HERACLES NEWSLETTER

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HERACLES

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CASE STUDIES

CRETE, GREECE:

1. *Minoan Knossos Palace*
2. ***Venetian coastal fortress of Koules***

GUBBIO, ITALY

3. Medieval Wall and High Town

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HEritage Resilience Against CLimate Events on Site

THE MONUMENT, ITS HISTORY AND PRESERVATION STATE

The Venetian Sea-Fortress is an emblematic monument for the city of Heraklion. Better known as Koules ("Su Kulesi"), the Ottoman name, which prevailed over its original one, Castello a Mare or Rocca a Mare. It is situated at the edge of the NW breakwater of the Venetian harbour. The large limestones used for its construction come partly from the Hellenistic fortifications of the city. In the past, at the same place was a rectangular beacon-tower, called by the Venetians, Castellum Communis. The tower was destroyed by the earthquake of 1508 and since 1523 it was decided that a larger fortress, built according to the bastion-system, had to replace it. The shape of the fortress is roughly quadrangular, with a semi-circle bastion at the SE side. Its outer walls are inclined and the main entrance is situated to the West, giving way to the Venetian fortified mole. On the western, southern and north-eastern façades, the marble emblem of Venice (i.e. the lion of St. Marco) was embedded. On the ground floor, to the left of the main corridor, there are barrel-vaulted rooms which hosted barracks, warehouses, prison cells and water-tanks. Light and air came into the rooms through the roof. All around the building there were openings for the cannons. A staircase and a ramp for the cannons lead to the upper terrace, around which there were other cannon-openings, barracks, a mill and a beacon. The surrounding walls ended up in a straight parapet, protecting the inner corridor. The battlements were added during the Ottoman occupation period.

Roccca a mare fortress, (F. Basilicata, 1636-1638, collection of the Biblioteca Comunale of Bologna)

Candia map (XVII Century, G. Corner)

The first attempts of restoration started in 1959 by the curator of antiquities Stylianos Alexiou. More work has been done by M. Borboudakis during the period 1972-75, according to the approved study suggested by A. Lampakis to make the fortress accessible to the public. No additional work had been executed during the following years, resulting in the decay of the monument. The binding mortar of the masonry has been badly weathered and the balusters, although recent restored, were almost ready to collapse. Salt black hard crusts were covering part of the walls, sea and rain water were entering from the broken skylights at the roof of the galleries. All the iron elements used in the monument were heavily corroded.

During the first decade of 2000, the Greek Ministry of Culture, anticipating the problems that the monument was facing, decided to take new measures for its protection and safeguarding. Under the direction of the Ephorate of Antiquities a National Strategic Reference Framework Project concerning the Restoration and Conservation of the Venetian Fortress (Koules), took place (2011-2016). In the conservation program the main concern was related to the static and reinforcement aspects of the monument.

In the conservation program the main concern was related to the static and reinforcement aspects of the monument. In order to achieve the desired result, previous interventions to masonries, both indoors and outdoors, have been removed, the lions' relieves have been consolidated and preserved, and the old frames of the cannon openings at the ground floor have been replaced with stainless ones. Restoration works aimed to the cleaning and protection of the stone surfaces from hard salt crusts and biodeterioration signs, where it was possible without losses of the material. In addition, the three lions' emblems on the facades of the monument were cleaned and consolidated in order to achieve compactness.

It has to be mentioned that during the restoration program (2009), the School of Mineral Resources Engineering of Technical University of Crete had performed analysis of stone masonry identifying four types of sedimentary stones: breciated fossiliferous limestones, microbreciated limestone, calcarenites sandstones, and bioclastic/biomicritic fossiliferous limestone.

St. Marco lion detail before and after restoration

The continuous exposure to marine aerosol of the fortress has produced severe weathering of the building stone (biocalcarenite), which is a porous material susceptible to the action of soluble salts and environmental conditions. The same problem concerns the materials used for restoration works.

RISKS/HAZARDS AND TECHNICAL ASPECTS

The fortress of Koules is surrounded by a number of major sources of pollution, as indicated in the image above. Specifically:

- Local airport of N. Kazantzakis is situated 2 km to the East
- Local installations of the Public Power Corporation are located 9 km to the West
- Industrial Area of the city of Heraklion is found 4 km to the SE of the monument.

All the above infrastructures contribute significantly to the air pollution load of the monument. According to statistics, during the summer period there are more than 150 landings and take-offs per day. Many of these take-offs follow the direction of the airstrip airport fortress burdening the atmosphere with air pollutants. Finally, smokestacks of the ships from the nearby port constitute an additional source of air pollutants.

The immediate contact of Koules with the sea makes the fortress vulnerable to salty northern winds, which are often very severe, reaching 9, 10 or even 11 in the Beaufort climax/scale. Especially during the winter season high waves are often literally covering the monument.

The fortress of Koules is affected by climate conditions coupled with the pollution, which can initiate and accelerate deterioration mechanisms for both original and restoration materials. Geophysical measurements recently carried out, have revealed that caves at the foundations of the monument are present and repeated at regular intervals, showing that are made deliberately for the circulation of seawater under the construction. Unfortunately, in the past, these caves/tunnels have been considered as resulting from the foundation erosion and for this reason were filled with concrete in order to stabilize the structure.

Crusts of salts and black hard encrustations are observed on the walls in several rooms at the interior of the monument. Similar black crusts have also been observed at the areas around the joints both internally and

externally to the monument. These crusts are rough and inhomogeneous and appear aggressive to the materials.

The cumulative effect of the weathering factors at the monument is unambiguous, since it has been acting for more than five centuries. Macroscopic investigation indicated that the deterioration of the stone, along with the detachment of the grain aggregates, proceeds to selective pitting, resulting to the formation of deep interconnected cavities. The stone appears to have suffered an irregular loss of material, which follows the alveolar weathering pattern. Furthermore, a number of cracks have been detected around the monument and their restoration is important.


Examples of weathering degradation

Due to this vicinity with the sea, it is expected that sodium chloride will prevail among the sea salts. Crystallization of sodium chloride (absorbed from the atmosphere or as seawater spray) plays a role in the decay process of the stones, together with stress due to water adsorption.

KNOWLEDGE TO BE ACQUIRED THROUGH THE HERACLES PROJECT

Here are presented part of the HERACLES activities more related to the study of the Fortress itself.

The role of the photonics for Cultural Heritage group IESL-FORTH, in the framework of HERACLES project works that are focused on the Venetian Sea-Fortress (Koules) is twofold:

a. It will contribute to the remote, non-destructive, high detail/accuracy in-situ analysis of the composition and possibly of the origin of the various weathering features encountered on the monument, such as efflorescence salts and other crusts, as well as to the monitoring of their progress and expansion on the areas of interest. This will be performed using portable instrumentation based on optical and laser spectroscopic analysis (LIBS, Raman, multispectral imaging etc.). Moreover, novel imaging techniques, as for example portable 4-D surface /volume topography, will be employed to non-destructively characterize, delineate and map materials aiming at gathering complementary high-resolution information for their composition and morphology. Among the aims of this work will be to assess how the climatic conditions influence the creation and expansion of these features, aiming at setting the alerts that would call for immediate action and preservation, as well as to evaluate the effectiveness of the treatments and /or the criticality and necessity of new restoration interventions.
b. It will perform (ex-situ) analyses, based on laser spectroscopy, in the laboratory on samples taken from areas under investigation of the monument, in order to characterize the structural, chemical and physical properties of the materials (ancient, new, as well as alteration forms).

The installation of a meteorological station and a wave recorder in the Venetian fortress "Koules" will be carried out by IACM-FORTH.

Both the meteorological and the wave data will play a pivotal role to the restoration processes of the Koules monument. Site calibration and microclimatic modelling rely heavily on the existence of accurate climatic data, spawn over long periods of time. Also, the available satellite weather data for the region will be correlated with the ground meteorological station time series (ground-trouthing and calibration). The combined use of these datasets as inputs for the computational predictions will improve the accuracy of the models and will lead to more realistic weather forecasting for the region.
The meteorological station will be installed on a 3-meter metal mast, which will be protected from lightning strike and will be able to withstand wind speeds exceeding force 9 in Beaufort scale. The installation position will be chosen, in order to minimize interventions on the monument of the Venetian fortress. The mast will be equipped on its highest point with a Franklin type lightning rod, which will be properly grounded outside the building.
The meteorological station will provide raw data (times series of wind speed and direction, temperature, humidity, rainfall, barometric pressure, solar radiation and UV Index), as well as graphical plots, all available online and accessible via the HERACLES project web page. All weather parameters will be recorded at 1 minute intervals. Every one to five minutes the weather station will generate and send a report for display on the website and will upload the raw data (in ASCII format) to the database.
An autonomous wave recorder will be installed in shallow waters, in the nearshore zone of Koules, to monitor sea level, wave height, wave period and sea temperature. Data will be collected and be analyzed to study the nearshore wave conditions that affect the monument.

Within the frame of the HERACLES project the contribution of the Crystal Engineering, Growth & Design Laboratory of the Department of Chemistry, University of Crete, will be focused on the current state of preservation of the stone building and architectural elements of the Koules which will be tested and evaluated in-situ. For this purpose, the mechanical properties of the aforementioned dominant lithotypes will be examined through the application of the micro drilling resistance measuring system. Thus, it will provide crucial information regarding the several parameters affecting the monument. Moreover, it will be made possible to evaluate the implementation and hence the performance of different consolidants and application methods used in the past, in terms of depth of penetration and development of consolidating compounds inside the stone mass (pores, discontinuities).

The University of Perugia (UniPg) will support all partners involved in the activities in Koules, by providing support for interpreting material properties and monitoring data in the perspective of structural vulnerability aspects of the fortress. UniPg will also carry on inspections of the fortress to identify possible aspects of structural vulnerability, including a visual survey of existing cracks in the masonry and the identification of the factors most likely causing the same cracks (e.g. settling of the foundations due to coastal erosion, excessive vertical loads and past earthquakes). Inspections will profit by the use of infrared imaging to discern between surface cracks and cracks passing through the whole width of the walls, as well as to detect the possible presence of voids and discontinuities in the masonry and to detect qualitative differences in materials properties from one portion to the other of the fortress.
Additionally, UniPg will carry on the microclimate dynamic monitoring of the fortress, in order to assess its local environmental conditions in terms of air temperature, surface temperature, relative humidity, wind speed, wind direction, and air quality by means of a brand-new portable experimental equipment specifically developed for the scope of the HERACLES project, i.e. payload. Therefore, such monitoring equipment will be used to map over both space and time of the above-mentioned parameters from different heights, i.e. at pedestrian level and above the fortress height by means of drone (where possible), in order to (i) investigate the parameters variability and (ii) evaluate their impact on the ancient fortress structure. This kind of experimental monitoring campaign will be replicated by UniPg in all the case studies of the project.

The Institute of Nanostructured Materials (ISMN) is a CNR research institute with expertise in the field of synthesis and characterization of materials.
The ISMN will contribute to the HERACLES activities with the expertise in material science diagnostics and synthesis of new or modified materials applied to CH. It will be done through:

(i) micro- and nano-physico-chemical and morphological study of ancient artefacts (in particular stones and mortars) for the determination of their material composition, provenance, production processes and manufacturing technologies;

(ii) assessment of the conservation state and study of chemical-physical phenomena at the micro and nano-scale for the identification of degradation agents and mechanisms;

(iii) design, synthesis and validation of new, long-lasting, reliable and nontoxic materials and methods for conservation and their tailored application and validation.

Studies in laboratory will be carried out in order to characterize the structural, chemical and physical properties of the original and new materials to be used in the restoration processes. These (ex-situ) analyses will be focused on the identification/classification of materials and determination of their composition and structure by using X-Ray Diffraction and X-ray Photoelectron Spectroscopy (XPS).
X-ray Photoelectron Spectroscopy (XPS) is a surface-sensitive quantitative spectroscopic technique that measures the elemental composition at the part per thousand range, empirical formula, chemical state and electronic state of the elements that exist within a material. XPS can be used to analyse the surface chemistry of a material and is routinely used to analyze a wide range of materials from inorganic compounds, glasses, ceramics, stones, etc.

Together with X-Ray diffraction (XRD), the nature of the crystalline compounds will be also assessed.
The Institute for Electromagnetic Sensing of the Environment (IREA) is a CNR research institute active in scientific and technological development in the field of remote sensing and in situ diagnostics and monitoring of the natural and built environment, based on electromagnetic sensing. It focuses on the study of methodologies and technologies for acquisition, processing, fusion and interpretation of data derived from electromagnetic sensors on satellites, aircraft and in situ for territorial management, supervision, security and risk assessment. With reference to the Venetian Sea-Fortress (Koules), in cooperation with e-GEOS, IREA will carry out analysis of satellite data acquired by imaging radar sensors, specifically the sensors of the Italian COSMO-SKYMED constellation, for the reconstruction of point clouds and monitoring of long-term deformation. Data of such sensors are characterized by very high resolutions, lower than 3x3 sqm., and will allow providing 3D geo-localized points with deformation time series useful to for the assessment of the stability of the site and for the structural analysis. IREA will be also involved in in-situ monitoring of the subsurface and structures by means of the Ground Penetrating Radar; in particular, it will exploit advanced data processing based on microwave tomography for a 2D/3D reconstruction of the subsoil and the inside of structures with the aim to provide information at support of the structural health assessment. Finally, IREA has expertise in the use of TeraHertz electromagnetic waves for the millimetric and sub-millimetric diagnostics of the surface and very shallower regions with aim to detect defects as delamination and fractures. IREA will make available its THZ system for studies in laboratory aiming at the morphological characterization of samples and materials.

UNINOVA, as a materials research institute linked to the New University of Lisbon, will be involved in all tasks considered necessary by the consortium for the evaluation of the state of conservation of materials, analysis of degradation phenomena and characterization of building materials such as stone, binders, mortars and new materials to be developed for use in the three case studies of the HERACLES project, i.e. the Medieval Town of Gubbio, the Knossos Palace and the Koules fortress. A multidisciplinary approach in close proximity with the remaining partners is envisaged and will consider a set of non-destructive analytical

techniques for the characterization of these materials, contributing with the equipment available at Uninova. Such methodologies give the opportunity for the minerochemical characterization through X-ray diffraction in the usual Bragg- Brentano geometry and X-ray fluorescence using a wavelength dispersive system. Observation of samples taken at the site through optical microscopy will allow for macroscopic constituents observation and the use of scanning electron microscopy will allow for a microstructural evaluation of the samples. Techniques, such as Ellipsometry for dielectric measurements or Atomic Force Microscopy for surface profiling, are also possible as well as measurements on the thermal behavior of materials through thermal differential analysis coupled with thermogravimetry.

PRESENTATION OF THE PROJECT

HERACLES PRESENTATION, "NEW HUMANISM FOR THE XXI CENTURY", 24-25-26TH OCTOBER 2016, PERUGIA

The aim of this meeting was:
a) To discuss and identify contributions of the Chairs to the UN 2030 Agenda for Sustainable Development, through independent but also joint projects;
b) To identify how the Chairs can increase their contribution to the implementation of the International Hydrological Programme for the current biennium (2016-2017) and the entire IHP-VIII phase (2014-2021);
c) To define mechanisms to increase the cooperation between regional/similarly-themed Chairs, e.g. initiating the establishment of an information sharing system among all Water Chairs.
A further aim of the meeting was also to discuss and express opinions on the concept of the "New Humanism for the XXI Century" in Education, Culture and Science. In other words, interdisciplinarity as the factor to address many of the current issues, including the achievement of water security and peace.

During her presentation, Giuseppina Padeletti evoked the different aspects around HERACLES project, that meet the UNESCO Chairs aims. The relevance of the Cultural Heritage in the life of people and in their education was underlined, as well the importance of projects like HERACLES, that provide solutions to maintain and preserve the cultural heritage to be passed on to future generations.

POLICY SEMINAR AND WORKSHOP 'CULTURAL HERITAGE, DISASTER RESILIENCE AND CLIMATE CHANGE: THE CONTRIBUTION OF EU RESEARCH AND INNOVATION', 7TH DECEMBER 2016, EUROPEAN COMMISSION, BRUSSELS

The event focussed on how to increase disaster resilience of cultural heritage sites in the face of climate change and natural hazards. It was organised by European Commission, DG Research and Innovation, Climate Action and Resource Efficiency Directorate, Sustainable Management of Natural Resources Unit, with the support of:
JPI CH – Joint Programming Initiative on Cultural Heritage and Global Change
EASME - Executive Agency for Small and Medium-sized – Enterprises
REA – Research Executive Agency.
DG Research and Innovation organized this full day event with policy makers, stakeholders and researchers and innovators to discuss the latest developments on cultural heritage at risk.
The initiative consisted of a policy seminar and a workshop gathering EU research and innovation projects. The aim was to open a confrontation between policy makers, stakeholders and the community of researchers and innovators on 'what is new under the sun' for heritage at risk. The open debate evoked the ideas to increase disaster resilience of cultural heritage sites facing natural hazards and extreme climate-related events; risks that are threatening cultural heritage sites; the innovative solutions to prevent and mitigate their

environmental, economic and social impacts and the recent results from EU research and innovation projects through the use of earth observation and smart technologies. The aim is to foster knowledge sharing, improve synergies and find common actions for the future.

During the day, G. Padeletti talked about the multidisciplinary and holistic approach of the HERACLES project, and about the expected results and the innovative solutions.

FOCUS NEWS: 2018- EUROPEAN YEAR OF CULTURAL HERITAGE

The 2018 will be the European Year of Cultural Heritage. The aim of the European Year of Cultural Heritage is to share our common cultural heritage and its potential for identification, participation and development with each other in the light of a heterogeneous European social structure and against the background of current economic challenges.

It is the best witness to Europe's rich history, which has been strongly influenced by values such as diversity, tolerance and intercultural dialogue. The European Cultural Heritage Year builds in particular upon the fact that our shared cultural heritage is always both local and European. The European Year highlights this dimension and uses it to respond to current challenges. It also builds on new opportunities to preserve and develop cultural heritage while underscoring the need to do so, because our cultural heritage is an essential, unique, irreplaceable part of Europe's social and economic potential which is closely tied to many other areas and is thus the foundation of our shared development in Europe.

The programmatic focus for the year is "Society in Transition", which reflects ongoing and diverse social change in Europe. Three aspects in particular are to be discussed during the European Year: cultural diversity, demographic change and sustainability. This will give the European Year its political and economic relevance.