the needs of the inhabitants and with the utopian idea of yore.

Figure 3: Crespi d'Adda. The private residences.

3. Assess performances and manage transformation

Performance based approach is a tool able to detect real assets for managing and evaluating change of edifices, and is established on six performance classes, as identified in Italian voluntary normative: safety, comfort, availability, appearance, management and environmental protection[14]. Evaluation of the present performances is currently used for ancient buildings, but new for a wide scale. The aim of the study is to assess characteristics of urban aspect, with particular interest in social and psychological effects induced by the urban planning. Describing complex building systems, we often meet a seeming contradiction: we can observe main characteristics from a few and often inaccessible viewpoints, as aerial views, fixed perspectives or reciprocal sights, but, even if we cannot distinguish the total plan, however we can perceive it in factual fruition. Previous studies suggest that urban aspect can be evaluated[15] as the whole of conditions of legibility and discernment in everyday experience; therefore, we ought to analyse the attractiveness evaluating both, the formal qualities (as paths, boundaries, nodes, references) and the possible uses.

The research bases on desk analysis, questionnaires, and repeated surveys in six significant places (Belvedere, Piazza Vittorio Veneto, Piazzale della chiesa, Viale cimitero, Piazzale Piemonte, Viale Donizetti.), in order to evaluate the factual use and the people's belief. The study assesses the use of public spaces for an indicative sample of users, during a considerable period (April- June 2008) analysed in favourable hours; people use the most public spaces during the morning and the afternoon and during non- working days. Finally, we can identify two main groups of users: the inhabitants and the visitors, with different paths, timetables and needs.

Finally, it might be possible to introduce in brief the most important elements for the upcoming urban planning: additional constructions near the residences obstruct several views, and are clearly identifiable on the plan. The overall view of the site is hindered and the interview reveals a general discomfort for residents and visitors. This uncontrollable legacy expresses reasonable needs but constitutes the focal challenge for the significance of the village, especially when the rejection of the industrial heritage jars with the obsessive filling of the private spaces. Indeed, referring to the meanings of the architecture, the outcome of desk analysis matches with the interviews, and reveals numerous decayed and unemployed buildings in the village. On the contrary, the new settlements, respectful of the green belt, have no influence on the general urban planning and awareness.

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THE CULTURAL VALUE OF THE BUILT HERITAGE IN THE INTERNATIONAL DOCUMENTS DEDICATED TO THE PRESERVATION OF THE CULTURAL HERITAGE

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Abstract

In this paper the evolution of the concept of cultural value in several international documents will be analysed. In 1931 the Carta di Atene[1] was released by the Advisory Council for Antiquities and Fine Arts in Italy. Monuments of historic, artistic or scientific value are recognised. The work of the past shall be respected without prescribing the style of a certain epoch. The 1933 Charter of Athens was a result of the 4th CIAM (International Congress of Modern Architecture), with the potential heritage of so-called "urban slums" being denied. The Venice Charter[2] or The International Charter for the Conservation and Restoration of Monuments and Sites was released in 1964 by ICOMOS (the International Council on Monuments and Sites). It extends the concept of historic monument to more modest works of art which have acquired cultural value. It also accentuates the value of historical evidence. 1975 was declared by the Council of Europe as European Architectural Year and in this year were released: the European Charter of the Architectural Heritage[3] and the Declaration of Amsterdam.[4] In the age of participationism they introduce the concept of "integrated conservation". Finally the Nara Document of Authenticity[5] was released at an ICOMOS Symposium.

1. Introduction

Culture means the totality of material and spiritual values created by the human kind and of the institutions necessary for the communication of these values.[6] Consequently, cultural value is the totality of material and spiritual values of the built heritage. Crişan[7] defines the cultural value as being the complex out of inner and associated values which characterise different components of the built heritage.

First the cognitive and educative value of the built heritage was recognised, implying also the aesthetic and the economic value,[8] during the French Revolution.

In 1903, Alois Riegl writes about the identity and social perception of the historic monument.[9] Riegl identifies the various values of the built heritage which makes it to be a monument:

- Rememoration values,
    - Age value,
    - Historic value,
    - Intentional rememoration value,
- Contemporaneity value,
    - Use value,
    - Artistic value,
        - Novelty value,
        - Relative art value.

The evolution of the concept of cultural value in the following international documents will be analysed:

- Carta di Atene (1931),
- Charter of Athens (1933),
- The Venice Charter (1964),
- European Charter of the Architectural Heritage (1975),
- Declaration of Amsterdam (1975),
- Convention for the Protection of the Architectural Heritage of Europe (1985),
- The Nara Document on Authenticity (1994).

2. Carta di Atene - 1931

In 1931 the Carta di Atene[1] was released by the Advisory Council for Antiquites and Fine Arts in Italy.

According to research undertaken by the Getty Institute[10] this document was a major source of ideas expressed in the Venice Charter. It is stated that preserved should be the works in which the civilisation has found its most high expression and which are in danger. In case that a restoration is unavoidable because of degradation or destruction, it recommends that the historic and artistic work of the past is respected without prescribing the style of a certain epoch. Monuments of historic, artistic or scientific value are recognised. Special recommendations are made for archaeological findings.

The conference recommends maintaining a function within the buildings, but the modern destination shall respect the historic and artistic character. Reinforced concrete may be used if the aspect and the character of the restored monument are not altered. It is also recommended that in the city, especially in the vicinity of antique monuments the character and the physiognomy of the city shall be respected. The same applies for picturesque views. Publicity, telegraph poles and aggressive industry shall be avoided in the vicinity of art and history monuments.

The document was followed in 1932 by the Carta Italiana del Restauro.

3. Charter of Athens - 1933

The 1933 Charter of Athens was a completely different document. It was a result of the IVth CIAM (International Congress of Modern Architecture). It promoted the functional city, with singular blocks within a green area instead of so-called "urban slums" the potential heritage value of these being denied. The "slums" around monuments shall be demolished and green space shall be created, as promoted by Le Corbusier.[11] Also, it promotes a "statistic" view on heritage,[8] as it recommends a selection of historic buildings to be kept, while similar ones can be demolished. It promotes reconciliation.

4. Venice Charter - 1964

The Venice Charter[2] or The International Charter for the Conservation and Restoration of Monuments and Sites was released in 1964 by ICOMOS (the International Council on Monuments and Sites) at the Second International Congress of Architects and Technicians of Historic Buildings.

According to the Getty research[10] it continues to be the most influential international conservation document.

"The concept of an historic monument embraces not only the single architectural work but also the urban or rural setting in which is found the evidence of a particular civilization, a significant development or an historic event. This applies not only to great works of art but also to more modest works of the past which have acquired cultural significance with the passing of time." (article 1).

The main principles are based on the concept of authenticity and the importance of maintaining the historical and physical context of a site or a building (articles 6, 7, 8, 14). It sees the monuments not only as works of art but also as historical evidence (article 3).

It continues the idea set in the Carta die Atene[1] regarding the preservation of monuments with works from different periods (article 11). It also continues the idea set in the Carta di Atene[1] regarding modern uses in historic buildings and the use of modern materials. The process of restoration shall "preserve and reveal the aesthetic and historic value of the monument and is based on respect for original material and authentic documents" (article 9).

5. European Architectural Year - 1975

The year 1975 was declared by the Council of Europe as European Architectural Year and in this year two important documents were released: the European Charter of the Architectural Heritage[3] and the Declaration of Amsterdam.[4]

European Charter of the Architectural Heritage - 1975

The Charter[3] first states the "irreplaceable cultural, social and economic values represented by historic monuments, groups of buildings and interesting sites in both town and country." In the first article it states that "The European architectural heritage consists not only of our most important monuments: it also includes groups of lesser buildings in our old towns and characteristic villages in their natural or manmade settings". Thus it sets accent on the surroundings of monuments which contribute to their character. "Entire groups of buildings, even if they do not include any example of outstanding merit, may have an atmosphere that gives them the quality of works of art, welding different periods and styles into a harmonious whole. Such groups should also be preserved." The nature, importance (spiritual, cultural, social and economic) and threats (dangers) to European architectural heritage are defined.

It puts forth a concept which is called "integrated conservation". This is a mean to avert the dangers in which heritage is. It encourages training facilities. It is achieved through sensitive restoration techniques and appropriate functions. For the integrated conservation legal, administrative, financial and technical support are necessary.

The Charter aims to a common European policy for the protection of architectural heritage and calls for co-operation.

Declaration of Amsterdam - 1975

The Declaration of Amsterdam[4] was adopted by the Congress on the European Architectural Heritage, Council of Europe, in the same year 1975.

It emphasizes the formerly stated roles of planning, education, legal and administrative measures in the protection of European heritage.

It goes in detail in explaining what "integrated conservation" means. "Integrated conservation" calls for co-operation between architecture and urban planning. Thus architectural conservation must become an integral part of urban and regional planning. Also "integrated conservation" calls for participatism. "A policy of conservation also means the integration of the architectural heritage into social life. The conservation effort to be made must be measured not only against the cultural value of the buildings but also against their use-value. The social problems of integrated conservation can be properly posed only by simultaneous reference to both those scales of values". Local authorities and citizens must be involved in conservation. Conservation must not remain a matter for experts. The public opinion and the affected people are important supporters of conservation measures. This was one of the key elements of participatism. Means for participation are also named in the declaration. If possible, the change of residents through restoration shall be avoided. "In order to enable the population to participate in the drawing up of programmes they must be given the facts necessary to understand the situation, on the one hand through explaining the historic and architectural value of the buildings to be conserved and on the other hand by being given full details about permanent and temporary rehousing […] This practical way of interesting people in culture would be of considerable social benefit". The recommendations of the Declaration of Amsterdam will be put in the greater frame of the participative movement in the 1970s.

A great importance is given to training and education of young people and for conservation as a prospective discipline. A basic consideration is that "apart from its priceless cultural value, Europe's architectural heritage gives to her peoples the consciousness of their common history and common future".

Again, it is stated that "the architectural heritage includes not only individual buildings of exceptional quality and their surroundings, but also areas of towns and villages of historic and cultural interest […] Protection is needed today for historic towns, the old quarters of cities, towns and villages with a traditional character as well as historic parks and gardens, The conservation of these architectural complexes can be only be conceived in a wide perspective, embracing all buildings of cultural value, from the greatest to the humblest – not forgetting those of our own day together with their surroundings".

Contradicting the Charter of Athens (1933) it sets for historical continuity in order to enable individuals to feel secure despite abrupt social changes. Thus it calls for a new town planning, other than the functionalist one. It was the age of participatism. It continues the idea of the Carta di Atene[1] and of the Charter of Venice[2] regarding new functions in old buildings.

"The recognition of the claims of aesthetic and cultural values of the architectural heritage should lead to the adoption of specific aims and planning rules for old architectural complexes". There must be an integration between the common planning regulations and those for protecting historic buildings. With this purpose it calls for an inventory of the buildings, complexes and sites with cultural value. Financial means for "integrated conservation" must be assured.

6. Nara Document of Authenticity - 1994

Finally the Nara Document of Authenticity[5] was released at an ICOMOS Symposium. Authenticity is a more recent concern in what regards the conservation of cultural heritage. The Nara Document builds on the Venice Charter[2] in what regards the cultural value. It introduces the concept of cultural diversity. Cultural and social values of all societies must be preserved, respect for other cultures must be exercised. The value of cultural property must be judged depending on the cultural context to which it belongs. Although the management and care of heritage are primarily in the hands of the culture which produced it, adherence to international charters and documents must be given. [10]

7. Discussion

Crişan[7] observes that built objects are not just material resources, but also cultural resources. In fact, the discourse on resource architecture is a contemporary one. The Congress of the International Union of Architects which took place 2002 in Berlin was about resource architecture. The 21st World Congress of Architecture had the main theme "Resource Architecture". The topic was in concordance with the growing importance of 'sustainable development', a lasting priority topic in the Framework Programmes of the European Union. One aspect of 'sustainable development' concerns the environment. Sometimes this has a focus on protection of the environment, for example from aging or disasters, other times it is explicitly oriented towards the cultural heritage. The built environment stays at this junction between 'architecture' and 'urban planning', between the single building and the city. The "resource architecture" stays even more, at the junction between the natural and the built environment. The building process has used the natural environment as a resource, while the built object is a resource in itself. The "resource architecture" shapes and is shaped by the ecologic, social and cultural side of our lives. Architecture takes place in a context, in a dialogue civilisations and cultures, but also of disciplines, as debated at the congress. A dialogue of civilisations concerns the techniques, one of cultures of traditions, but the materials used in the process of building concern how innovations can build on traditions. Local materials are a material resource and regional identity a spiritual resource. Genius loci can mean how to build in context respecting the heritage in techniques and concepts of beauty formed over history and tradition, planning and building to protect the material resources and to increase spiritual resources.

The 20th century offers a methodological perspective on restoration in its policy documents.

According to Crişan[7] any architectural product includes cultural value elements. The author also states that even the architecture works not protected legally if they belong to historic-architectural heritage they possess characteristics which belong conserved from the point of view of associated cultural values. The author proposes a classification of cultural value which is common in Romanian site surveys in:

- Outstanding cultural value: potential monuments, conditioned by the authenticity of the resource,

- Architectural value: conditioned by cultural identity;

- Environmental value: the resource contributes to the cultural quality and significance of a historic urban context, the cultural identity is at urban scale;

- Minor cultural value: the cultural significance of any architectural product.

Seen from the point of view of such a classification, the concept of cultural value evolved during the 20th century from considering only the first category up to the environmental value of a building in a group of buildings of outstanding value as a whole. It is about the scale at which the objects of cultural value are seen.

Another matter worth discussion is the participatism. While the Carta di Atene[1] called for interdisciplinary co-operation, the documents released in the European Architectural Year (1975) call for something broader, the so-called communication.[13,14] Communication is a collective concept of the following activities in the process of planning:

- Information, as pre-requisite,

- Participation, as communication in tighter sense with the citizens,

- Coordination, as accord about measures, programs etc. between the dependent actors of a sphere,

- Cooperation as work together of independent actors from different spheres. A step between coordination and cooperation is the work together of independent actors from a sphere.

The history of participation and communication is now 40 years long, and in this development we can distinguish two generations.[14] The 1960s were the pre-history of participation. In the 1970s it was the blossom time of participation. In the 1980s and 1990s there is already the second generation, the one where it is more about communication than about participation, the modalities of involvement of affected people change. It was the 1970s when the concept of "integrated conservation" was released, and it promotes the participation of affected people and decision makers like local authorities besides of the experts. Although it cannot be compared to more complex models of participation, it is an attempt to include these views.

Finally, the Nara Document on Authenticity[5] differentiates the groups of people, being experts, affected people or local authorities dealing with the cultural heritage object. Authenticity can be material authenticity, concept authenticity, execution authenticity and location authenticity.[8]

It must be noted that the "integrated conservation" concept was developed in Europe, and the classification of epochs of participatism refers to Western Europe[14] while in other cultures it may be different.

8. Conclusions

An evolution in the attribution of cultural value can be observed. First the Carta di Atene (1931) recognised the monuments of historic, artistic and scientific value, recognising the contribution of all epochs. The next analysed document, the Charter of Athens (1933) is a radical document. While still recognising the value of monuments, it denies the value of historic urban tissue which takes the form of so-called "slums", and in the environment of monuments it promotes replacing these with public green spaces. It is one of the areas where significant evolution will be made in the following documents. The Venice Charter (1964) expands the concept of historic monument to more modest works of art which have acquired cultural value. The physical context of a building shall be maintained. The context becomes even larger as set in the European Charter of the Architectural Heritage (1975) and the Declaration of Amsterdam (1975). Both promote the so-called "integrated conservation". Within this concept, the conservation expands from the single building to urban or regional scale, to groups of buildings and interesting sites. Even if none of the buildings in a group has outstanding merit, the group as a whole can have. Apart of expanding the scale at which cultural value and conservation are dealt with, the documents released in the European Architectural Year call for broader participation as just the one of experts. Already the Carta di Atene (1931) called for interdisciplinary co-operation, but in 1975, during the first generation of participatism, this shall be more, it shall be communication with non-experts, the affected people and the decision makers in the local authorities. Finally, the Nara document on authenticity, though bringing up a concept dealt with already in earlier documents, expands the role of those concerned. Only the culture which brought out a certain heritage can decide over its conservation. It is participatism seen in a broader way. Also here the affected people decide.

The layout in the plans of buildings, its innovative elements, is part of the concept authenticity. It builds one of the elements contributing to architectural value, one cultural value category. Therefore the study of cultural heritage policy documents regarding the cultural value is useful for the study of "The innovation in the plan of the current floor: Zoning in blocks of flats for the middle class in the first half of the 20th century", an ongoing research project of the author, in order to determine which are the elements to be conserved in interventions for changed living standards today.

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THE ARCHAEOLOGICAL PARK ACTIVITY IN SLOVENIA: BUT WHEN?

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1.Introduction

The aim of this article is to present archaeological open-air sites and monuments in Slovenia or so called archaeological parks. First I am going to introduce the past management which was in many ways inappropriate for the monuments and I am going to show some obstacles that seem to be the reason for the current as well as past situation. Also, I am going to present some potentials and possibilities for the development of cultural tourism or any other form of heritage usage in the frame of Slovenian legislation, and offer some solutions.

There are several problems concerning the topic, however, the most pressing is the absence of any kind of management of these sites. A proper management, including better presentation, interpretation and the usage of archaeological open-air monuments, would, for example, increase the understanding and experience of the monument and archaeological past, improve the access, prolong the stay of visitors at the site, and last but not the least, increase the promotion and recognition of Slovenia's rich heritage and in a long-term, offer some possibilities for the development of cultural tourism.

The solution for the problems seems to be the organisation and establishment of archaeological parks as such. We actually have in mind the archaeological park activity, which includes employees who properly interpret, prepare and perform supplementary activities for the visitors, as well manage the restaurants, souvenir-shops, etc.

Although more than 100 years have passed since the opening of the first open-air museum in the form of organization, and soon after several archaeological parks have been founded all over the world[1], this practice of heritage management has not been adopted and applied so far in Slovenia.

2.Situation: Opportunities and obstacles

Terminology and Definitions

Before we start I would like to stress the two terms that represent the two main issues of this article. The first is archaeological park in the narrow sense of the word and which represents a protected area with archaeological remains in situ, has the form of a park with walking trails and includes no other additional activities.

The other term is the activity of archaeological park which requires the organization that manages the archaeological site, performs a series of activities, provides visitor service and usually includes additional interpretation centre or museum, restaurants, souvenir-shops, etc[2].

At this point we could discuss the use of different terminology[3]; however that is not the main topic of this article. In the article, we are interested in the conditions and steps that have to be made to transform archaeological park to the activity of archaeological park and factors that have brought to the current situation in Slovenia.

I would also like to mention the distinction between the two additional terms: archaeological park and open-air museum, where the main difference is the position of the monument: whether we refer to the monuments *in situ* or we refer to a collection of monuments that have been moved to the park from their original site. However, when we talk about the activity of both phenomena there is no significant difference between the two[4].

The number and types of archaeological parks in Slovenia

Slovenia has a rich archaeological heritage from all the archaeological periods. Since the end of the 19th century almost 50 monuments or sites have been transformed into a form of archaeological park[5] (Figure 1). The classification of open-air sites in the main groups has been done by Marjan Slabe[6], as well as presentations with park arrangement, single monument units, monument ambiences with functional characteristics, monuments in natural or urban environment and monuments inside modern buildings. To his typology we could add archaeological trails, several of which have been designed in the past 20 years.

Figure 1: Distribution of archaeological parks in Slovenia.

In Slovenia we can find all types of presentation (i.e. conservation, restoration and reconstruction), all types of sites (settlements, graveyards, military and civil objects, profane and sacral objects), as well examples of sites from all archaeological periods. The most common are presentations from the Roman times and early Middle Ages. Presentations of prehistoric sites are less numerous and mostly deal with historical landscape. So far, only one reconstruction of a late Bronze Age settlement with several houses has been built.

Figure 2: Ruins of Roman villa in Simon's Bay near Izola: monument of a state significance in neglected condition, without any interpretation tables and with no access provided (Photo: A. Breznik).

Shortcomings of the sites in question and management of archaeological parks in the frame of Slovenian legislation

A short description shows a rich past activity in presenting archaeological monuments. The main problem with the Slovenian archaeological sites is almost a complete absence of the monuments in public life, which means that they do not get recognised, nor they receive any credit from their environment. Unfortunately the absence of proper management also results in neglect and ruin of several spots. I guess it is needless to say that that the main care for the monument starts after its presentation, which includes constant conservation, maintenance, revitalisation and inclusion of the site in local tourism scheme. At this point we must critically admit that we have failed in that.

There are several serious problems that stand out when dealing with the monuments in question:
- The absence of proper signalisation and interpretation tables in many cases;
- The monuments have been kept outside the public domain;
- The absence of general information and promotion in the media;
- Almost a complete absence of any usage or inclusion in tourism;
- The time spent at the site is very short, about 10–30 min;
- No additional interpretation or reconstruction are offered that would add to the understanding of the ruins;
- Some of the monuments are locked and therefore closed to public with no access provided;
- In worst cases, some of the monuments are neglected and on the verge of destruction;

At this point I must stress that there are a few outstanding bright examples, such as Šempeter Necropolis, Ajdovski Gradec, Most na Soči, where the care for the sites, but not the management, has been provided by the local societies.

However, there was no interest in appropriate use or inclusion of these monuments into the public life or tourism in the past. Partly this was due to the former Slovenian legislation, which did not allow for management of cultural heritage within the private sector. Only management within the public sector was possible. The problem issues of public service seems to have been (or still is) the lack of interest, knowledge, financial support, business-like mentality and the lack of human resources. The new Cultural heritage protection Act[7], enacted this year, introduced some improvements in this area. Now privately owned institutions or private persons may also manage these sites, so positive changes are expected in the future in this area.

3 The establishment of archaeological park in a form of organisation?

Archaeological park in a form of an organisation seems to offer some solutions for the problems mentioned above. Of course, we cannot establish 50 new organizations for all the monuments, but in some cases this type of organisation and management would represent the most suitable option. Such institutions employ a large number of people, offer a classical way of presenting archaeological findings, and generate supplementary activities. This kind of presentation actually offers a leisure time activity and is also attractive as a tourist product.

4. Suggestions

The main question is how to realize the archaeological park activity in Slovenia? Although the new Cultural Heritage Protection Act as well the National Program for Culture[8] in general support such projects, they only provide some basic guidelines. What we miss are more tangible provisions that would ensure proper management of these sites. Generally speaking, part of the blame also lies in the lack of business-like mentality and in the failure of potential managers and financial investors from public and private sectors to recognise the potentials for the development of various tourist activities[9].

Our suggestion is that the state and its institutions, such as the Ministry of Culture and the Institute for the Protection of Cultural Heritage of Slovenia, start to play a more active role in finding suitable managers and in supporting business-like mentality.

We would also suggest the formation of a multidisciplinary group of professionals from the institutions mentioned, with skills in heritage management, economy, tourism and law. The main mission of this group is to be the preparation of the guidelines for the site management, controlling the use of the sites, and active search for managers, supporters and financial investors.

We would also suggest the founding of one or more organisations to perform the activity of an archaeological park, similar to ethnographic open-air museums in Slovenia which operate as governmental non-profit institutions. This idea is also supported by comparison of most famous foreign examples of ethnographic and historic open-air museums in Western and Central Europe[10]. Of course, before that, a reasonable categorisation of the sites should be done and selection of the few with greatest potential for development of archaeological park activity, which is also the topic of my PhD dissertation.

5. Conclusion

Despite the fact that the idea of archaeological parks and open-air museums has been alive for more than 100 years since the establishment of the first open air museum in Sweden, the activity of archaeological park presents a modern concept of heritage management. The presentation of ruins has been improved by new attractive presentations and series of activities for visitors, which all together form a tourism and leisure time product. The activity of archaeological parks has become a multidisciplinary activity that combines functions of heritage protection, education, science, marketing and tourism.

Figure 3: Roman Necropolis in Šempeter near Celje: a good example of archaeological open-air museum with potentials for development of tourism attraction (Photo: A. Breznik).

Slovenia, on the other hand, has so far failed to adopt the associated strategies. In fact, the situation in Slovenia is paradoxical, especially because the country has more than 50 open-air archaeological monuments of the highest quality which are all kept outside the public domain. It is obvious that the potentials of "dead cultural capital" have not been recognized yet and modern concepts of heritage management have not been adopted so far. One of the obstacles could be the past legislation;

nevertheless we could also claim that the problem did not receive enough attention in the past.

The current situation demands from us to pay more attention to the problems, to look for and employ heritage managers and other experts to manage these sites, to encourage local communities to help, etc. By looking into and comparing some foreign parallel examples we could righteously claim that a full governmental support is needed in the first steps.

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WHO CONTROLS THE PAST.... AN INVESTIGATION INTO THE ROLE OF HERITAGE IN POST-CONFLICT NATION NARRATION

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1. Introduction and context

"Value has always been the reason underlying heritage conservation. It is self-evident that no society makes an effort to conserve what it does not value"[1]. Since its inception, the heritage movement has concerned itself with decisions on which parts of the past are selected in the present for contemporary purposes. The exponential increase in the scope of designated heritage has seen its constituent elements change from formerly 'grand monuments, unique treasures and great heroes' to 'the typical and the vernacular'[2]. This democratisation of heritage coupled with a burgeoning multi-disciplinary academic interest in place meaning highlighted the multivalent nature of heritage and the fact that values are not immutable: "Places, processes and events are inevitably subject to multiple or competing interpretations, yet rarely do interpretive sites present alternative versions of the past or of process. Rarely is an interpretation presented as precisely that – one amongst several possible interpretations"[3].

Tunbridge and Ashworth's thesis on the contested nature of heritage or 'dissonant heritage'[4] to use the term they coined is premised upon the "... zero-sum characteristics of heritage, all of which belongs to someone and logically, therefore, not to someone else. The creation of any heritage actively potentially disinherits or excludes those who do not subscribe to, or are not embraced within, the terms of meaning attending that heritage. Fortunately, much of this disinheritance is irrelevant or trivial: some, however, results in serious discomfort, offence, distress and anguish"[5]. The divisive quality of heritage is particularly problematic in areas experiencing ethno-nationalist-military and ideological contests over the control of territory. This research will investigate the inherent difficulties of managing the deeply contested dissonant heritage sites associated with 'The Troubles' in Northern Ireland.

'The Troubles' in Northern Ireland was the period from 1968 until the Good Friday/Belfast Agreement in 1998 which was characterised by recurring acts of intense violence between elements of Northern Ireland's nationalist/republican community (principally Roman Catholic) and unionist/loyalist community (principally Protestant). The conflict was caused by the disputed status of Northern Ireland within the United Kingdom and the domination of the minority nationalist community, and discrimination against them, by the unionist majority. The violence was predominantly orchestrated by armed paramilitary groups, including the Provisional Irish Republican Army (PIRA) campaign of 1969-1997 which was aimed at the end of British rule in Northern Ireland and the creation of a new "all-Ireland", Irish Republic, and the Ulster Volunteer Force (UVF) and Ulster Defence Association (UDA) formed in the late sixties in response to the perceived erosion of both the British character and unionist domination of Northern Ireland. This sectarian conflict caused over 3500 deaths, millions of pounds worth of damage to property and it has resulted in a highly polarised and divided society. Since the Good Friday Agreement, the political institutions and devolved Northern Ireland government at Stormont operated only intermittingly with the fourth suspension following allegations of an IRA spy ring lasting from 14th October 2002 until 7th May 2007. Following the signing of the St Andrews Agreement and significant acts of IRA decommissioning, on 8th May 2008, devolved government was restored to Northern Ireland.

2. The challenges of managing the physical legacies of 'The Troubles'

In 'The Book of Laughter and Forgetting', Milan Kundera stated famously that "The struggle of man against power is the struggle of memory against forgetting"[6]. In Belfast and Northern Ireland generally, the physical traces of 'the Troubles' such as military installations and paramilitary murals are being removed at an unprecedented rate as part of a process of normalisation. This phenomenon is operating alongside a burgeoning dark tourism industry which utilises and commodifies the sites associated with 'The Troubles' with guided black taxi tours of Belfast's 'Peace Walls' and sectarian murals and prisons such as Crumlin Road Gaol in North Belfast are being opened for visitors. The simultaneous and counteracting phenomena of the erasure of the structures associated with the sectarian conflict juxtaposed with the explicit commodification and exploitation of the same past has raised the issue of whether memory or forgetting is the best strategy for reconciliation. The impacts of the removal of the physical legacies of this past necessitates further investigation into the relationship between contested tangible forms and the intangible significance attached to the materiality of their traces. The peace dividend and the proposed future tourist utilisation of sites such as the Maze/Long Kesh prison (Figure 1) has re-created grounds for contestation on how such remaining sites are narrated and by whom. Since the re-establishment of an elected assembly in Northern Ireland, the government has initiated a discussion on the legacies of the conflict including the creation of a consultative group on the past.

The magnitude of the challenge facing this group and society in Northern Ireland in general was highlighted by the high profile dispute over the future usage of the site of the prison most associated with 'The Troubles' – the Maze / Long Kesh prison. The disused prison complex, which was the site of republican hunger strikes in 1981 when 10 inmates died, was proposed to be redeveloped to incorporate a national sports stadium and an International Centre for Conflict Transformation within a preserved 'H-block' prison building. These proposals now appear unlikely to come to fruition as opposition from unionists and victims' groups to the conservation of parts of the site have illustrated its zero-sum nature: "It represents a singular claim within a republican narrative of resistance and appears to have little potential as a site of atonement or reconciliation."[7]. This example encapsulates the difficulties that heritage professionals are faced with in deeply contested societies, whilst the structures in question are of negligible architectural merit they do constitute a significant and emotive part of the province's recent history: a history which is subject to two dominant narratives competing for acceptance. This research will investigate how through decisions on whether such sites are promoted, conserved, neglected or destroyed a nation narrates its recent history in built form.

Before focusing explicitly on conservation policy and practice for contested sites in Northern Ireland, this piece of research will investigate case studies on the post-conflict treatment of the heritage of the 'other' in the former Yugoslavia with particular reference to Bosnia & Herzegovina and Kosovo. Sites in this region were selected for comparison with Northern Ireland because of the ethno-nationalist nature of the 1990s wars and also because of the shared challenges of dealing with the legacies of their recent pasts (albeit that there are notable differences in the respective weights of these conflicts and 'The

Troubles'). The research will investigate the social, political and economic implications of interventions in the contested built environment by critically examining case studies on the role of memory and the changing nature of place meaning in post-conflict societies. The selected case studies will range from well-known monumental symbolic interventions such as the reconstruction of the old bridge in Mostar (Figure 2) to the challenges facing conservationists in re-constructing and conserving the heritage of the 'other' as part of a wider strategy for post-conflict reconciliation in towns such as Jajce and Stolac in Bosnia & Herzegovina. The core focus of this research will investigate the extent to which heritage interventions can play a role in creating shared narratives in post-conflict societies.

Figure 1: The Maze / Long Kesh prisone by Neil Galway

Figure 2: Old Bridge of Mostar.

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INTEGRATED CONSERVATION - NEGOTIATING URBAN HERITAGE VALUES

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Abstract
Much of our cultural heritage is to be found in our towns and cities, where it plays an important role as historical documentation and also makes an important contribution to a city's image giving it character and atmosphere. Our cities and other urban areas are changing rapidly. The urban transformation process affects these different heritage expressions in many ways and represents a threat to separate cultural heritage sites and to the character of the city. The condensing of urban areas increases the pressure on the cultural environment. In the debate about urban heritage conservation, many ask why the urban heritage should be an obstacle for urban development. That means a lot of conflicts in the appreciation of the values of urban heritage. Through a process of integrated conservation the interests of the cultural heritage should be taken into consideration and negotiated with other interests in the urban transformation. Through case studies from the cities of Oslo and Trondheim, I am studying how these conflicts between different comprehensions of urban heritage values are expressed and how the urban heritage values are maintained and safeguarded through the process of integrated conservation.

1. Introduction

Our urban heritage plays an important role as historical documentation and makes an important contribution to a city's image giving it character and atmosphere. This cultural heritage expresses itself at many different levels – as landmarks, townscapes, skylines, urban fabrics and as different heritage buildings with their historic style and mode of expression. The urban transformation process affects these different heritage expressions in many ways. Our cities and other urban areas are changing rapidly. Many cities are expanding substantially and occupying new land. Manufacturing companies are closing down factories or moving out and "brown areas" are being transformed in to areas for housing, trade and commerce. The condensing of urban areas, another important element in urban development, also offers a strategy for sustainability, reductions in transport and maintenance costs connected with the urban infrastructure. This condensing strategy increases the pressure on the cultural environment. Urban transformation is often carried out as individual projects, unconnected with the environmental context. This process could have substantial consequences and poses a great challenge to the environment in many cities. It also represents a threat to separate cultural heritage sites and to the character of the city, the urban structure with the street grid and urban places, which constitute the basis for social, cultural and visual diversity in the cities. The skyscrapers affect the townscape, the comprehensive transformation project often affects the urban fabric, and the infill projects challenge the existing cultural environment.

In the debate about urban heritage conservation, many ask why the urban heritage should be an obstacle for urban development; obstruct the city in developing an architectural expression that is in accordance with its own time, instead of a "narrative conservation", telling the history from the past or reduced to a décor.[1] The development of the cities should to a greater extent be based on the needs of today and develop a contemporary architectural style, instead of being based on the past.

On the other hand we are noticing an increasing consciousness about conserving the values of existing urban structures and historical environments and in that way develop the diversity of the city. Due to the shift from an industrial economy to a post industrial economy, emphasizing more on services and cultural activities, tourism etc., the economic values of heritage have increased. Urban areas are being forced to compete for investments and skilled labour. According to modern urban theory, historical environments are important for developing an urban diversity which is critical in order to attract industrial and commercial development and housing. This means that towns and cities have to cultivate distinctive features that can create diversity and make them special and attractive.[2]

2. Questions to be addressed

In this paper I will through presentation of some case-studies of different urban transformation processes from the cities of Oslo and Trondheim, discuss how to maintain and safeguard urban heritage through this transformation process. I will look into how the tension between protecting the established, historical structures and the demand for transforming and adapting the city to new demands and production methods, comes into conflicts with different interests and evaluation of values. The city's continuous demand for adapting new conditions for production, creates conflicts with the desire to conserve the city as a living environment.[3] On the other hand modern economical theory points out the demand for developing an urban diversity in accordance with post-industrial urban development.

Through international charters and agreements, the understanding of cultural heritage values and the theoretical basis for conservation has changed substantially.[4] Today we recognise "*all traces of human activity in our physical environment, including places associated with historical events, beliefs and traditions as cultural heritage*" (The Norwegian Cultural Heritage Act).[5] The diversity of the cultural heritage should be conserved as resources for use and form the basis for knowledge, experience and added value, while a representative sample of cultural heritage should be conserved as sources of knowledge. To cope with the large and increasing number of historically interesting buildings and cultural environments which do not qualify for preservation, we need another approach than the antiquarian principles. By replacing the prevailing view with a new type of dynamic approach, focusing on *protection through use*, it may be possible to protect a substantial number of cultural heritage buildings and cultural environments. But what shall be protected and how to protect are questions to be addressed through negotiating with other stakeholders in an integrated conservation process.

Integrated conservation means that the cultural heritage values should be assessed in relation to other interests and values associated with the use of the building or the premises, such as utility, usability, universal design, energy saving, building costs, etc. An integrated protection of the existing built-up environment will handle the interface between cultural history considerations, economical realities, social and human relations and put them in a planning context. Which values should be safeguarded? What are the economical gains, directly and indirectly, of different urban transformations? What has been lost and what has been achieved?

3. Empirical studies

I study this problem by means of two cases:

The City of Oslo has developed a master plan for the development and conservation of the inner city for the period of 2005 to 2020.[6] The aim of the plan is to adapt the city to a sustainable urban development. Historical town districts and other important historical environments shall be protected and the image of the city as a compound historic town shall be safeguarded through renewal and condensing, thus developing a compact city. The conservation areas shall be integrated in a living and dynamic commercial and cultural city. The master plan establishes a strategy for conservation that is based on a perception of heritage values that are manifesting on different spatial levels. The spatial character of the city is expressed through the interaction between topography, urban fabric and buildings with their elements and details. The plan aims to develop the inner city's spatial character, the diversity of the city with its different architectural styles, while also giving room for new demands for development and changes. This plan has turned out to be a controversial document and has met with resistance from cultural heritage authorities who considered that the plan does not provide sufficient predictability or governmental backing for safeguarding the cultural heritage. On the other hand real estate developers mean that the plan is too restricted and does not give room for a satisfactory urban development and a modern architectural expression.

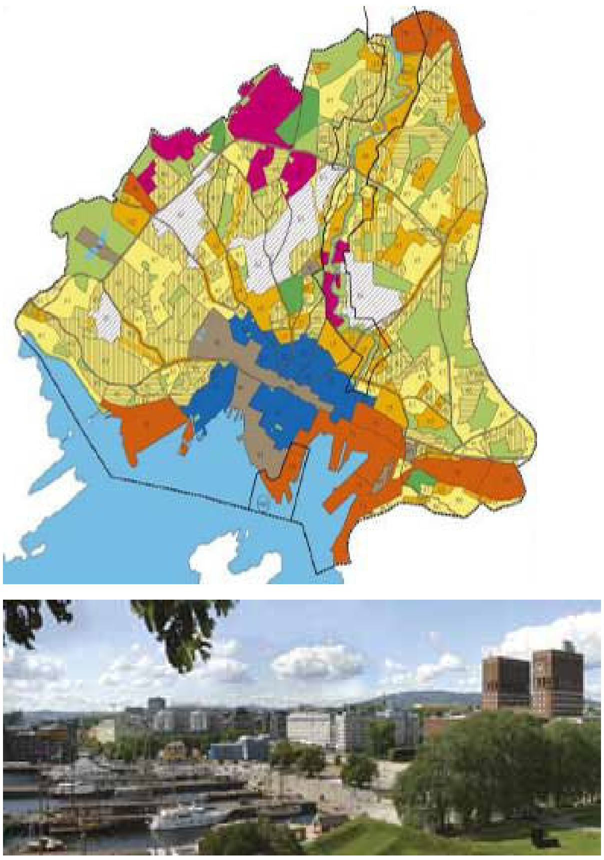

Figure 1: Master plan for urban development and conservation for Oslo Inner City 2005-2020. Map and photo: City of Oslo / PBE.

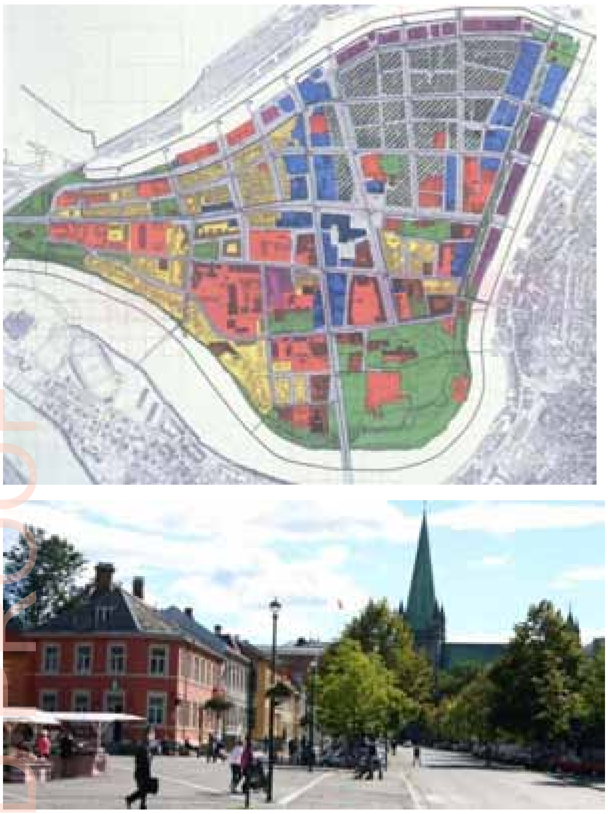

Figure 2: Local plan for the Inner City of Trondheim. Map: Municipality of Trondheim. Photo: Kittang.

Trondheim's planning authorities are preparing a new master plan for the historic centre of the city. The existing plan shall safeguard the historic image of the city centre as a wooden town, taking care of the scale of the historic city and the specific wooden building. Building projects after several fires have actualised a new plan since a lot of exemptions from the existing plan have emasculated the building regulations of the master plan from 1985. The debate has been focusing on building heights and scale, use of materials, authenticity, design, land use etc., but also on how to keep and develop the diversity of the city, architectural and functional. Today there is a special focus on how the city shall give room for modern and more expressive architecture, expressing the architecture of our time.[7]

4. Theoretical and methodical approach

The case studies express the conflict between different attitudes in an integrated urban conservation. These attitudes are conditioned by different social and cultural circumstances and by how the city and buildings are perceived and used by different stakeholders. Urban planning theories and architectural conservation theories express different structures of meaning and shape different and conflicting conception of the city and the qualities of the existing buildings.[8] Such different discourses construe the city and the buildings in different ways, establishing different bases for evaluation and prioritization.[9,10] In an integrated conservation these different discourses and forms of understanding fight for a hegemonic position. In this study I discuss how different discourses influence the perception and the social practice in the development of urban areas within the frame of an integrated conservation.

I can register a tendency towards a weakening of the heritage values in the urban planning discourse. Greater emphasis is put on contrast rather than adaptation, on breaking with the past rather than pursuing continuity, on what is modern rather than traditional, on simplicity rather than diversity.

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TOWARDS STANDARD QUALITY CONTROL OF PAPER MASS DEACIDIFICATION

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Due to the paper production technology in use between ca. 1850 and 1990, typically 70-80% of Western archival and library collections are prone to rapid decay due to inherent acidity. Due to the size of the problem, mass deacidification has been proposed as a possible strategy for active conservation of paper originals. During the procedure, tens or hundreds of objects are immersed in solutions or suspensions of alkali earth metal compounds in organic solvents. Upon drying, the acids are neutralised and a surplus of the mildly alkaline alkali earth metal compound (alkaline reserve) prevents further accumulation of acids.

Several different mass deacidification services are currently on offer and in order to evaluate immediate consequences of deacidification, a variety of analytical aspects of quality control in existing mass deacidification were examined: homogeneity of the deposit, amount of alkaline reserve and quantity and off-gassing of the remaining organic solvent.

In order to investigate deposit homogeneity, laser ablation sampling with inductively coupled plasma mass spectrometry (LA-ICP-MS) was used while the alkaline reserve was determined using automated titration. Both techniques can be performed on model samples inserted into real objects.

Determination of homogeneity of alkali distribution using inductively coupled plasma/mass spectroscopy with laser ablation sampling was performed on mock samples (max. size ca. 2×2 cm), inserted into a laser ablation sampling chamber (Figure 1). The laser beam (Nd:YAG laser, 213 nm) is used as a "light chisel" in order to take a tiny amount of sample from the surface, and the sample is then transported into an analyser consisting of inductively-coupled plasma and a mass spectrometer (ICP-MS). This technique allows reliable quantification of almost all elements at trace levels and with spatial distribution >4 µm. For laser ablation analyses (LA) we used a New Wave Research UP-213 system, equipped with a Supercell and He carrier gas. The diameter of the laser beam was 100 µm, the repetition rate was 20 Hz. The LA instrument was coupled to Agilent 7500ce ICP-MS. Helium at 0.95 L/min was used as the carrier gas for ablated material to ICP-MS. Argon at 0.75 L/min was used to make up the gas flow to ICP torch.

The process solvents remaining in the deacidified material may represent a health risk and their determination was performed over a period of time after deacidification using gas chromatography in combination with mass spectrometry. Several deacidification processes based on organic solvents were examined: Bookkeeper, CSC, Sable, PaperSave at ZFB and at Wimmis. 2D maps of the remaining solvents across a book page after deacidification were constructed after the analyses of 16 samples. All the examined deacidified books show profiles with larger amounts of solvents in the centre of pages. These profiles can be explained by migration of the solvents to the edges of the page and from there volatiles are emitted from the books. The exceptions were books deacidified with the PaperSave (ZFB) procedure, where reverse profiles were found with extremely large amounts of the remaining solvent at the edges of the pages. These can be explained with procedure step involving re-humidification of deacidified books after drying in the vacuum (Figure 2).

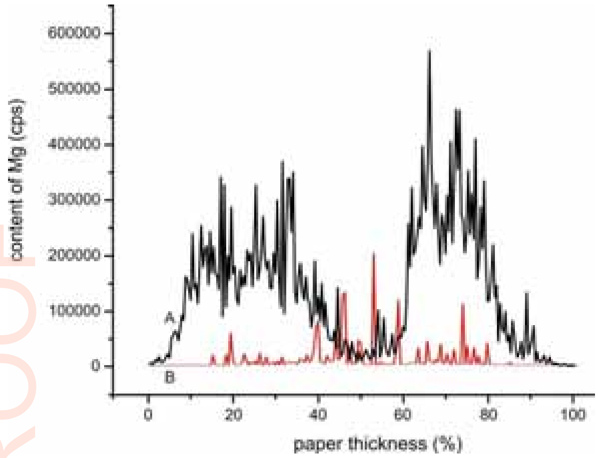

Figure 1: Two LA-ICP/MS traces of Mg content through paper cross-section after deacidification. A – Bookkeeper treatment, showing higher content on the paper surface and less migration towards the centre of the paper sheet, B – PaperSave (ZFB) treatment, showing better penetration and a lower overall content of the deacidification agent.

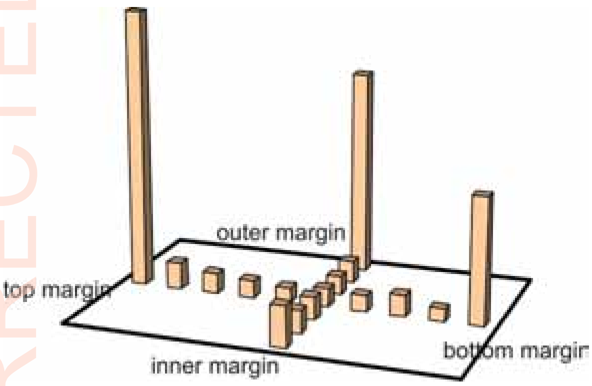

Figure 2: 2D map of the remaining solvent (hexamethyldisiloxane) concentration (relative scale) across a model book page after mass deacidification (PaperSave/ZFB).

In order to evaluate the kinetics of the remaining solvent emissions from model books after deacidification, they were analysed immediately after the process was finished. Further analyses were performed after two weeks, after a month and after three months. Measurements show that after two weeks and after a month, the contents of remaining solvents are comparable and are between 30 and 50% less than at the beginning. After three months, less than 10% of the solvents remain in the books (Figure 3). From such data the mass transport of the remaining volatiles from books can be calculated and therefore maximum concentrations of volatiles in the storage rooms can be determined. These values can be compared with occupational limit values for hazardous substances and according to the results, and appropriate ventilation can be suggested. These results also enable us to evaluate the associated health risks.

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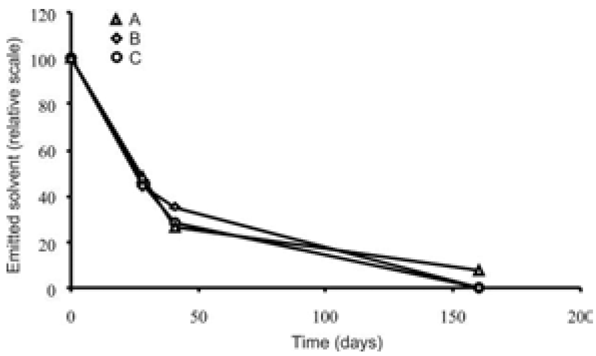

Figure 3: Kinetics of emission of the remaining solvent (A: methanol, B: ethanol, C: 2-propanol) in model books after the Sablé deacidification process (relative scale).

SNEŽNIK CASTLE – A JEWEL TO BE ENJOYED WITHOUT TOO MUCH DAMAGE

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1. Introduction

In the nook of the southern Slovenian woodlands nests a medieval fairytale castle, complete with genuine 19th century furnishings. State-owned and entrusted to the care of the National Museum of Slovenia, it has recently been restored with EU funds and is again open to the public. Snežnik (= The Snowy one) Castle is unique in several ways. It is the only one of the multitude of Slovenian castles surviving the two world wars and the following tradition-hostile decades with intact interiors. It is one of the few historic buildings still surrounded by a beautiful unspoiled countryside. And, it is one of the first castles in Slovenia to be just about fully restored after 1945. All this makes Snežnik of supreme national importance. The castle as seat of a great country estate in a historic landscape is inseparable from its historic gardens and park. The once scrupulously-groomed English park with its outbuildings, tree-lined roads and clearings still remains to be restored to its 19th century beauty. The building itself is taken care of by enthusiastic full-time keepers, a couple living in the nearby village of Šmarata, while the park lacks a qualified gardener. A magnificent romantic landmark, reflecting the styles and tastes of past generations, the castle has already become a much-visited tourist destination in this attraction-rich karst region, featuring the huge Postojna cave, disappearing Cerknica lake and the wild-life abundance of the last immense remaining European deep wood complexes.

Now is the time to engage the commitment of everyone interested to improve people's understanding of this exquisite historic environment in its cultural, economical, ecological and social context. More research is needed to come up with the facts[1] and suitable ways of education and promotion. National and local policy makers must be helped to recognize Snežnik Castle, as well as other Slovenian historic buildings and sites, as invaluable non-renewable environmental resources with the lasting power to improve the quality of life. Our job is to win more countrymen over to intensely value the past existing within today's world and contributing to the local character and atmosphere. Historical identity makes us who we are and this is what attracts tourists. We have to become more aware of our responsibility to preserve the nation's cultural and natural assets for future generations. Hic et nunc, by enhancing the development of existing communities living in historic environments there are immediate and lasting sustainable benefits. Snežnik Castle can turn into a catalyst to the economical regeneration of the Lož valley.

This wonderful biodiverse countryside with numerous ancient landmarks and kind people offers all sorts of cultural and sporting activities for Slovenians and foreign guests alike. Local strategic partnerships must be created to chart the key objectives for the near and far future and to make plans for their realisation. By now around Snežnik Castle there had already gathered many stakeholders: representatives of the local community and the state, regional tourist boards, societies and firms, nearby villagers, the National Museum of Slovenia and individuals. Our first immediate task is to sort out the unclear rights of use of the buildings and lots, and the second to jointly decide who and how will be providing information, entertainment, local products, bed and board for guests. Now is also high time to lay down a sustainable policy for the upkeep and development of this singular historic site. An assessment will have to be made how many visitors to the castle and park and in what ways we can handle without putting too much strain on the people engaged and on the historic environment itself. Guests can always be more encouraged to visit other fetching sights nearby. Snežnik also has to generate enough income to sustain itself in the long run. For old vulnerable buildings, interiors and parks maintenance costs are bound to be growing and tourist money will not be enough. Therefore new sources will have to be tapped. History, the supreme teacher, indicates the most reliable of them: for centuries this as other country estates throve on the riches from their forests. Our Ministry of Culture would have to negotiate with the present-day owner of Snežnik forests, the Farmland and Forest Fund of the Republic of Slovenia, to make a fraction of the former many square kilometres of forests over to the present-day Snežnik estate as a foundation of a firm income.

Figure 1: Exterior with the grounds (photo Andreja Breznik).

If Snežnik Castle is managed in this assiduous way, it should become the model for all other Slovenian state- or private-owned decaying and neglected historic buildings of its stature still waiting their turn. Next to be restored is Šrajbarski turn Castle in south-eastern Slovenia.[2] As a research and reference centre, Snežnik could provide standards, practical advice and above all be living proof of fair intentions, clear responsibilities and hard work turning a historic environment into a lasting source of highest measurable and immeasurable benefits all-round.

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Figure 2: Genuine 19th century interior (photo Maja Lozar Štamcar).

SUSTAINABILITY STRATEGIES FOR THE PRESERVATION OF CULTURAL HERITAGE

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1. Abstract

Sustainability of built environment requires strategies for a continuous monitoring and control of the conservation state of monuments and complexes. Issues of strategic and technological convergence are: the establishment of procedures for continuous monitoring and control, according to the Cultural Heritage stakeholders; of inventories according to the type of monuments and complexes; of protocols according to the methodologies and techniques used to diagnose the state of decay and pathology of materials and structures, as well as, of architectural design alterations and the introduction of decision making processes and criteria, regarding all phases of interventions as inspection, diagnosis, study and works. In the present work these issues are examined resulting in proposals for strategic and technological convergence in planning sustainability for Cultural Heritage Protection. Furthermore the paper presents how the use of NDT techniques comprises a new tool for assuring the sustainability of structures.

2. Introduction

The conservation, maintenance, and safeguarding of the level of services offered, for historic buildings is of substantial importance for the preservation of cultural heritage and the enhancement of the interface to the contemporary socio-economic web. The historic preservation works demand a tight organizational structure of supervising and management in order to increase the building's lifetime, by ensuring that incidents of future failure are avoided (preventive maintenance). An integrated methodology that incorporates the tasks of, documentation, monitoring and inspection, diagnosis, study on interventions, intervention works, and final inspection of the restoration works is proposed and is currently under development.[1]

Additionally, new methods, such as non-destructive testing techniques, which provide data in real scale and time, as well as analytical ones, are being developed. This task is essential for the integration of quality in the historic preservation works. In addition, new tools for information management, and the life-through monitoring and control of a construction are required. The integrated methodology is shown in Figure 1 for the case of a single building.

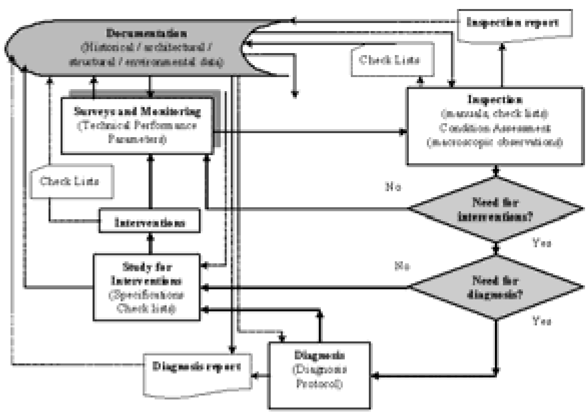

Figure 1: Diagrammatic representation of the proposed methodology for a single building.

When handling a multi-array of buildings, it is of interest, to employ necessity indices of performing the tasks of inspection, diagnosis, or intervention. These measures will be used to rank the buildings and prioritise the activities.

3. Case Studies of NDT testing

The use of NDT is an innovative field that requires the knowledge, the experience and the critical judgment of the user. In bibliography there are many references concerning NDT applications at bridges, airports, buildings etc.[2] Non destructive testing (NDT) comprises a modern technological tool for constructions quality control. With the use of NDT it is possible to assess the state of construction maintenance in real scale.[3] Especially for concrete structures this is of great interest, given that NDT provides information that cannot be acquired with observation or sampling. NDT testing includes various techniques, such as: Fiber optics microscope, Ultrasonics, IR thermography, Image analysis software, Ground penetrating radar. The aforementioned techniques have been used by the Laboratory of Materials Science and Engineering, School of Chemical Engineering, National Technical University of Athens at various applications (National Bank Buildings, Medieval fortifications of Rhodes/ Irakleion, National Archaaelogical Museum etc). All collected data provide a structured basis for future investigation and development of systems for programs of monitoring and maintenance. Some characteristic applications are presented below.

- Environmental impact assessment at building scale. Fiber optics microscopy is a technique that can be used for the study of architectural surfaces morphology, as well as of their state of maintenance. With the aid of this technique the deteriorating action of the environment can be assessed (especially for urban areas and marine environment). In Figure 2 is shows dustfall at marble surfaces of the National Library building at Athens city centre (Figure2,3).[4]

Figure 2: Building of National Library.

Figure 3: Magnification x25 of dust depositions.

- Calculation of mechanical strength. Ultrasonics can be used for the calculation of materials elastic modules, parameters of great importance concerning structures seismic behavior.[5]

- Study of masonry Mass/ Heat transfer phenomena. Moisture is one of the most deteriorating factors for buildings. With the use of infrared thermography it is possible to investigate the qualitative moisture of masonries. An example is the use of infrared thermography for the study of the Medieval Fortifications of Rhodes. Figure 4 presents the masonry under investigation. In the thermograph (Figure 5) the different distributions of moisture in the masonry are visible, due to the temperature differentiation caused by the moisture.[6]

Figure 4: Masonry of Medieval Fortifications of Rhodes.

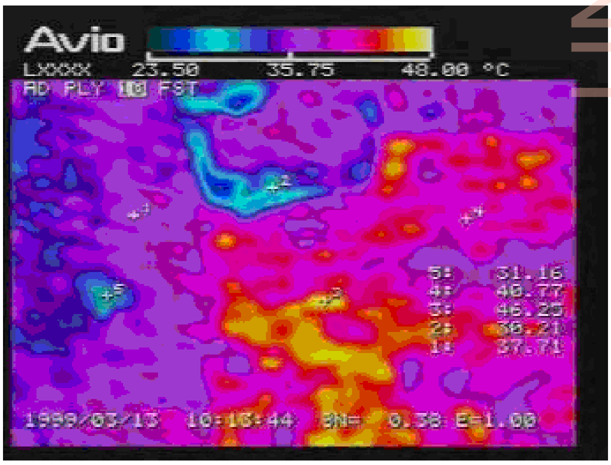

Figure 5: Masonry Thermograph.

- Conservation interventions assessment. NDT techniques that can be used for the assessment of conservation interventions are fibre optics microscopy, digital image analysis, infrared thermography, ultrasonics. An example is the use of Image Pro Plus software, for the assessment of different cleaning intervention methods, at the Bank of Greece, at the city centre of Athens. In Figure 6 the pilot cleaning application area is shown. At a zone to the left the cleaning intervention method that was applied was the micro-sandblasting (Al_2O_3 particles, diameter 150 μm, pressure 2 atm and nozzle 1 mm) at Kapandriti stone. At the right part of this area a poultice of $(NH)_4CO_3$ 15% was applied. Figure 7 represents the digital processed image, where it can be seen that the poultice intervention was more effective.[7]

- Concrete structures quality control. Reinforced concrete has been one of the most widely used building materials in the 20th century architecture, but now, at the beginning of the 21th century, the durability and the service life of concrete has become a worldwide concern. Many of the structures constructed at the previous century present extended deterioration, in many cases without reaching their intended service lifetime and the cost for their maintenance and repair is extremely high. It is estimated that approximately 50% of the expenditure of the construction industry in Europe is spent on repairs. A large percentage is due to the deterioration of concrete structures.

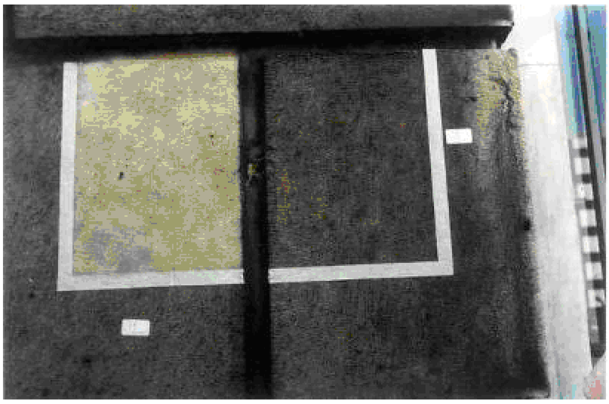

Figure 6: Pilot cleaning interventions at Bank of Greece.

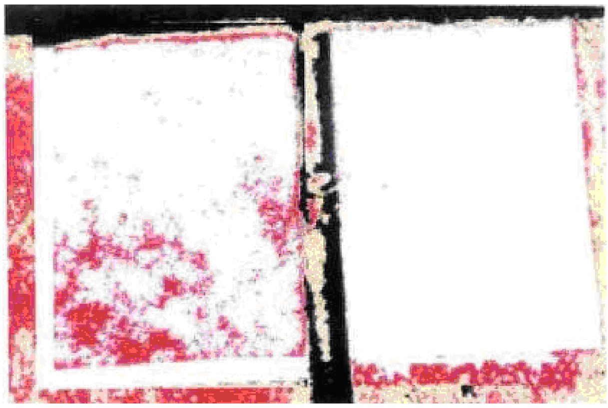

Figure 7: Digital processed image.

The spa complex at Kallithea in Rhodes consists of structures Rotonda and Dome buildings. The spa was constructed in 1927 by the Italian architect Pietro Lombardi, using reinforced concrete. In Figure 9 with the aid of fiber optics microscopy the concrete surface at Rotonda building was investigated. The concrete was examined with ultrasonics as well. Low values of ultrasound velocity transmission in comparison with sound concrete (Velocity=3800-4900 m/sec), were investigated. This revealed that the concrete presented a lot of voids and discontinuities and it could be characterized as extremely decayed. In figure 9 can be observed loss of binding material, creation of fissures and cavities, as wall as, deposits of salts.[8]

In European Union the European Construction Technology Platform (ECTP) analyses the major challenges that the construction sector faces in terms of society, sustainability and technological development. Research and innovation strategies will be developed to meet these challenges engaging with and mobilising the wide range of leading skills, expertise and talent available to us within our industry over the coming decades, in order to meet the needs of the Society. In this framework the Hellenic Construction Technology Platform (HCTP) acknowledges the significance of protection of cultural heritage, along with the sustainability issues and gave emphasis to Sustainable Construction and Protection of Cultural Heritage. Over 100 members (companies of construction works study and implementation, companies of environmental design, industries of building materials, research and technology centers, companies of design / management / operation of cities – cultural heritage, infrastructure work, underground work) have expressed their interest to participate in HCTP. The main purposes of HCTP are the:

Figure 8: Rotonda building.

Figure 9: Magnification x25 of Rotundas concrete.

4. Setting Policies

In European Union the European Construction Technology Platform (ECTP) analyses the major challenges that the construction sector faces in terms of society, sustainability and technological development. Research and innovation strategies will be developed to meet these challenges engaging with and mobilising the wide range of leading skills, expertise and talent available to us within our industry over the coming decades, in order to meet the needs of the Society. In this framework the Hellenic Construction Technology Platform (HCTP) acknowledges the significance of protection of cultural heritage, along with the sustainability issues and gave emphasis to Sustainable Construction and Protection of Cultural Heritage. Over 100 members (companies of construction works study and implementation, companies of environmental design, industries of building materials, research and technology centres, companies of design / management / operation of cities – cultural heritage, infrastructure work, underground work) have expressed their interest to participate in HCTP. The main purposes of HCTP are the:

- Demonstration and exploitation of the research technological products, highlighting the Greek Engineers' work.
- Promotion of the cooperation between various sectors like users, industrial partners and stakeholders as a European consortium for the submission of Joint Programs of Research and Technology, with emphasis on Sustainable Construction and Protection of Cultural Heritage.

5. Conclusions

Historic buildings have a unique sustainability context. By using our existing historic buildings, fewer raw materials are used, less waste is generated, and the need for additional infrastructure is reduced. Historic structure protection consists of a valuable source of knowledge and experience regarding structural materials/components behaviour. Recording and analyzing this knowledge can contribute to the development of new criteria and methodologies for increased building sustainability. A demand for a future for our past and a future for our future is more than a necessity, it should be a commitment and priority for all related strategies.

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PRESERVATION OF MODERN MOVEMENT ARCHITECTURE – BUILDING OF TWO SECONDARY SCHOOLS IN KRIZANICEVA STREET, ZAGREB

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Abstract
A historic building (with surroundings and interior) is a composite work of art and document of history. The basic architectural values such as function, form, structure, materials, methods of construction, relation to location, space organization, air and moisture movements are main guidelines for renovation project and should be properly understood.

This article deals with questions how to preserve the architectural heritage of Zagreb Modern Movement architecture in its integrity and authenticity, in particular those sites, which were built between the two World Wars. Those achievements can be compared with European but the current state of many buildings reveals advanced decay.

Croatian architect Egon Steinmann (1901-1966) designed the building of two secondary schools in Krizaniceva Street in Zagreb (1930-1932). This large U-shaped building was built 80 years ago and until today it hasn't been adequately renovated and maintained.

The main goal set for the renovation is the preservation of historic building substance and equipping the space in accordance with contemporary requirements. The preservation project has to respect various regulations and guidelines that insure the best building construction in terms of form, construction, building physics and economizing.

1. Introduction
In the first half of the twentieth century, a distinctive kind of architecture appeared across Europe, characterized by simple volumes, pure white walls, flat roofs, roof gardens and terraces, large areas of glass and balconies. From private houses to public buildings, this architecture was constructed from brick, reinforced concrete and steel characterized by rejection of ornament and elimination of "unnecessary" details.

In recent years many of Modern Movement buildings have been legally protected from demolition and have been restored and reconstructed. This has provoked renewed interest in origins of individual buildings, including both little-known and more familiar examples in Europe. Iconic buildings of Modernism in Europe such as the Bauhaus at Dessau (Walter Gropius, 1925/26), the Villa Savoye near Paris (Le Corbusier, 1929/30), the Penguin Pool at London Zoo (Berthold Lubetkin, 1933/34) or the Zonnestraal Sanatorium at Hilversum (Jan Duiker and Bernard Bijvoet, 1925-31) became monuments of cultural value. They have been scientifically evaluated and many among them conserved by experts.

All countries have sites of local or national interest, which are quite justifiably a source of national pride. It is of no importance if they represent an ordinary example or so called "icon" of modern movement architecture. The importance of retaining worthy works of the architectural heritage of the Modern Movement lies in the significance of the era, which these works represent. Over the last decades there is a greater interest in the ideas and heritage of the modern movement.

2. Preservation and Conservation of Architectural Heritage
Preservation and conservation of the architectural heritage is a very complex work and hardworking challenge. The support of all participants (population, governments, economic circles, etc.) is very important. It is necessary to bring together historians, architects, town-planners, landscape architects, conservationists and public officials who are constantly having balance between social, economic and environmental realities. Conservation can generally be considered as actions taken to prevent decay and to prolong the life of architectural heritage. Protection of Modern architecture is a part of the general theory and practice of conservation of architectural heritage. The most often question is how to accommodate changes without loss of special character of the building. The majority of buildings can accommodate some improvements, even though the modern standards and techniques might not be appropriate. These measures should not be applied without due regard to the special characteristics of a historic building.

According to English Heritage building regulations there are basic principles of repair and alteration to historic buildings:[4]

- The sensitivity to historic buildings: A historic building (with surroundings and interior) is a composite work of art and document of history. Historic buildings vary greatly in the extent to which they can accommodate change without loss of their special interest.
- Identifying the special elements: Elements that make up the special character and interest of the building are external features (facade, windows, doors, etc.), the space and internal layout (the plan of the building, interior plan), internal features (floors, doors, wall surfaces, stairs, etc.) and details (wall and ceiling decorations, etc.). Retaining existing elements of construction in old building and seeking to enhance their thermal performance, rather than replacing them, is a heritage conservation principle in line with concept of sustainability.
- Principles of minimum intervention: Structure, materials, methods of construction, air and moisture movements should be properly understood. A fundamental principle is to minimise intervention. A conservation approach is needed with knowledge and experience how changes can be made with least effect on the character of the building.
- Principles of repair: Where new work can be carried out with minimal effect on historic fabric, it should be carefully matched with the old in order to achieve an architectural whole. The detailing of the new work should match the original or existing work exactly.
- Principles of alteration: When alterations are proposed, regard should be given to: ensuring that the building is well understood, minimising disturbance to existing fabric and appreciating that some parts of buildings are of such quality that they should not be altered at all.
- Understanding how the building works: Before any work is carried out, it is therefore important that a building's system of construction and the way in which this might have changed over time is understood and that alterations are compatible with this system.
- Introducing modern materials: To use modern substitutes and modern materials into traditional construction is usually not a good practice. As a general rule materials and techniques designed for new construction should be treated with caution.

3. Energy Conservation

Discussions about the efficiency of residental and non-residental buildings are being dominated by the matter of climate change and concept of energy savings. The main goal set for the renovation of historic buildings is finding an appropriate balance between historic building conservation and energy conservation. Sustainable architecture can attain considerable contribution in decreasing emission of greenhouse gases. Buildings consume significant amounts of energy participating in the total annual energy consumption with almost 40%. The biggest share in current energy consumption goes to space heating. Energy used for heating is accounted for 50-60% of total energy used in buildings (52% in non-residential sector and 54% in residential sector). Heat losses through windows and doors represent 70% of all thermal building losses. Thermal insulation of the whole building envelope can reduce the energy consumption by 50-80%. Therefore priority is laid on modernization, renovation and improvement of existing capacities. The present calculation method focused on the heat necessary for space heating in buildings was based solely on the construction part of the building without taking into consideration the efficiency impact of heating, air-conditioning and ventilation systems and does not present the actual energy consumption.

Many old buildings have little or even no thermal insulation, and there is substantially great potential for energy savings in the existing buildings. Buildings built before 1970s don't have any thermal insulation and even buildings completed before 1980s have poor thermal insulation. According to housing statistics data over 80% of existing buildings in Croatia have unsatisfactory thermal insulation.

4. Legislation

During the last years a range of changes in the legislation in the field of building and architecture were entered in Croatia, but it is still necessary to improve systematic historical and architectural surveys, protective planning measures and conservation approaches based on internationally approved scientific principles. For implementation of all strategies and plans there has to be the efficient legal system. Architectural and urban planning complementation has to be in accordance with conservation services and ministries. The Municipal Institute for Protection of Cultural and Natural Monuments (Gradski zavod za zastitu spomenika kulture i prirode) is responsible for the cultural heritage throughout Zagreb, protecting, maintaining and preserving Zagreb's cultural monuments. The process of identification, protection and preservation has to be statutory. This is the only way how to ensure their safe and continuous life for the future generations. The basic Zagreb town-planning regulation is Master Plan (Generalni urbanistički plan), which includes a conservation study for every location in Zagreb.

5. Energy Efficiency Legislation in Croatia

The Ministry of Environmental Protection, Physical Planning and Construction and the Ministry of Economy, Labour and Entrepreneurship are the government bodies in charge of the transposition of the Energy Performance of Buildings Directive 2002/91/EC in Croatian legislation and its full implementation. This Directive has not been fully transposed, the preparatory activities have been underway for several years in Croatia and energy efficiency standards have been included in a series of laws, ordinances and regulations. In the area of thermal protection and energy saving in buildings numerous European standards were accepted which are the integral parts of methods for thermal performance calculations for buildings. A number of national technical regulations refer to the calculation methodology according to European standardization system accepted also in Croatia. The new Technical Regulation on Thermal Energy Savings and Thermal Protection of Buildings (OG No. 79/05, 155/05 and 74/06) came into force July 2005 and its obligatory application started July 2006. Technical Regulation introduced new calculation method for energy performance denoted as Qh or the annual thermal heat demand necessary for the heating of the building (in kWh/m2 for residential buildings or in kWh/m3 for non-residential buildings). In order to successfully apply this calculation method the experts developed some supporting computer programmes.

6. Modern Movement Heritage in Zagreb

Zagreb was always a cultural, intellectual and political centre and a source of ideas on new architecture for many years. From the small "free royal city" in the mid-13th century Zagreb became the capital of the national state. Zagreb is the city of the 19th century architecture. Most of its streets, parks and urban blocks in the centre designed with the regular street network were planned and constructed in that period. Modern architecture gradually developed at the end of the 19th and at the beginning of the 20th century. It grew up as a reaction to rigid norms of the 19th century historic architecture. A stressed role of Vienna, and strong influence of Budapest and Prague was always present, but in all smaller towns of Monarchy a very specific architectural impression could be seen. Foundations of Croatian architecture are based on the European modern movement and the western cultural circle. Between the two World Wars, Zagreb was an established urban centre. The 30th and 40th years of 20th century Croatian architecture is coincidental with the European.

Modern architectural form is always simple, rational and functional, an expression of the "spirit of the modern age". The introducing of modern architecture in Zagreb was done on a relatively large scale by a group of many young architects. They were using new building technology and modern materials such as reinforced concrete, glass, and steel with minimum decoration to keep construction costs low. Simplicity, rationality, and beauty are the main characteristics featured in buildings belonging to modern architecture. Until the 1930s, all the architectural firms in Zagreb were basically foreign. The first local architecture school was established in the year 1919 as the Royal High Technical School with Architectural department. Professors were educated mainly in Vienna. The first group of locally educated architects graduated in 1924. Between the two World Wars many Modern movement buildings in Zagreb were erected and built. Some of the buildings demonstrate a typical Modern movement style of simple functional facades, designed along horizontal lines, with flat roofs, with white rendered facades.

Historic cities are currently facing great pressures resulting from the needs of mobility, economy, housing, the service society and other development, so preservation of architectural heritage is very important.

7. Architect Egon Steinmann

This article takes a look at the building of two secondary schools in Krizaniceva Street in Zagreb built between the Two World Wars, designed by Egon Steinmann (Karlovac, 1901-Zagreb, 1966), architect of the Technical Department of Savska Banovina. Steinmann's greatest contribution to Croatian architecture is the period between the thirties and forties of the 20th Century, when public and residential buildings were constructed. They provide, an important picture of Zagreb Lower Town and are a significant part of Steinmann's field of activity: the Physical Institute of the University of Zagreb on Marulic Square (1927), the Orthopaedic and Dental Clinic of the Medical Faculty on Salata in Zagreb (1929), two secondary school buildings in Krizaniceva Street (1930), Gym hall and Sokol sports hall in Kaciceva Street (1933), new secondary school building in Kuslanova Street (1934), residential block for savings bank post-office workers in Petrova Street (1937) and the Post Office II in Branimirova Street (1939). He was educated in Zagreb at the architectural department of the High Royal Technical School (1920-1924), got the scholarship in Paris (1925), and was employed in public service where he worked for 20 years. After the Second World War he was working at architectural firm Plan designing industrial architecture. Still today, the majority of above-mentioned public buildings are functioning very well, continuously working from the moment of their erection and presenting the key building of Modern movement architecture in Zagreb.

8. Two Secondary Schools in Krizaniceva Street

Construction of the school building in Krizaniceva Street in Zagreb began in October 1930 and was inaugurated in September 1932. The school complex is situated in the SE part of the city surrounded by four streets: Krizaniceva, Svearova, Domagojeva and Solovjevljeva. The area of the rectangular site (9725 m^2) has dimensions 135.15 x 71.95 m. The large U-shaped symmetrical building has basement, three upper storeys and pitched roof. The new school building was the first secondary school building opened after the First World War and at the same time the biggest and most modern school building in the whole country. The school is a recognizable individual architectural work of interwar modern architecture and therefore evaluated as registered cultural heritage (protected zone A). Today II and VII gymnasium with the main entrance in Krizaniceva 4 are situated in the northwestern part and XVI and Classical gymnasium with the main entrance in Krizaniceva 4a are situated in the northeastern part. Over the years the building has undergone several minor changes and alteration but the original state of the building from 1932 remained almost unchanged. Hardly any constructional changes or additions were made in the school throughout the occupancy of the building. The building was built eighty years ago and until today it hasn't been adequately renovated and maintained. For traditionally build structures the typical cycle of repair is that they require a medium level of refurbishment every 50-60 years and a major refurbishment every 100-120 years. For many modern buildings the time for a first refurbishment occurs much sooner than with traditional buildings – after 25-30 years rather than 50-60 years.

Figure 1: Building of Two Secondary Schools in Krizaniceva Street, Zagreb – view from NW 1932; 2007.

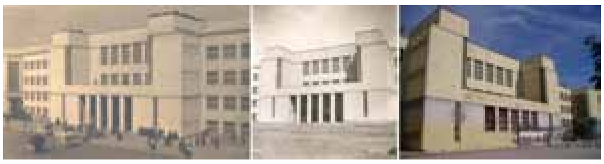

Figure 2: Building of Two Secondary Schools in Krizaniceva Street, Zagreb – views from SE 1932; view from SW 2007.

This research project was designed respecting various Croatian building legislation and conservation guidelines that insure the best building structure in terms of form, construction and building physics. It includes detailed analyses of existing structure, a survey of the building in terms of form, construction and materials, comparison between now and then and calculation of building's consumption.

9. Results

The survey of current structural conditions and approximate calculation of physical properties of selected building concerning the energy saving and thermal protection showed following results:

The structure of building construction and materials of external building envelope do not correspond current regulations, with exception of the recent roof sanation in one part of the school 2007. The building envelope is not insulated. Building construction parts do not fulfill the standardized requirements for overall heat transfer coefficient (U-value) for heated buildings ≥18 ºC. Current space conditions are not under danger of building damage or unwanted condensation in the building construction parts. Concrete rib slabs are used for the ground floor slab as well as the roof construction, again without insulation. Facade is in bad condition, currently painted in yellow colour. Windows are old, wooden, with secondary glazing, completely damaged and in desperate need for repair. The approximate calculation of thermal losses of selected building showed that:

Real transmission heat loss is 94% higher than quotas set for specific transmission thermal loss.

Annual thermal heat demand needed for heating is 65% higher than annual set quotas for heat demand needed for heating.

The problem of heat flow through the outer building envelope (facade - external walls and windows, roof and basement) is the physical and structural key problem of the inter war period buildings built mainly without thermal insulation. Today's technology and science development is producing materials with the most convenient characteristics, thickness and way of building in, make a great contribution in building construction or renovation. With optimal renovation planning project heat loss can be prevented, greater savings attained in heating energy consumption and old buildings can be usable again.

The energy-saving potential for renovation (concept of refurbishment):

1. The heat requirement can be reduced by insulating the unheated attic ceiling (by adding the insulation layer – i.e. MW: 10 cm). In order to attain a satisfactory heat loss limitation level thermal insulation should be also applied in the basement floor (for example - EPS: 5 cm) and basement wall (EPS: 8 cm). Through complete conversion of the attic floor and through insulation of basement, the heat requirement can be reduced by almost 50%.

2. Renovation planning project for this type of building is based on basic principles of facade thermal renovation. Usually, the rendered thermal insulation layer is attached to external structure. Externall wall is brick wall construction (38 cm). The proposed thermal insulation is attached on inner surfaces of external structures. This principle is used when outer changes are not allowed because of historical value of the building. The vapour barrier is integrated inside prior to fixing the expanded polystyrene (5 cm) in order to prevent condensation. With additional insulation of the inner surfaces of exterior walls, almost 50% of the heat requirement can be saved. From the outside these two proposed renovation measures are not visible.

3. After windows repairs, the heat requirement can be reduced by another 25%. Wooden windows should be kept, repaired,

and advanced with double glazed low E (3+8+3 mm) secondary glazing. Overall heat transfer coefficient of windows should be less than 1,8 W/m2K. Openings and proportions of the windows should adapt to the style in shape and detail.

Table 1: Comparison of thermal characteristic of building envelope before and after the proposed measures.

Energy consumption					
Building of Two Secondary Schools in Krizaniceva Street, Zagreb					
Geometrical characteristic		comments			
superficial area – building heated part m^2	23806.15				
volume – building heated part m^3	56423.00				
shape factor $1/mm^{-1}$	0.42	normal value			
usable building area m^2	14537.00				
window area part in the whole facade area	22.84	acceptable value for this type of building			
Building construction					
Overall heat transfer coefficient (U-value) W/m^2K	U – value current	U – value allowed	U – value proposed measures		
wall construction WC1 (brick)	1.289	0.80	0.444		
wall construction WC2 (reinforced concrete)	2.544	0.80	0.534		
wall construction WC3 (basement)	2.115	0.80	0.526		
floor construcion FC2 (basement)	2.552	0.65	0.37		
floor construction FC1 (towards attic)	1.763	0.70	0.326		
flat roof FR1	1.659	0.55	0.254		
pitched roof PR2 (sanation 2007)	0.222	0.55	0.222		
window W1	2.51	1.80	1.80		
window W2	2.78	1.80	1.80		
door D1	4.50	1.80	1.80		
door D2	4.0	1.80	1.80		
Thermal losses	current	allowed	proposed measures		
specific transmission heat loss H_T' W/m^2K	1.22	0.66	0.96	0.61	0.49
necessary thermal heat demand Qh' kWh/m^3a	33.25	20.07	25.59	15.19	12.93

10. Conclusions

The primary goal of this research was the preservation of historic building substance and its adjustment to the new requirements and today's needs. Renovation project has to be designed respecting various regulations and guidelines that insure the best building construction in terms of form, construction, building physics and economizing. By giving some of the basic principles of historical buildings techniques and specific technical measures, cause of further building decadence can be prevented and solved.

The thermal comfort inside the building could be crucially increased by additional insulation on the roof, the external walls and the floor slab. The outward appearance of the building is preserved. The relative proportions of possible energy savings in the school building in Krizaniceva Street in Zagreb are approximately as follows:

> - Through complete conversion of the attic floor and through insulation of basement, the heat requirement can be reduced by almost 50% but these measures of renovation are not sufficient.
>
> - Due to aspects of historic preservation the insulation can only be added to the bricked walls from the inside. Additional insulation of the inner surfaces of exterior walls can save almost 50% of the heat requirement.
>
> - Along with this it would be possible to cut the heat requirement by repairing the original wooden windows approximately by 25%.

Investigation of thermal characteristic of building envelope showed that it could be reduced by up to 70% of the original level.

These figures show the great potential for the renovation of public buildings from the construction period 1930 to 1940. Concept of refurbishment project for the listed building should be planned and realized according to energetic and thermal comfort aspects.

Protecting and preserving the built heritage has to be imperative of the public and the authorities concerned with the built environment. Croatia is following international strategies. It is necessary to pay attention to the environmental protection relating to harmonization with requirements under international conventions (especially in connection with climate changes) and the accession to the European Union. A more widespread consciousness of the need for preservation measures to historic buildings and at the same time possible energy savings by renovation of existing buildings should become the main concern in Croatia.

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ISSUES IN RELATION TO CONSERVATION OF 20TH-CENTURY ARCHITECTURAL HERITAGE OF TURKEY - FORMER T.C. CENTRAL BANK IZMIR BRANCH BUILDING

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1. Introduction

In the last decades, architectural heritage of the modern movement appeared more at risk than during any other period. At the end of the 1980s, many modern masterpieces had already been demolished or had changed beyond recognition. This was mainly due to the fact that many were not considered to be elements of heritage, that their original functions have substantially changed and that their technological innovations have not always endured long-term stresses.

All the architectural heritage elements should be considered as unique and important and worth to be preserved not depending on the time they date to. All architectural values are representatives of the social, cultural, and economic life of the time in which they were conceived. Architectural values belonging to Hellenistic times, for example a temple dating to the Hellenistic period is the representative of the cultural, social and religious life of the society dating to that period. The 20th century architectural values have the same characteristics as well.

The 20th century architectural heritage is very important in Europe, and there are important movements, such as DOCOMOMO, in charge of the protection, conservation and documentation of these monuments.

2. Preservation of 20th century architectural heritage in Turkey

It can be stated that in Turkey, the most easily ruined and demolished buildings are the ones from the 20th century. The reasons for this are:
- They are not valued to be old enough to be preserved
- There are many examples
- They are not associated with prior artistic, architectural and aesthetic values

Unfortunately, these demolishment movements are supported by the local and other major authorities. When the legislation rules of the preservation of the architectural and cultural heritage are examined, there is no definite legal rule for the 20th century architectural heritage. It depends on the architects who are in charge of the transformation process of these buildings whether to demolish them or to preserve them or partially preserve and demolish them.

During the recent years, following the European movements such as DOCOMOMO, their branches are organised in Turkey as well. With the help of Universities, academics, and the Chambers of Architects, these monuments are documented. The Chamber of Architects is in charge of giving lectures to architects about the importance of preservation of cultural and architectural heritage of the 20th century architecture. These efforts by the chamber of architects and the universities, on the preservation of Turkish 20th century architecture make architects aware and conscious.

3. T.C. Central Bank Izmir branch building

Izmir is the third biggest Turkish city, which was re-erected from its ashes after the Independence War. Izmir has examples of the 1st National Architectural Movement, Early Modernism, 2nd Nationalist Architectural Movement, International Style and the Post-Era. T.C. Central Bank Izmir Branch Building is one of the examples dating to that period.

The T.C. Central Bank Izmir Branch Building is one of the few public buildings in Izmir the project of which has been obtained through an architectural competition in early 20th century. This public building was located in Alsancak District on the corner of the intersection of two main streets, and designed by Orhan Bolak, Doğan Tekeli and Ergun Unaran. The project was the winning proposal of the architectural competition in 1950. Between 1930 and 1960, the majority of public buildings constructed in Turkey were winning designs in architectural competitions.

The formal qualities of the building can be considered as an expression of the period of transition during the 1950's from the Second Nationalist Style to the International Style. This building has a scheme organized around a sheltered courtyard. The building has a grid-like pure modernist façade, flat roof and roof terrace accompanied by a curvilinear entrance canopy.

4. Importance of the restoration

The works on transformation of the building into a boutique hotel started in the beginning of 2008. The construction works are still in process, but the building is planned to be open to the public by the beginning of 2009.

As mentioned above, even if there is no limitation in the transformation of 20th century architectural heritage, this restoration project respects the originality, identity and authenticity of the building. This building will be a very well preserved example once the construction process is over. Both the plan and the façade of the building will be preserved. Only the function of the building will change.

The building is a unique building in Izmir's architecture and identity. It is one of the most significant buildings in the area.

In front of it, there is a small square which is commonly used. The public-semi public-semi private-private network of the building is very well organised with the square in front of it (public use) and its atrium (semi-public use). These characteristics – the period, the plan and the façade, its architectural importance in Izmir public life, make it one of the landmarks worth to be preserved, even if there is no legal limitation imposed on the preservation of this type of cultural and architectural heritage.

As a conclusion, this restoration work can be considered to be one of the most important examples of the transformation of 20th century architecture of Izmir.

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TRACKING TOURISTS TO DISCOVER PATTERNS OF MOVEMENT IN HERITAGE SITES

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The impact of tourism on historic sites can lead to cumulative erosion of historic surfaces. Information about the expected loss of materials exists but damage is dependent on the amount of traffic. Devising ways to analyse tourist movement can help develop strategies to reduce loss of valued material. To improve access and preservation in practice requires understanding of how tourists move around locations.

The problem of visitor wear and tear on historic buildings is one increasingly faced by heritage managers in the UK. Growth in tourism and an increasing UK population with a greater proportion than ever before of older people with leisure time and spending power, is leading to greater visitor numbers at heritage sites. For example, membership of The National Trust in the UK was 100,000 in 1961 and rose to one million in 1980. Over the last 10 years alone, it has increased by more than 50%, and now exceeds three and a half million people in England, Wales and Northern Ireland.[1] These highly impressive achievements impact on heritage in numerous ways, and the need to understand the effects of wear on tear are greater than ever before.

Yates and Chakrabati measured the abrasion caused by visitor footfalls onto stone floors in historic buildings, using a micro-erosion meter.[2] They found that stone floors in buildings with high rates of visitation, such as Westminster Abbey, St. Paul's Cathedral and Canterbury Cathedral, were typically recessing at a rate of 0.1 mm per year. They did not attempt to correlate the abrasion rate with visitor numbers, though they note that previous measurements in London underground stations did show a correlation between people numbers and the rate of abrasion.

Global Positioning Satellite (GPS) technology is being used to study tourism movement in the World Heritage City of Bath in the UK. In cooperation with the Bath Tourism Plus, visitors are lent small GPS devices to log their journeys around the city which are used to build up a database of tourist movement. The tourists are asked carry around the small GPS devices and continue with their day as they would have done. When they finish their visit, they return the GPS device for the data to be downloaded. The trails are sent to the tourists as an email to use as a souvenir or postcard. Any photos they took connected to the point on the trail. This provides an incentive for tourists to take part in the experiment.

Collecting data can provide graphical illustration of visitor routes on wide open spaces. This can provide insight into person movement that can be analysed in connection with predicted movement and areas of vulnerability for the site. GPS devices which have a very good level of accuracy in external locations log the position of the carrier every three seconds. The trails of each individual device, as well as specified groups, can be displayed on Google Earth™ to reveal patterns of movement.

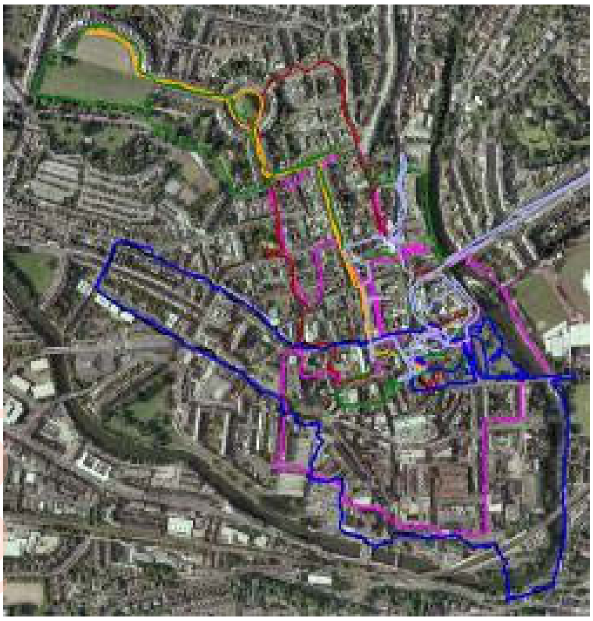

Figure 1: A Google Earth™ image of Bath with tourist trails generated using GPS data.

These trails can be isolated to look at the movement of tourists with a particular quality, such as age or way finding method. In order to carry this out, tourists are given questionnaires after the devices are returned. Information that is requested includes; age, nationality, aims, intended destinations, group size, whether any pre-planning was involved, way-finding strategies and ease of navigation. The study is being carried out several times throughout the year (December, March and July so far), to gather seasonal data. This allows areas of heavy person traffic to be identified in large open spaces, and decisions about visitor management to be based on evidence, rather than expectation or assumption.

Existing techniques using digital technology to observe, analyse and influence movement in urban morphology[3] can be applied to develop demand-led solutions for sustaining heritage. Urban spatial morphology not only reflects and expresses social patterns, but can also play a part in generating these patterns,[4] providing a sustainable platform for heritage management. Analysing person traffic using GPS technology enables suitable, passive methods of controlling rates of deterioration of the historic fabric to be made and can increase safe access and regeneration through tourism.

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MONITORING, MAPPING AND MODELLING THE ENVIRONMENT OF ST. PAUL'S CATHEDRAL LIBRARY, LONDON

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1. Introduction

The Cathedral Library in St Paul's Cathedral was fitted out in 1709 and remains largely unaltered today (Figure 1). It consists of historical library collections, original timber bookcases, mezzanine and wall panels and the magnificent architecture of Sir Christopher Wren. As part of a collaborative development project, an in-depth one year environmental campaign is being carried out in the Wren Library and Cathedral Triforium so that future plans to improve the environment and increase access will be based on a detailed understanding of environmental behaviour.

Figure 1: An image the library of St Paul's Cathedral.

2. Materials and Methods

Temperature and relative humidity (RH) are logged hourly in the library, with sensitive Hobo dataloggers. Three vertical cross sections, each with at least eight data loggers, create a three dimensional frame. Logging is also taking place in areas around the library and externally for comparison.[1] Light levels are also logged continuously (integrated with temperature and RH positioning) and spot checks are also carried out. Light and UV are also measured with spot measurements.[2] Pollution and volatile organic compounds (VOCs) are measured using passive sampling devices, quarterly exposures of a month, and spot measurement in and around the library, including external conditions.[3,4]

Insect pest presence is monitored using blunder traps located in dark corners and access points in and around the library.[5] Dust is measured by week long exposures of glass slides, on which reflectance changes are measured using a gloss meter.[6]

3. Results and Discussion

UCL Centre for Sustainable Heritage will develop a number of unique environmental maps of the Library including seasonal three-dimensional contour maps of temperature and relative humidity, air quality contour maps of SO_2, NO_x,O_3 and volatile organic compounds (VOCs), insect pest maps, thermographic images of heat loss/gain (Figure 2), light and ultra-violet radiation monitoring and dust deposition.

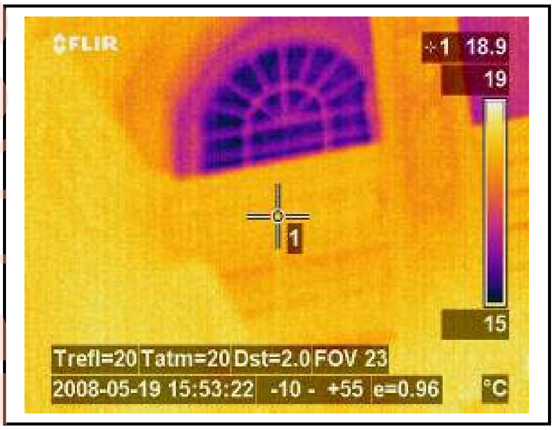

Figure 2: Thermal image of a book stack and north-facing window in St Paul's Cathedral library.

Monitoring is taking place intensively in the library, as well as in the spaces connected to and comparable with the library, and correlated with regularly logged visitor numbers. The data gathered will be integrated to build up a clear picture of the factors affecting the library, and other spaces within the cathedral, throughout the year. Strategic, intensive mapping will provide horizontal and vertical profiles of the library environment, which will be used to inform models and predictions of the space's environmental performance. An example is the measurement of dust, which correlates closely with visitor figures recorded in different parts of the cathedral (Figure 3). Visitor figures in the library are low but more accessible spaces, such as the Geometric staircase next door, have high levels of dust.

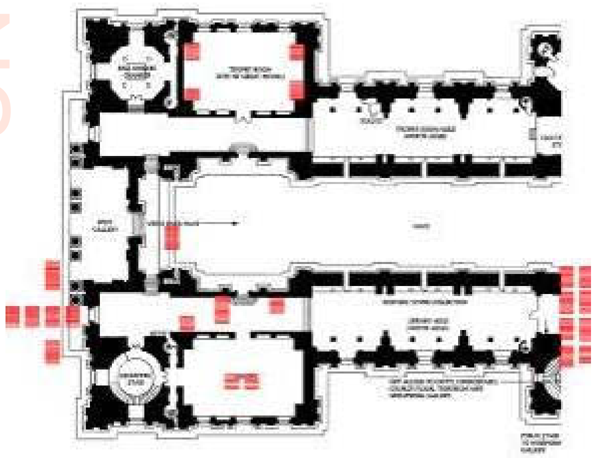

Figure 3: A map of dust deposition for the west end of the cathedral. Each bar is a third of a soiling unit.

A computer model will be developed in order to predict the influence of a potential increase in visitor numbers, changes in activities within the space, environmental control, visitor numbers, refurbishments and ventilation. The collected environmental data will be used to validate computer models. The outputs will be integrated with other specialised studies of the Library including book condition, building fabric condition, including a study of how the assembly was constructed.

Recorded and predicted data will be used to assess the environmental effects on the library collections and fittings, using a variety of techniques, including IMPACT software[7] created by the Centre for Sustainable Heritage. By examining a range of future scenarios, potential strategies can be evaluated to determine the most suitable options.

These will inform plans by the Cathedral to increase the level of access to the Library and enable the Cathedral Conservation Architect to understand the effect that changes to heating and air flows within the space might have on the sensitive fabric and contents. This exemplar demonstrates how scientific research is applied in practice to develop sustainable solutions for preservation and access.

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THE ECONOMICS OF HERITAGE AND THE ROLE OF HERITAGE IN THE ECONOMY: A REVIEW

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Abstract
During last decades, the Heritage sector has experienced great transformations with a kind of development not experienced before. The Cultural Heritage notion itself has been extended also to include all tangible and intangible elements that strengthen the identity of a community. This process has been impelled by a relatively recent phenomenon, the ever-increasing social appreciation for Cultural Heritage and the new roles it develops at present: nowadays, Heritage goods are considered an important cultural, social and economic resource. The social use of Cultural Heritage makes reference to the possibility it embodies for collective use and enjoyment, independent of its ownership mode. Regarding the economic use aspect, Cultural Heritage goods are considered a potential economic resource that, properly conserved and valorised, may become a source of wealth and economic development to the society which it belongs. New social behavioural patterns related to the use of leisure time and the growth of cultural tourism have decisively contributed to this fact.

This paper analyses, from an economic perspective, the way these changes on the socioeconomic level are affecting the Cultural Heritage conservation and management. We will also analyze the economic impact and benefits of the Heritage conservation and valorisation processes and the main economic methods and techniques used to measure these repercussions. The main objective of this review is to point out that Economic Science and its analytical instruments provide an especially useful frame to understand the Cultural Heritage sector and its related processes: conservation, valorisation and diffusion, among others. We would like to emphasise on the ability of Economics to inform Cultural Heritage policy-makers about the preferences and incentives of public and private agents and stakeholders, both on the supply and demand side, and to assess the economic impacts and benefits of the policies implemented.

1. Introduction

The Heritage sector has experienced great transformations with a kind of development not experienced before. The Cultural Heritage notion itself has been extended also to include all tangible and intangible elements that strengthen the identity of a community. This process has been impelled by a relatively recent phenomenon that is the ever-increasing social appreciation for Cultural Heritage and gradually it has taken on a new role. Formerly, Heritage goods were considered a "treasure", known and appreciated only by a minority. Nowadays it is increasingly seen as a valuable resource that contributes to the cultural, social and economic development to the community to which it belongs. Together with its aesthetic and historical traditional values, the cultural value of Heritage is acknowledged, as well as its social and economic dimension. The social use of Cultural Heritage does reference to the possibility it embodies for collective use and enjoyment, independent of its ownership mode. This aspect is increasingly incorporated in national legislations. Regarding the economic use aspect, Cultural Heritage goods are being considered a potential economic resource that, properly conserved and valorised, may become a source of wealth and economic development to the society which it belongs.[1] This idea is reinforced when the focus is put on the potential it has as a strategic resource for deprived regions and territories[2] that have an important cultural legacy. New social behavioural patterns related to the use of leisure time and the growth of cultural tourism have decisively contributed to this fact.

In this new context, conservation and management policies and projects on Cultural Heritage demonstrate important economic implications and driven factors.[3] On the one hand, conservation and valorisation policies have economic repercussions that affect the individual and collective welfare: herein public intervention generates individual and collective benefits, it has effects on economic agent decisions, and it also consumes public resources, thus it competes with other public sector policies and programs. On the other hand, these policies are conditioned by a wide range of economic factors that affect the process of decision making, the instruments' selection, and the incentives or disincentives for the valorisation and use of Cultural Heritage goods.

All these aspects have increasingly contributed to create awareness and promote Cultural Heritage as an object of economic analysis. Thus, at present, the so-called "Economics of Heritage"[4-12] is a consolidated research field, with an ever-expanding literature. Within this scope, the study of the heritage policies occupies an outstanding place. This study usually concentrates on the analysis of the decision making processes, on their implementation and the assessment of the effects of their measures and instruments. However, these studies do not aim to question the decisions made in the matter of conservation and the existence of this kind of policies based on economic reasons: the existence of these policies and the social agreement on the necessity of preserving the Cultural Heritage is previous to the interest of the economists. In fact, economists try to analyze the rationality of this intervention and to contribute with instruments that allow an advance in the design of efficient and effective heritage policies, able to guarantee the use and enjoyment of the Heritage in the present, while they guarantee its preservation for future generations or, that is, their sustainable use.

After these considerations, throughout the following sections we will analyze, from an economic approach, the way all these changes on the economic and social consideration of the Cultural Heritage are reflected in their conservation and management. First we will review the main characteristics and components of the demand of Cultural Heritage in the present societies. In the next section we will see the way these new demands are shaped in regards to the conservation processes and management of the Heritage, that is, for the supply of Heritage. Also we will analyze the main problems of the private markets when satisfying social demands relative to the Heritage, thus impelling public sector to become involved. Finally we will review several analysis tools that may help to establish the existing relation between the Cultural Heritage and the economy by means of the identification and quantification of the economic impacts and benefits derived from the conservation and valuation of the heritage goods.

2. Economic analysis of the Cultural Heritage sector

The demand for Heritage

Last decades, due to the deep transformations occurred on developed economies, Cultural Heritage has received an increasing interest, new needs and demands appearing in relation to the Heritage goods. Proof of this is the strong growth of the demand of Heritage anywhere in the world, which can be stated through the increase from visits to heritage sites, museums, etc. turned our days in traditional points of tourist concentration.[13] It must be pointed out, however, that the value currently assigned to these goods and the nature of their demand are a complex phenomena that do not include just a mere demand of use or direct consumption by visitors. Additionally, it is necessary to consider other demands, related to intangible values of cultural heritage goods, and that impel individuals to demand their conservation independently of their possible present use.

The "value" of heritage goods makes no reference to their simple physical asset value. In fact it refers to all kind of cultural and social values, in its intrinsic and extrinsic form, that are nowadays assigned to these goods. Therefore, the Heritage value is a multidimensional phenomenon that depends on the context and the implied agents, thus it evolves throughout time. These arguments explain why there are different classifications of the value of Heritage goods on the Literature. This is nothing but a reflection of different motivations that have pushed to value (and to conserve) these goods.

In an economic scope, the majority of authors distinguish two basic components in regards of the value of Heritage goods: a value of use and a value of non-use. These two categories are used to determine both components of the present demand of Heritage. The first one is the value of use or immediate utility, which would come from the benefit derived from the direct consumption of heritage goods and services. We may distinguish between a demand of cultural use and a demand of non-cultural use. The former may include, among others, the benefit of those people who wish to visit a monument or heritage site –access demand–, the benefit related to certain services bound directly to the heritage goods –educative guides, services, etc.– and other ancillary services.[14] The later comes from individuals, firms and public institutions that wish to use them for housing or installing a site for their activities, etc. On the other side we may have a demand of non-use integrated by three components:

– an *option's demand* that derives from those individuals that are not users of the heritage goods at the moment, but that assign a value to the possibility *–option–* of being able to visit them in the future;

– an *existence's demand*, based on the existence value, that leans in the belief that heritage goods have an intrinsic value, independent of its value of use;

– a *demand of bequest*, that is based on the utility or value that individuals of present generations obtain from the knowledge that heritage goods would also be enjoyed by future generations.

Therefore, the demand of Heritage at the present time is very complex. Furthermore, these demands usually are not revealed through the market. Concretely, it is possible, in principle, to charge for satisfying the demand of use, either cultural or non-cultural, but the situation is very different when considering the demands of non-use of the heritage goods, that are not expressed through the conventional mechanisms of the market and, therefore, they are going to lack a specific weight on decisions related to private resource allocation when their destination is the conservation and valorisation of the Heritage.

The demand and consumption of Heritage also include some remarkable features. On the one hand, it concerns to values, services or experiences that can be obtained from the Heritage, but not to the support that directly constitutes a heritage object or site.[5] When heritage goods are demanded, it is not intended to "consume" the object itself, but the values, experiences and services supported by them, which constitute the real source of utility for users or consumers. On the other hand, the consumption of Heritage gives rise to *addictive* behaviour in the sense that an increase in its current consumption by individuals, will predispose to the increase in its future consumption (often increases the desire for this goods or experiences, and thereby cause their consumption to grow over the time).[15-17] The reason of this behaviour is that consumption of experiences related to heritage supposes an accumulation of knowledge and experience –of *consumption capital*, using the Stigler and Becker terminology[15]– who reduces the consumption cost in relation to the benefits that are obtained from them. The consumption of Heritage must not be seen only as an act that produces satisfaction at present, but also as an investment in *human capital*, as far as it entails an accumulation of knowledge and experiences that will affect future consumptions.[16]

The supply of Heritage

On the supply side generally we cannot speak of the existence of a true "supply" of Heritage,[i] but of a stock of goods that, in most cases, were not originally produced with the idea of reminding future generations of their heritage, but as a means for satisfying contemporary tastes.[8] As a consequence, it is necessary to "transform" the heritage goods at present in such a way they may satisfy the new wants and demands of the society, and become the support of the social use to which, by definition, they are destined. This is, in fact, the objective of the processes of valorisation of the heritage goods since some years ago, that actually are aimed to convert them again in sources of services –values– for the society, in products adapted to the contemporary preferences and demands, apt for their use and social enjoyment.[1,3]

An overall description of the process of conservation and valorisation of the heritage goods, in which by using an economic terminology we could denominate the process of heritage "production" or model of heritage supply, as shown below**.** This process begins when individuals, institutions or communities decide, by means of a selection process, that several objects or places deserve to be preserved, that represent something on themselves and their past that ought to be transmitted to the future generations,[18] indeed, by means of its *valuation*.[ii] Afterwards, those chosen goods become part of the Cultural Heritage or, following the terminology used by Throsby,[9,19] of the existing *stock of cultural capital*[iii] in a country or community at any given time. Later on, from these goods of the Heritage and after a process of production or transformation the heritage product is obtained. This "generic product" corresponds, in fact, with an ample range of goods, services and values of all type, that jointly take place, aimed to satisfy diverse and varied demands.

The concept of *production* of Heritage, as we have used it on this analysis, makes reference to any type of activity that maintains or augments the value of the heritage goods. That is why the name of "valorisation" is used regularly to designate this process. Activities included within this process are truly varied, however we consider that, taking into account his features and their common purpose, it is possible to distinguish two main groups among them:[1,3]

– A first group may comprise the conservation activities, all those activities related to the improvement and maintenance of the heritage goods or, in general, the stock of Cultural Heritage.

– A second group includes the activities oriented to the production and distribution of heritage services and, in general, to the diffusion of the Heritage. This section would include all the activities whose purpose is the production and commercialisation of derived services of a Heritage site and, in general, those oriented to make possible the access of public, from a physical or intellectual point of view.

In other words, we are talking about the existence of two different activities, in fact about two phases of the productive process, with a clearly differentiated purpose: on the one hand, activities oriented to guarantee the survival of the heritage goods and, on the other hand, those that facilitate their use and enjoyment. Each one of them will have, therefore, different effects from the point of view of the utilities and values they generate: whereas conservation of the Heritage mainly produces important values of nonuse –values of existence, bequest to the future generations and potentialities of future benefit–, the activities of diffusion and production of services generate important values of use for individuals and collectives.

In fact these two types of activities are usually closely related: the state of the stock will have an effect on the flow of services derived from them, in amount, quality and, vice versa, the use and management of the Heritage will affect its state of conservation. In this sense, the exploitation of the Heritage does not necessary carry out a negative effect on its state of conservation, reducing its values of non-use; on the contrary, the "good use" of the Heritage contributes to augment its non-use value. In addition, in many occasions it is difficult to classify the interventions on one or another group, because many activities developed on the heritage goods take care of both objectives simultaneously.[21]

In spite of the disadvantages of generalizations, this description allows to clearly explain the process applied to most of heritage goods before they arrive to the citizens. Logically, depending on the final use given to them, this process can be simplified or become more complex. In addition, in many situations this process does not take place and the "supply" matches the heritage good. The reason for this is that, in the field of Heritage, the existence of a stock does not guarantee the existence of a parallel flow of services,[5] that is, the transformation process that we have described above will not be produced spontaneously.

With all of this in mind, we can say that the supply of Heritage on a country, region or community at any given time will be composed by the set of *outputs* or products derived from the production process of heritage goods that make them available to the demand. In fact, the dimensions and characteristics of this Heritage supply will be the result of the aggregation of the production decisions made by different agents who participate in this process –owners or managers, local governments and so on– that, *a priori*, are adopted independently, although within the same regulating frame established by the State.[22] These decisions will reflect the different objectives and restrictions from each one of these agents, often very different to each other.

3. The failures of the market of Heritage: economic basis of the heritage policies

Once analyzed the main features of the demand and the supply of Heritage it is possible to consider if the "heritage market", defined as the place where the supply and the demand of Heritage meet, as we have described them above, can arrive by itself to equilibrium. Also, from a normative perspective, we must assess if the balance or reached situation would be socially desirable. The general opinion is that the market –the private economy– fails when providing sufficient levels of conservation and heritage services. In fact, most economists consider that the failures of the market in the case of the Heritage are not the exception, but the rule, thus the collective intervention can improve market results promoting the heritage goods valorisation and guaranteeing a sustainable use according to its conservation. Next we will briefly see the main failures of Heritage markets that justify the public involvement in this field on the basis of the social welfare they can provide.

Beginning with the principle of consumer sovereignty, basic hypothesis in the operation of competitive markets, the conservation and valorisation of heritage goods, what we called the supply of Heritage in a society, will depend on the existence of a demand from citizens.[iv] Normally, the market is the regular mechanism where individual preferences for different goods and services are revealed, thus it is the instrument that provides the necessary information to determine the demand. In the case of Heritage, nevertheless, the confluence of a series of circumstances gives rise to inefficiencies or failures in the allocation process. Here it is possible to emphasize the public good[v] characteristic of many values and services derived from these goods and the presence of externalities[vi] in their production and consumption.[9,23-27] Then, decisions made by different agents will only reflect the demand or private value expressed through the market, but not the true value, the social value that citizens attach to heritage services, so its likely to get inferior levels of provision than those socially desirable. In addition, the field of the Heritage is featured by the existence of important *information failures*.[24,25] It is worth mentioning that the

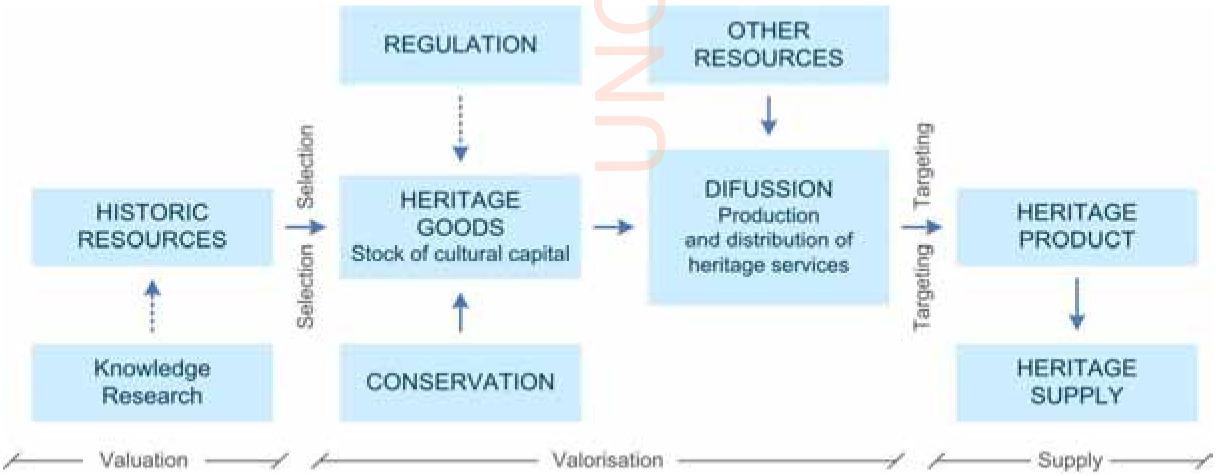

Figure 1: Model of the supply of Heritage. Adapted from Tunbridge and Ashworth.[20]

taste for the Heritage or, in general, for the Culture, is an acquired taste, which is obtained progressively with the consumption of cultural goods and services and the experiences in this field.[25,28,29] It is supposed that with no previous experiences, consumers are not able to anticipate the benefits that the cultural consumption is going to provide them in the future. In the same way, potential consumers of Heritage can not know the value and the authenticity of many heritage services. The lack of information also affects the Heritage owners, who may ignore the value of those goods they own and, therefore, the necessity to conserve them. In these circumstances, they could make no desirable decisions in relation to the conservation and use of these goods that would affect their integrity as well as their survival, a very important aspect in a field featured by the irreversible character of many decisions.

These would be, mainly, the most important arguments that support the public intervention in the Cultural Heritage sector from the point of view of the efficiency in the allocation of resources. However, more arguments from a distributive point of view also support the public interventions in this field. In particular, the argument based on the nature of *merit good* of the Heritage constitutes one of the traditional pillars of the heritage policies.[7,10] These goods have an inherent or intrinsic value due to the fact that they have many qualities recognized by society's majority, which allow them to receive the denomination of commendable or merit goods. The problem that appears in this case is that if their provision is trusted to the market they will not reach the socially desirable levels of provision.

All these arguments constitute an *a priori* justification of the public intervention in the sector of the Heritage. They can be considered as a necessary but no sufficient justification given that it will be necessary to evaluate the convenience of this intervention, analyzing the benefits and social costs derived from the adopted measures. It is necessary to point out, also, that the intervention of the State is not the only possible solution: the collective action can also be undertaken by no lucrative organizations that are acquiring an increasing involvement in this sector, and they allow canalizing demands of nonuse that are not revealed through the markets.

With regards to public intervention, in the development of their heritage policies, governments and public administrations ought to adopt multitude of decisions relative to the conservation and use of the heritage goods, which include many aspects: the determination of the public budget allocated to the heritage policy, the selection of the goods where intervention is required, the election of the instruments applied or the type and level of services provided to the citizens (conservation, diffusion, access), etc.

All these decisions have opportunity costs, because resources can be used for alternative purposes. In order to rationalize these decisions, public authorities must be able to evaluate the benefits or social value derived from their activities comparing them to other alternatives.[10,30] The Economy has, in this sense, some competitive advantages, given that it has an ample set of techniques and methods that allow assessing, in economic terms, the value derived from the activities in the matter of Heritage. As we will see next, the common objective of all these methods is to evaluate the benefits or variations in the social welfare derived from this type of activities.

4. The economic valuation of the Heritage.

There is a broad social agreement about the benefits that Cultural Heritage conservation and use provides to the society. This important role attributed to the Cultural Heritage in modern societies contrasts, however, with the scarcity in the past of empirical studies about the features and outcomes of these benefits. Nowadays, however, we have found an authentic proliferation of economic studies that intend to identify and to quantify these effects. Although it is too soon to consider the existence of a dominant model to measure the benefits derived from the conservation of the Heritage,[31] there is no doubt that this kind of studies are an important advance to show the existence and importance of these positive effects.

When quantifying the benefits derived from a heritage project, the economic studies usually focus on the analysis of the different categories of value derived from the flow of heritage services generated by the project. In this sense, following Throsby,[19] it is possible to distinguish three kinds of benefits: the value of use, the value of non-use and the externalities. The first one makes reference to all a series of private goods and services that the project generates. These goods and services can be destined to final consumption or to become part of the process of production of other goods and services. We may also encounter values of non-use derived from conservation and valorisation Heritage projects –like the values of option, existence and bequest analyzed above– that benefit to all individuals, either users or nonusers of the heritage goods. There are, in addition, more benefits that have an effect onto the society as a whole: the improvement on the educative levels, their contribution to the maintenance of the identity and as a consequence the increase in social cohesion, the formation of an image of prestige for the territory, etc. Finally, these projects also generate externalities –induced effects on the economy–, which usually produce increases in the levels of revenues and employment, attraction of tourism, attraction of new activities and businesses, etc.

The quantification of the total economic value derived from a heritage project deal with important difficulties, accentuated by the characteristic of public good of many of the benefits previously enunciated. The Economic Theory arranges, in this sense, an ample set of techniques that may help to calculate the economic benefits or social value derived from the development of projects and heritage policies. We can distinguish, at least, two different approaches with different targets with regards to the evaluated benefits: the economic impact studies and the willingness to pay studies.

The methodology applied on the traditional economic impact studies is based on identifying and measuring the set of benefits or flows that can be imputed to the existence and development of a heritage activity from the existing financial flows in a reference economy, and considering their joint impact.[29,vii] This is a reductionism approach, limited to the valuation of the monetary impact of this kind of activities. For this reason, in the last few years a methodology that calculates also the social impacts of these activities is under consideration. Although these studies are not free of criticisms, perform a vital function in supplying data which allows comparison between alternative urban or regional planning strategies in terms of their tangible financial consequences.[32]

The willingness to pay studies (WTP), unlike the previous ones, adopt an microeconomic approach that is focused on the assessment of the utility that individuals obtain from the heritage service or, in equivalent terms, in estimating the value they assign to those services through their willingness to pay for them. Whereas, due to their characteristic of public good, many of the values assigned to the heritage goods and services are not materialized in an effective demand through market, it is necessary to choose other valuation methods. Throughout the last decades the economists have developed, in this sense, several estimation techniques that calculate the economic value of this kind of goods and services. These techniques, known under the generic denomination of *nonmarket valuation methods* have been applying successfully in other fields, mainly in the evaluation of environmental resources. It is possible to highlight three specific methods, selected because of their importance in this field: first of all, *the contingent valuation method*, that basically consists of asking through a survey directed to the implied population (benefited) whatever would be arranged to pay for the conservation or recovery of a good, simulating, therefore, the contingency of a market; the *hedonic pricing method*, in contrast, is based on indirectly calculating the value associated to the heritage projects through the increase in the prices of other associated goods, for example, the house's price in an historical centre; and, finally, the *travel cost method* that, beginning with the hypothesis that the cost of the trip to the heritage sites is a suitable proxy of the willingness to pay of the visitor, calculates the valuation of heritage goods by measuring the varied costs people are willing to incur to travel to visit them, which basically include the cost of transport and the entrance fees. These methods allow not only to assess the value of use assigned by individuals to the heritage goods, but even in some cases, like the method of contingent valuation, its value of non-use.[viii]

Although all these techniques have a great potential for the assessment of the benefits derived from the heritage projects, they have several difficulties, from a methodological and also from a practical point of view, which limit their daily application in the analysis of these activities. It must be pointed out that these methods cannot make a global assessment of all the benefits that these activities provide to the society.[31] Thus, these results must not be taken like a mechanism of adoption of decisions, but simply like means to provide information to those who in last instance have assigned the responsibility of decision in the matter.

5. Conclusions

Last decades, the concept of Heritage and also its own sector have experienced great transformations with a kind of development not experienced before. Nowadays, conservation and enjoyment of the heritage goods arises an increasing social interest, thus Heritage is called to perform multiple functions at different levels. In this context, the Heritage administrators and policy-makers have an important and renewed role. The heritage policies must adapt to this new context and try to answer to the increasing and multiple social demands related to Heritage. These greater citizen exigencies force to advance in the design of heritage policies and to improve the efficiency and effectiveness in the commitment of their objectives. In this process, the analytical instruments of Economic Science are revealed especially useful because they can help to heritage administrators and policy-makers to take their decisions with a greater understanding of the Cultural Heritage sector and the preferences and values assigned to heritage goods and services by different stakeholders. In the same way, they can help to assess and clarify the relations between the Heritage and the economy, providing information to cultural institutions and local governments, useful for the implementation of development programs and urban renovation strategies. In the long run, all of this will result in greater levels of social welfare.

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7. Endnotes

i. In the economic analysis context the term supply makes reference to the amount of goods and services available to the demand at any given time.

ii. In this case, following Peacock,[8] it is not possible to merely speak of the existence of an organized production process, but of an accretion process in which specialists and experts in this field have an outstanding contribution.

iii. Throsby[19] proposes using this terminology to distinguish cultural goods –featured by a cultural and economic value– from the typical economic assets –that only provide economic value.

iv. Accepting the principle of sovereignty of the consumer supposes, in this case, the crucial assumption that users know the value of cultural consumption and cultural heritage conservation for society as a whole, and they are willing to pay for them.

v. The concept of "public good" implies two features: they are nonrival in their consumption, as far as their consumption by a person does not reduce their availability for others; they are also nonexcludible, in the sense that it is impossible to prevent anyone to consume them once they have been produced.

vi. Goods generate externalities when their production or consumption affects to the benefits or well-being of agents different from their producers or original consumers, with no reflection on the market price. With regards to Heritage, the economic benefits that its production provides to other agents of the area like beneficial hotels, restaurants are usually addressed, but we may also consider the effects on the level of general education, its contribution to the reinforcement of the national identity, to the increase of the social cohesion and harmony, to the formation of an image of prestige for a territory, etc.

vii. A recent application of these studies in the Heritage field can be seen at Vicente et al.[33,34]

viii. Several examples of the application of these techniques in the Heritage field can be found at Navrud and Ready.[35]

PRESERVATION MANAGEMENT AND RISK ASSESSMENT IN SLOVENIAN ARCHIVES

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1. Introduction

Preservation management is one of the basic activities of all institutions working in the area of preserving and managing heritage, and is therefore also one of the basic expert and management tasks of every archive. Differences among institutions are primarily in the manner of processing, use and presentation to the public. Archivists, librarians and curators differentiate heritage primarily with regard to its content and the intended purpose associated with it. In preservation management, it is not important whether the object comes from a museum, a library or the archive collection of an institution, a company or an individual; what is important is the nature of material it is made of, the type and level of damage, the frequency of its use, and its historical or artistic value. It is therefore in principle the same, in terms of the manner of preservation management of heritage, in which public or private collection is a certain material or object; it is only important that adequate recommendations regarding storage and use are respected which for similar materials are the same everywhere, regardless of the owner or trustee.[1] Large quantities of material and relatively complicated preservation of various materials, from classical and machine-readable (also electronic) materials, as created in the last century, require consideration of certain rules and recommendations related to the buildings, storage, use, safety, selection, reproduction, exhibition, and conservation or restoration. The problematic therefore with each generation gets a bit more complicated, and with the appearance of electronic media even more complex, and to be honest, also more expensive.[2] Following the rules and recommendations should contribute to an improvement of the conditions which are necessary for the storage and use of archive materials. In this, standards and policy for preservation at local and national levels are of great help, but that is not enough; it is necessary to regularly ensure certain financial means, and above all an efficient management.

2. Methodology

Risk assessment survey of archival premises is the essential part of an effective preservation management.[3] Of great help for such assessment are standards and guidelines and of course the already formed models for evaluation of the premises, which are in use for keeping archival records. In the particular case we used standards and guidelines suitable for the climatic conditions in Slovenia, together with the model presented at the ICCROM 2005 preventive conservation course Reducing risks to collections in archives and museums.[4] The situation in Slovenia is presented on the base of the results presented at the conferences of the Slovenian archivists in Velenje 2007[5] and Radenci 2008.[6]

A risk assessment was carried out in all Slovenian public archives at least in one storage room per archive. A detailed dossier with information about the short history of the archives, buildings and material was prepared for each presented archives. Possible risks were identified for all ten agents of deterioration: physical force, theft and vandalism, fire, water, pests, air pollution, light and radiation, inappropriate temperature, inappropriate relative humidity and loss / misplacement.

For each of the ten agents of deterioration a scenario,

possible damage or losses was worked out. The risks were classified in 3 types:

Type 1: Rare in frequency and catastrophic in severity

Type 2: Sporadic in frequency and intermediate in severity

Type 3: Constant in frequency and gradual or mild in severity.

In accordance with Stefan Michalsky's classification of evaluation we need to estimate possible risk that threats to the collection. We expose only those which are realistic, and eliminate those that do not represent any risk in accordance with the specific characteristics of individual institution. Risks are than semi-quantitatively evaluated in accordance with the collected data, condition of the institution and possible eventual risks in the following scale:

*** high risk,

** medium risk,

* low risk,

Ø no risk.

3. Results and discussion

The dangers that threaten materials are fundamentally the same for all materials. Experts have classified them into ten agents of deterioration which affect the decay of materials, regardless of the form or material. In Table 1 we present the data obtained from the results presented in Velenje 2007 and Radenci 2008 and is presenting the average situation of the archival repositories in Slovenian archival repositories. On the base of the results of the risk assessment survey done in years 2007 and 2008 we may established that the biggest risks that are: poor handling, all sorts of pipes under the ceilings, lack of hydro and thermo isolation and incorrect humidity, which is partly represented in Fig. 1.

Experts who are engaged in management are finding that the majority (80%) of the benefits of an organization are normally obtained by a small (20%) percentage of invested efforts.[7] Therefore, we can say that a substantial part of successful storage and protection is achieved with a short list of recommendations, which we could also call the Basic Strategies of Storage, and they represent an important step in the process of effective storage and protection of archive materials:
- Records of the condition of the collections
- Well-informed and adequately educated personnel
- Reliable roof, walls, floors, windows and doors
- All problems of humidity solved
- An effective fire-prevention system
- Safe locks on the doors and windows; an efficient safety alarm that has a shorter response time than a possible break-in time
- No intense light, direct sunlight or strong electric illumination
- Regular cleaning and examination of the materials in the depots and at exhibitions
- Boxes, wrapping, folders and other types of protection and support for sensitive objects

The basic steps in this list can reduce the risk of several factors at the same time, often also at low cost, or they can reduce the risk of one single larger factor that could seriously affect all collections or perhaps even the whole building. For example, a reliable roof and walls stops nine of the ten factors that influence the decay of materials, perhaps not always entirely, but definitely to a large extent.

Table 1: Estimation of risk for the majority of the Slovenian archives (year 2007/08).

Agents of deterioration	**Specific examples of damage or loss**	**Magnitude of risk**
Direct physical force	Collapse of part or whole building	Ø
	Poor handling, distortion, abrasion, vibration…	***
Theft and vandalism	Professional theft or vandalism	*
	Inside theft	*
Fire	Soot, smoke, water damage…	*
Water	Roof leaking	Ø
	Capillarity and condense water	***
	All sorts of pipes	***
Pests	Insects, rodents, birds, bacteria…	*
Air pollution	harmful gases, dust particles, salt, grease …	**
Light / radiation	Inside	*
	Outside	*
Inappropriate temperature	high temperature: melting, fragility, chem. reaction, disintegration from drastic change of T	**
Inappropriate humidity	High or low humidity: mold, corrosion, swelling… or dehydration or checking	***
Loss or misplacement	Loss or misplacement of object or data	*

Fig. 1: An often seen situation in underground repositories.

4. Conclusion

In planning and implementation of the preservation management of materials, we often like to make the mistake of seeing solutions above all in building or buying something new. In fact many other, perhaps even more efficient, possibilities exist, which are based primarily on education of the personnel and on good mutual communication. The most important thing should be the common interest, connecting, pooling knowledge and experience, with a common objective of preserving heritage for future generations and enabling access to it to the greatest possible extent.

We must therefore seek integrated solutions for storage and protection of materials, which means that we should try to introduce the activity of preservation management throughout the whole public archive system. Our objective is not theoretical, but practical implementation of measures. We must search for lasting and persistent solutions which are in harmony with the professional, economic, and today also with ecological and energy-saving aspects.

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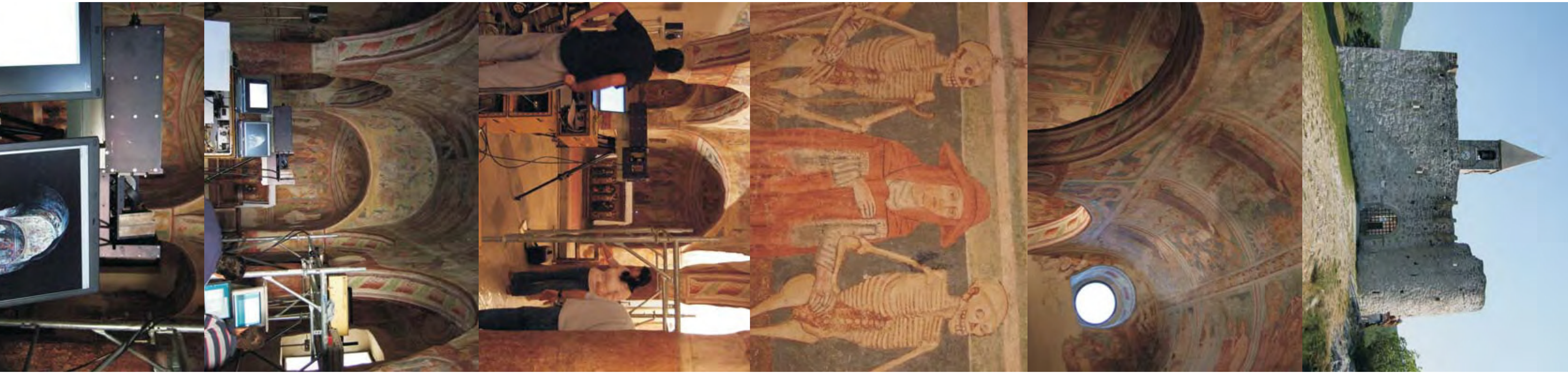

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