Hyperion

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Development of a Decision Support System for Improved Resilience & Sustainable Reconstruction of historic areas to cope with Climate Change & Extreme Events based on Novel Sensors and Modelling Tools

EDITORIAL

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Editorial by HYPERION Project Coordinator, Dr. Angelos Amditis

Dear readers,

I am very pleased to welcome you to the 2nd issue of the HYPERION Magazine! An annual publication created to present the project's major results and achievements, through its second year of activities. During these challenging times of COVID-19 pandemic, HYPERION team stayed connected virtually and continued to work together to carry out our vision to promote the sustainable preservation of cultural heritage around the world. As Climate Change is becoming more and more a crucial topic globally, HYPERION's research objectives become even more significant and relevant. Climate Change, ravages of time, intense geological phenomena, extreme weather conditions, all having an impact on historical areas hosting Cultural Heritage sites. Resilience is an essential attribute as we move through this crisis and into the future. In this context, during its second year, HYPERION is diving even deeper, aiming to address these challenges, bringing a major impact on improving the conservation-restoration process and safeguarding of tangible cultural wealth. In this magazine, you will have the opportunity to review HYPERION's research progress and learn about its recent results. A major thank you to all our partners in HYPERION consortium for contributing to this issue by sharing their most recent research developments.

Welcome message by HYPERION Project Manager, Dr. Antonis Kalis

Dear readers,

Welcome to the second issue of HYPERION's annual magazine! HYPERION is a pivotal EU funded project which started in June 2019, and marks the strong concern of the European Commission on preserving Cultural Heritage in times of Climate Change (CC). The project aims to create a strong safety net for supporting both the Cultural Heritage structures, and the surrounding communities supporting their resilience. This is of utmost importance in an era of globalization and extreme CC related events, helping in the development of communal bonds, now and in the future. In this issue, we are pleased to present all the recent developments of the project, which pave the way for reaching HYPERION's goals towards resilient Cultural Heritage districts. During this year, the consortium worked on innovative methodologies which will help to assess the effect of a multitude of CC or human inflicted threats on the landmarks themselves and decision support tools and training environments to assess and mitigate the effects of unforeseen events. HYPERION also developed community engagement tools that amplify community involvement both proactively and reactively to major disrupting events, and business continuity plans to strengthen community responsiveness. Read all about its significant progress in the following pages.

Happy reading!

HYPERION's Progress

One of the main goals of HYPERION is to identify extreme climate indicators and atmospheric stressors in connection to specific hazards. This includes dynamic downscaling of the regional climate model predictions, simulation of average climate and extreme events in the meso-local-site scale, including an estimate of uncertainties. In doing so, during the past year, HYPERION focused on the construction and installation of smart tags, edge network devices, equipped with environmental sensors and of micro-climate stations, which provide measurements of a set of atmospheric parameters, such as the air temperature, humidity, UV index and wind direction and speed. Both smart tags and micro-climate stations were installed and tested on certain Tier 1 buildings at the project's pilot sites. Based on the collected data, there were created maps of quantified impact, extremes, and environmental forcing at local scale. All input data came from external sources, either provided by local partners (when available) or from online publicly available sources. The output is currently used in WP4, in WP5, and in WP7 where the smart tag and micro-climate station measurements' are visualized and presented to the end-users.

Networked unattended, low-cost Micro-climate stations and Smart Tags

The building materials of Cultural Heritage monuments are subjected to continuous degradation throughout the years. The specific climatic conditions, at the area where the monument is located as well as at its walls, have a significant impact on the type and rate of deterioration. Generalized models that are based on climate data from publicly available weather stations can provide an insight on the deterioration and its type but fail to offer a deeper understanding of the rate and the causes of this phenomenon, information that is critical for the proper maintenance and protection of the monument. To this end, in the context of HYPERION, a distributed smart sensor network is deployed at the Cultural Heritage monuments in the four pilot cities. The network includes microclimate weather stations that are deployed at the broad area of the monument as well as smart tags that are installed on the wall of the monuments.

Smart Tags

As mentioned earlier, smart tags are edge network devices, equipped with environmental sensors that are installed in certain buildings of the Cultural Heritage site. The smart tags are responsible for monitoring the environmental conditions and changes in the vicinity of Tier 1 building walls, by acquiring accurate air temperature and humidity measurements. The tags are also calculating the dew point temperature and monitor the dry/wet condition of the building walls. The smart tags are designed according to the needs of the pilot areas, taking into consideration the lack of infrastructure such as power and/or connectivity, in order to provide a reliable solution that will be power efficient and weather resilient. As a result, a distributed network of autonomous, unattended, reliable and long-life wireless tags, deployed on specific spots in the interior/exterior walls of the buildings, is demonstrated. The smart tag case was designed using the Autodesk EAGLE software package and printed by a 3D printer. It is constructed using ABS filament and it has IP56 rating, being waterproof and suitable for the required environmental conditions. The case is designed to be a compact element that contains the smart tag board and the battery in the interior space and the solar panel in the exterior. Externally white colour is used in order to absorb as little as possible heat. There are also, small openings on the front and on the sides of the case to allow air circulation for cooling of the sensors. The case design is shown in Figure 1and its dimensions are presented in Figure 2.

Figure 1: Smart Tag case overview

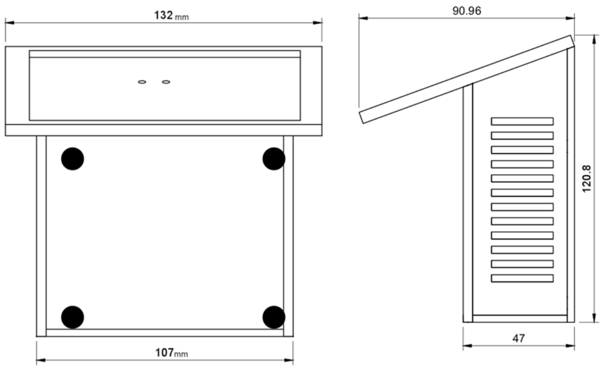


Figure 2: Smart Tag case schematic/dimensions

Microclimate stations

The microclimate is a distinctive climate in a relatively small area, that differs from the climate in the surrounding areas. In our case, the areas of interest are in the vicinity of the Tier 1 buildings of the Cultural Heritage site. To monitor the environmental microclimate conditions and changes, and assess climate risk parameters for the buildings, microclimate stations were designed and deployed. The microclimate/weather stations provide measurements of a set of atmospheric parameters, such as the air temperature, humidity, UV index and wind direction and speed. The stations also provide edge processing capabilities and have relatively low power needs. The microclimate stations collect measurements every 15 minutes and transmit them daily. The station is installed on a poll, that will be at least 1.5 m higher from all the surrounding buildings to avoid turbulence and the urban canyon effect that affects the recorded measurements. It records air temperature, air relative humidity, solar radiation, wind speed and direction and will include a rain gauge. The specifications for the sensors used for these measurements are the following

- Air temperature: Range: -20 °C to 100 °C, Resolution: 0.1 °C, Accuracy: better than ±1.0 °C
- Air relative humidity: Range: 0 - 99.9% RH, Resolution: 0.1% RH, Accuracy: ±5%
- Solar radiation: Range: 0 - 2000 W/m^2. Resolution: 0.5 W/m^2, Error Due to Clouds: up to 15 %

Characterization of the building materials and identification of the deterioration patterns

Another goal of HYPERION project is to provide the (1) characterisation and classification of the building materials, (2) refinement of the dose-response functions, (3) identification of the physical decay and chemical weathering processes occurring on the building materials, map deterioration micro- and macro-morphologies, and (4) evaluation of the physical-mechanical behaviour of materials. These data will feed a Hydrothermal (HT) simulator for accurate predictive assessment of old building materials under risk scenarios. Experimental setups that were installed in selected areas of interest facilitate the assessment of systematic differences between micro-climate conditions on materials' surface and time-series of climate data from the micro-climate stations installed at the demonstration areas. In addition, this Work Package (WP) includes the refinement of damage and dose-response functions based on accelerated decay tests and on-site recession measurements, integrated within d-HAM models. It also includes the prediction of the hydrothermal performance of old building materials in Cultural Heritage sited under Climate Change (CC) risk scenarios and assesses the deterioration caused by extreme events. Input from WP3 (i.e. smart tag and micro-climate station measurements and the downscaled climate models) and from WP6 (i.e. routine and the post-disaster monitoring of Tier 1 buildings) is used. The outputs of WP4 are used by the system risk assessment module in WP5 and by the HRAP platform in WP7.

Assessment of hydrothermal and textural features controlling building materials decay, and hydrothermal simulations

Chiara Coletti and Luigi Germinario[1]

During the second year of the HYPERION project, the research team involved in WP4 was engaged in the petrographic (optical microscopy, scanning electron microscopy, x-ray powder diffration) and physical (uniaxial strength, ultrasounds) characterisation of the selected rock types characteristic of the Tier 1 buildings of Granada (Spain), Rhodes (Greece), Tønsberg (Norway) and Venice (Italy) and of historical bricks of a Tier 2 building in Venice (Italy). These materials were tested under artificial conditions with accelerate aging tests (salt crystallization and freeze-thaw cycles), hydrothermal and hydric tests. On site analysis (hyperspectral maps and InfraRed acquisitions) were performed in the Tier 1 (Clock Tower) and Tier 2 (Santa Maria dei Servi Church) buildings in Venice, in particular, to detect the current state of decay, and to characterise the building materials used (natural stones and bricks). Part of the activities of this year also involved the development of a novel method for the monitoring and long-term prediction of the outdoor weathering of selected building materials (stone and timber), based on critical climate and microclimate parameters and their changes. An apparatus for conducting long-term field exposure tests was designed and built for monitoring the temperature and humidity of the samples at different orientations (Figure 3). The relevant data will be compared with those measured at selected historical sites (including the HYPERION's Tier buildings) by the "smart tags" developed within the project, and the official climate data records published by national or regional agencies. The equipment was tested and will soon be installed in different locations in Italy and Norway.

Moreover, the samples will be periodically analysed (after 12, 24, etc. months) for quantifying the changes in colour (by colorimetry), surface recession, topography (by profilometry), and chemical composition (by micro XRF), comparing the results with those obtained so far, before the equipment installation. Examples of analyses procedures are shown in Figures 4 and 5.

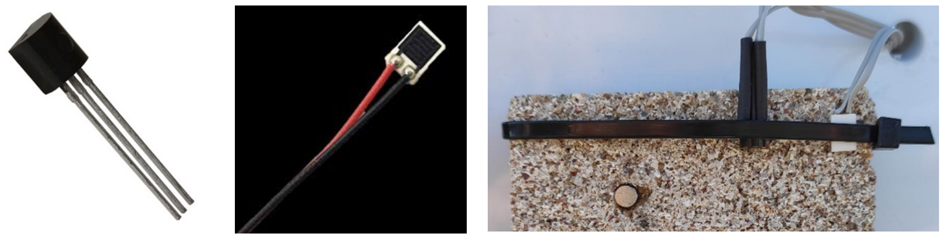


Figure 3: The temperature and humidity sensors (left side) and their mounting on one of the stone samples (right side)

[1]University of Padova, Department of Geosciences

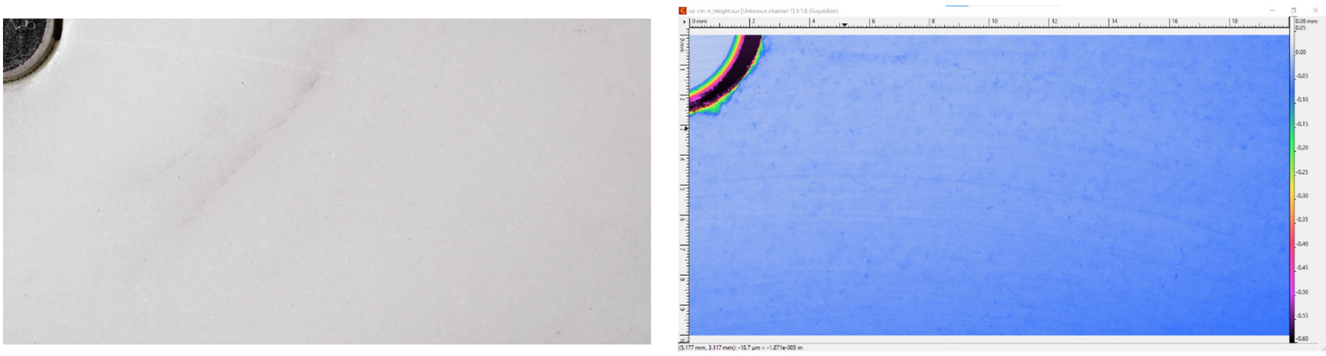


Figure 4: Macro photo and corresponding profilometric map of a sample of Carrara marble (the top left corner is taken up by the reference stainless steel surface)

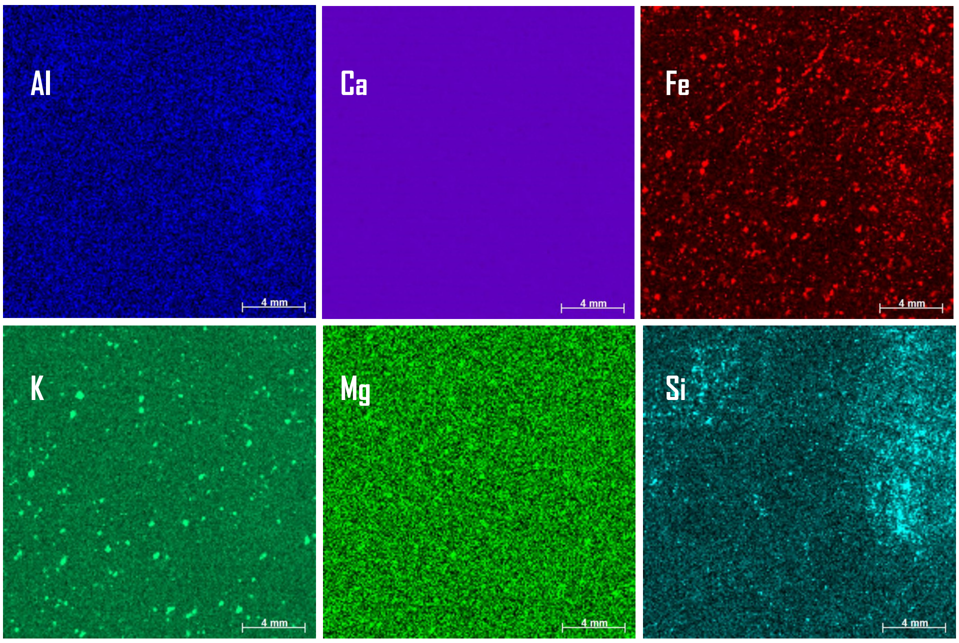


Figure 5: XRF elemental maps obtained on a sample of Carrara marble

Salt crystallization and freeze-thaw tests highlighted the good durability of bricks under stressed environmental conditions. Most of the samples showed similar behaviour, except for the more porous rocks, the Costozza stone (Italian lithology), the Santa Pudia stone (Spanish lithology) and the Sfouggaria stone (Greek lithology). Differential damage was mainly observed to edges and corners of the cubic samples or, where present, along stylolites, according to the rock type features (Figure 6). To assess the evolution of the damage effects of salt and ice in the pore system, ultrasound waves were measured at regular steps (each 10 cycles) during the ageing tests, in order to detect potential internal micro-crack and fissures, or different behaviours, not detectable by the visual observation.

Carrara Marble (Italy) at 90° freeze-thaw cycle Carrara Marble (Italy) at 90° salt crystallization cycle

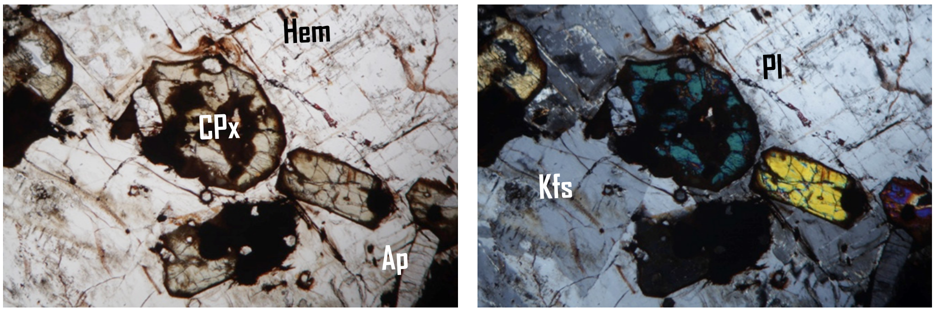
Macael Marble (Spain) at 90° salt crystallization cycle

Sfouggaria Stone (Greece) at 60° freeze-thaw cycle

Figure 6: The temperature and humidity sensors (left side) and their mounting on one of the stone samples (right side)

A petrographic characterization was carried out with optical microscopy and scanning electron microscopy (SEM) on polished thin sections (Figure 7). This provided useful information on the porosity, texture, and mineralogy of stones and the historical bricks studied.

X-ray Powder Diffraction performed on bricks showed in most of the samples examined the coexistence of carbonates (calcite and dolomite) and new Ca- and Mg- silicates formed during the firing process, giving information on materials and process adopted in the XIII century in Venice (Figure 8): e.g. a certain homogeneity in raw materials used, the absence of a good standardization in production, and a general temperature of firing of 800-850°C. Gypsum and mirabilite are often present as weathering products.



Photomicrographs of representative thin sections of the Monzonite TSy

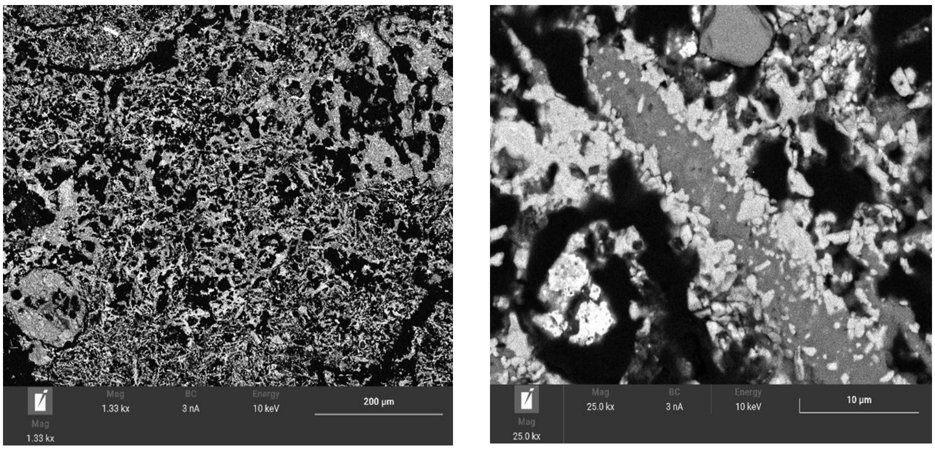


Figure 7: SEM-BSE images of historical bricks from Santa Maria dei Servi Church

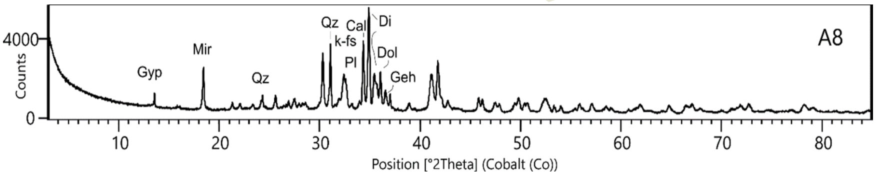
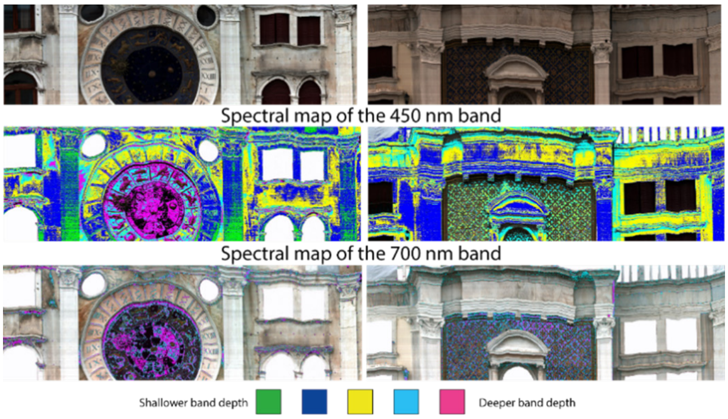


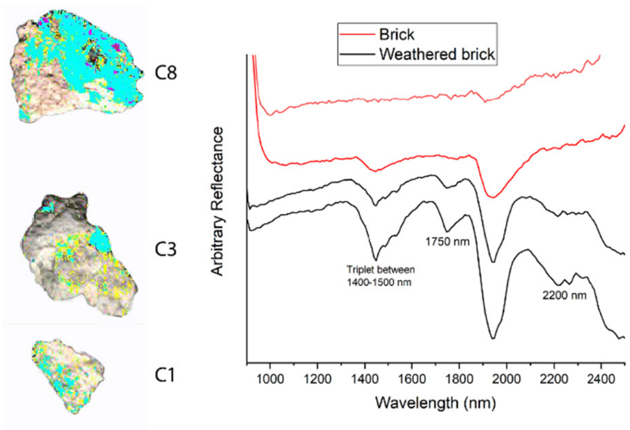
Figure 8: X-ray Powder Diffraction pattern of a brick sample from Santa Maria dei Servi Church (notation: Qz = quartz, K-fs = K-feldspar, Pl = Plagioclase, Cal = calcite, Dol = dolomite, Di = diopside, Geh = gehlenite, Gyp = gypsum, Mir = mirabilite)

Beyond the knowledge on intrinsic material features influencing the degradation rate, on-site analyses were formed, supporting the HYPERION partner for developing appropriate HT simulation models. The hyperspectral survey allowed to better estimate decay weathering on-site (at the Clock Tower in Venice, Tier 1) and in laboratory on samples collected (from the Santa Maria dei Servi Church in Venice, Tier 2), as shown in Figure 9

On-site hyperspectral analysis with the use of drones at the Clock Tower (Tier 1).



Hyperspectral maps of two main portions of the Clock Tower. At the top of the image are shown the original acquisitions. False colours indicate the band depth, and thus the abundance of the related compound. Band depth increases from green (lowest values), blue, yellow, cyan and purple (highest values) respectively. .



Samples collection on the main façade of Santa Maria dei Servi Church in Venice

Spectral maps of the weathered bricks there are many features of the sulphate's spectra, absent in the original spectra.

Figure 9: Hyperspectral survey and sample collection

Hazards Vulnerability and Resilience Assessment of the Historic Areas

In the WP5 of HYPERION project, the research team is focusing on the development of advanced models for natural hazards and the design and development of interfaces for the SG tool. In this context, a multi-tiered multi-hazard vulnerability assessment module is being developed along with tools for modelling single Cultural Heritage and non-Cultural Heritage assets. Bayesian model updated for near-real-time, post-event, site-specific vulnerability assessment will be also provided. In addition, system risk and resilience assessments of assets will be offered along with a mitigation tool for different hazards. Input from other Work Packages is utilized. From WP3 (impact indicators and downscaled climate models), from WP4, mainly the hydrothermal simulator, the materials' properties, and the dose-response recession functions, from WP6, the routine and post-disaster monitoring of Tier 1 buildings, and from WP7 the user validation of the model outputs after the realization of a hazard that will allow the overall assessment of the model's performance and will inform of the need for the Bayesian update as needed. The output of this Work Package is used by the HRAP platform in WP7.

Structural Vulnerability Assessment of Cultural Heritage Assets

Amirhosein Shabani and Mahdi Kioumarsi[2]

Masonry is a composite material with units and joints. Natural catastrophes, including earthquakes, have led to a dramatic increase in human injuries/fatalities and economic losses in the past few decades. Seismic vulnerability assessment, which describes the vulnerability of a structure subjected to ground shaking, is a pivotal part of a loss model. Unreinforced masonry is a prevalent structural system in high seismicity areas, and a large number of Cultural Heritage assets are made of masonry. In recent decades the resiliency of structures and infrastructures has attracted wide attention of researchers, authorities, and policy makers, leading to the requirement of a robust vulnerability assessment methodology suitable for large scale applications. Such methods should be user-friendly due to the high number of archetypes, as well as be fast in computation. A comprehensive review was performed on the simplified analytical methods for the seismic vulnerability assessment of unreinforced masonry buildings and the pertinent classification is illustrated in Figure 10.

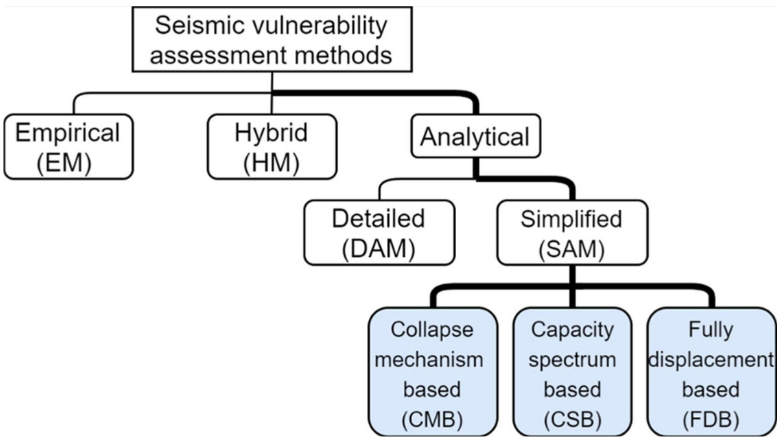


Figure 10: Seismic vulnerability assessment methods classification

In a more detailed modelling strategy than the aforementioned methods, the finite element (FE) method can be utilised by assuming a homogenised approach for the masonry material. Historical masonry structures with complex architecture should be modelled with this approach since both in-plane and out-of-plane failures are considered. However, the higher computational effort is the main limitation of this method compared to the simplified analytical methods or the equivalent frame methods. Analytical methods have been developed for deriving the initial in-plane stiffness of the masonry walls with openings in different configurations. Two methods have been selected from the literature, and the accuracy of each method has been investigated. For this aim, FE models of the walls with different dimensions and different configurations of openings have been developed. The results from the FE analysis were compared to the results from the analytical methods, and modifications to improve the accuracy were developed. The accuracy of the effective height method (EHM) and the modified boundary conditions stiffness method (MBCSM) is indicatively examined in Figure 11 with scatter plots by considering the bending and the spandrel stiffnesses effects.

[2]Oslo Metropolitan University, Faculty of Technology, Art and Design, Department of Civil Engineering and Energy Technology

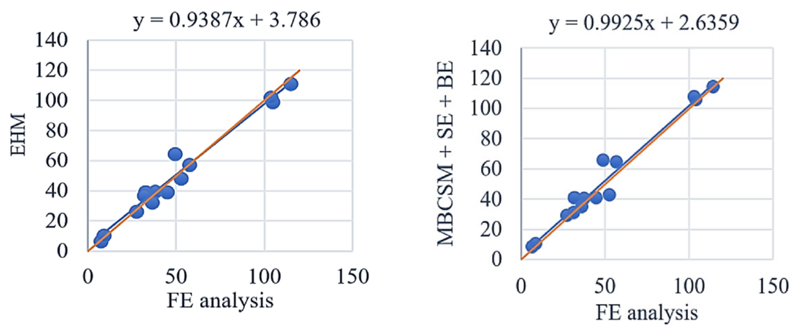


Figure 11: The accuracy of the EHM and the MBCSM considering the bending and the spandrel stiffnesses effects

Furthermore, the FE models of two case studies have been developed. The first case study is the Slottsfjell tower in Tønsberg, Norway. The geometric documentation was carried out using 3D laser scanners, and the FE model was developed by importing the 3D model into the FE software. A parametric investigation was performed for the boundary conditions (Figure 12): (1) the rigid-based model was developed by neglecting the effect of soil-structure interaction and (2) two models were developed for considering the soil-structure interaction effects. Furthermore, operational modal analysis was performed to investigate the dynamic characteristic of the tower based on the ambient vibration tests' results from accelerometers. Finally, all three FE models were calibrated based on the results of the operational modal analysis, and the digital twin of the structure was developed at OsloMet.

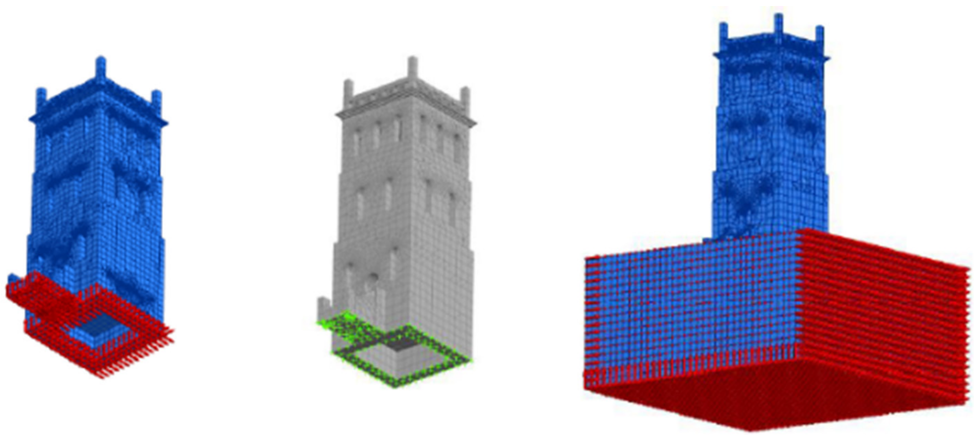


Figure 12: FE models of the Slottsfjell tower in Tønsberg (Norway) with rigid boundary conditions (left side) and considering the soil-structure interaction effects (middle and right side).

Another case study is the Roman bridge in Rhodes, Greece (Figure 13). A holistic methodology for developing the 3D model of the bridge using drones, ground cameras, 3D laser scanners, and total stations is presented. The nonlinear FE model of the bridge was developed based on the dimensions derived from the 3D geometric documentation in FE software. The effect of material properties on the modal responses of the bridge was investigated. Furthermore, contact interface elements were utilised to model the masonry-backfill soil interaction, and the effect of modelling this interface element is evaluated. The first five mode shapes of the Roman bridge model are illustrated in Figure 14.

Figure 13: The Roman bridge in Rhodes, Greece

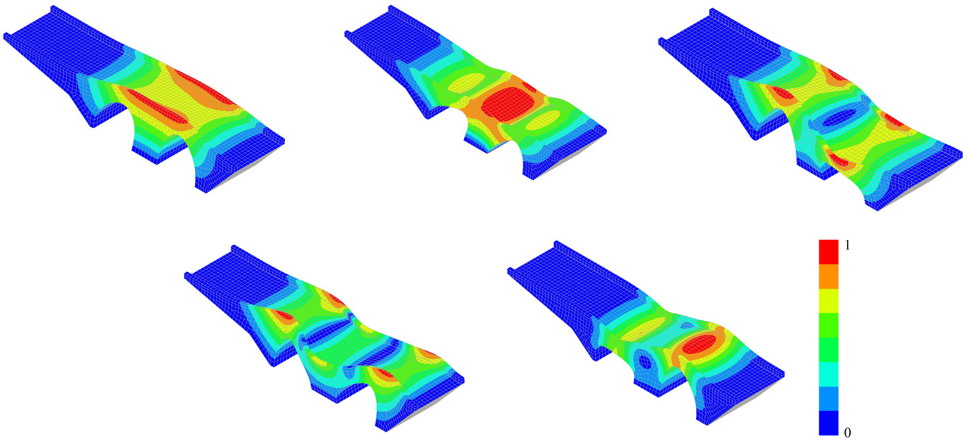


Figure 14: The First five mode shapes of the Roman bridge model.

Furthermore, the 3D model of the San Jerónimo Monastery in Granada, Spain, was provided using 3D laser scanners and the FE model was developed (Figure 15). The FE model updating of the Monastery was carried out based on the results of the ambient vibration testing using twelve accelerometers. The ambient vibration testing was performed by the University of Granada.

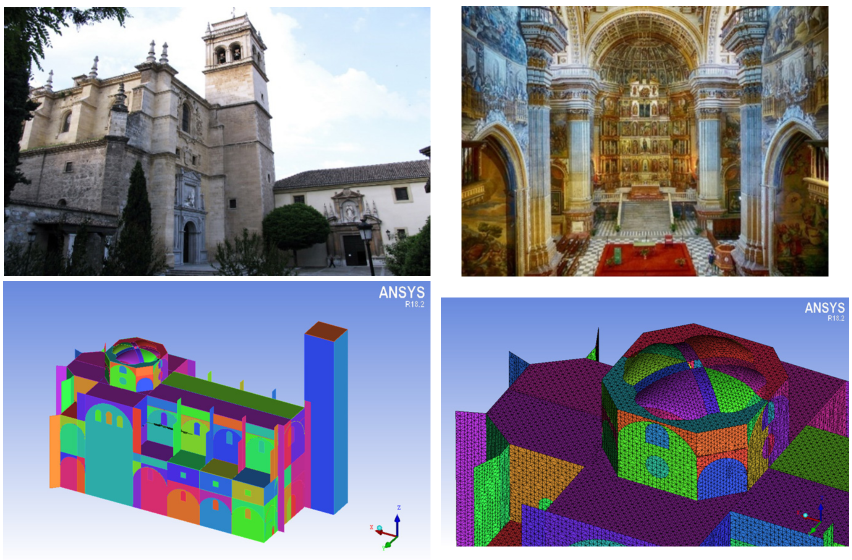


Figure 15: The San Jerónimo Monastery and the developed FE model.

The second part of the work is dedicated to the assessment of heritage timber buildings because timber is considered as the oldest organic construction material. A methodology for the conservation of heritage timber buildings is proposed as depicted in the Figure 16. A preliminary structural survey of heritage timber buildings in Tønsberg, Norway, has been carried out. Moreover, 3D models of two timber log houses have been developed, and 3D laser scanning was employed for the structural health monitoring of these heritage buildings.t.

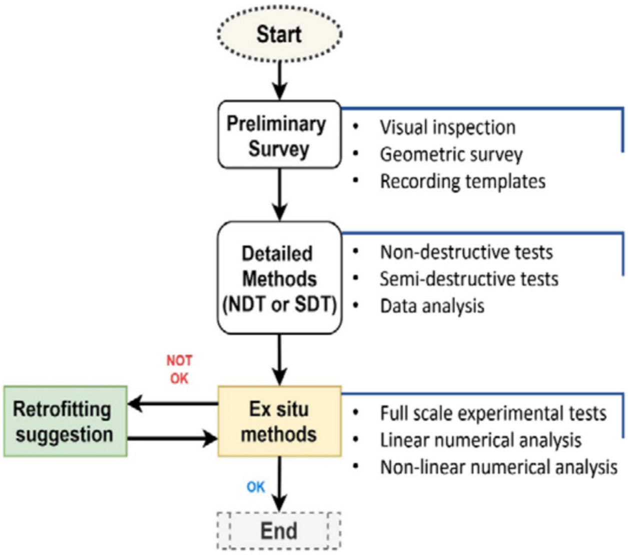


Figure 16: The HYPERION methodology for the conservation of heritage timber buildings

Modelling future climate for multi-hazard resilience assessment of historical cities

Akrivi Chatzidaki[3], Dimitios Vamvatsikos[3], Fotios Barmpas[4], Miko Auvinen[5], Antti Helsten[5]

Climate and weather models/data come with a spatial and temporal resolution that may refer to kilometres and days, respectively. On the other side, civil engineering materials, structures, and infrastructure are characterized at the level of centimetres or meters, while they dynamically respond to load time histories discretized to fractions of a second. Bridging these two different scales is essential for projecting the effects of weather and climate on any individual structure. Further challenges are posed by building ensembles and interconnected infrastructure networks that also require cotemporaneous spatially-correlated fields of weather data too, e.g., assess losses and downtime across a complex system swept by a single weather episode/event. This is the case of assessing a historical city core whose monuments are under the constant barrage of freeze-thaw cycles, moisture, precipitation, and temperature that erode them over time.

[3] National Technical University of Athens, Department of Structural Engineering
[4] Aristotle University of Thessaloniki, School of Mechanical Engineering
[5] Finnish Meteorological Institute

Densifying data that is sparse in time and space is not an exact science, nor is it possible without introducing noise. Barring trivial cases, there cannot be an interpolation approach that perfectly recreates the results of a model with a finer spatiotemporal resolution, thus we offer such a finer resolution that still respects long-term and large-scale statistical trends identified from existing data. The results of such a procedure bridge the resolution gap to provide consistent time-varying fields of weather parameters at a scale that is suitable for building-level engineering work. In the context of Europe, and especially for predicting the effects of future climate, the coarse weather projections provided by the Euro-CORDEX (Figure 17) are employed, typically at a 12.5x12.5km grid per each day until 2100, which are transformed to correlated hourly, 10min or sub-second time-histories at each geolocated point of interest. To this scope, historical weather station data are considered to generate artificial time-series for each future day, termed a "Frankenstein day" by its Mary-Shelley-esque virtue of comprising initially-mismatching parts of actual weather station-days fitted together to recreate plausible high-detail characteristics of a Euro-CORDEX-day. These synthetic, realistic but not real, Frankenstein days retain the correlation of the weather station measurements in time and space, while the point-specific dataset is expanded to encompass the entire region of interest to allow assessing risk and resilience for the entire historical city. To achieve this for wind speed and direction, large-eddy computational fluid dynamic simulations are performed considering the topographic complexity of the site and simulated wind turbulent flows (Figure 18), thus allowing us to capture the spatial variation of the wind (Figure 19). While winds are extremely sensitive to local site effects and details of the simulation, weather parameters such as precipitation, ambient temperature, and solar radiation are considerably less sensitive, thus a less detailed field over the entire is employed, in lieu of a resource-intensive simulation. Specifically, a meso-scale surrogate model is employed to extrapolate the local dataset over a larger grid of points, and help us gain some extra resolution in space. The generated time-histories are not forecasts, i.e. they are not expected to be actually observed in the future but they are plausible realizations of long-term predictions of what may happen, statistically speaking, in a future day. They conform with the long-term statistics provided by Euro-CORDEX and have the right temporal and spatial correlation to allow estimating risk in the long term. In many ways, they provide the needed information to connect coarse regional-level weather predictions with the resolution required for the asset-specific fragility and risk assessment of structures and historical towns practiced by engineers.

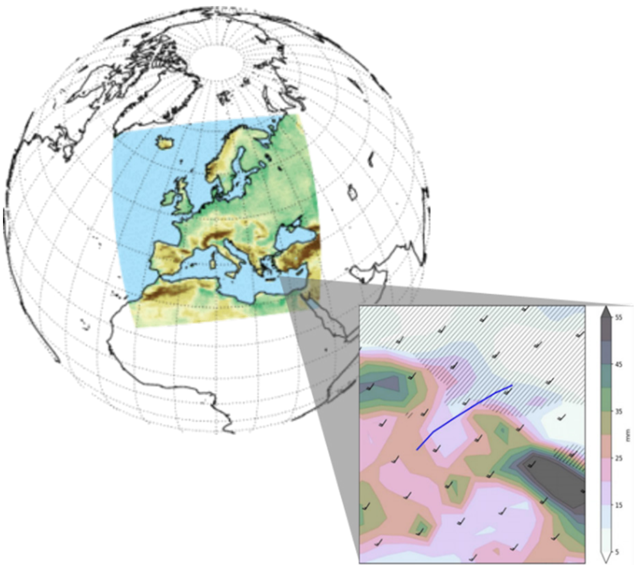


Figure 17: Example of Euro-CORDEX data for a part of the Greek demo site on an arbitrary day. The shading of the lower right figure shows daily precipitation values, the hatch is used to show areas where the wind speed is higher than 15m/s, and the barbs show the mean wind direction. The upper left figure is adopted from https://www.euro-cordex.net/.

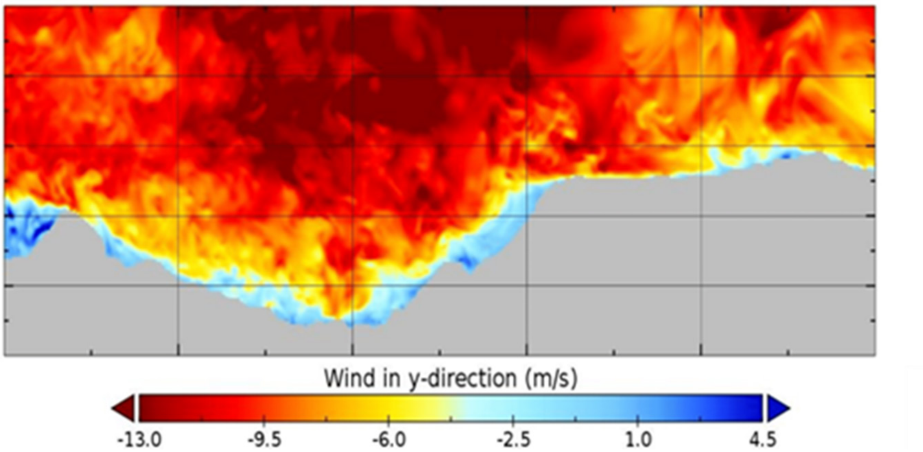


Figure 18: Vertical section of the turbulent wind velocity distribution computed via computational fluid dynamic simulations around a valley in Greece.

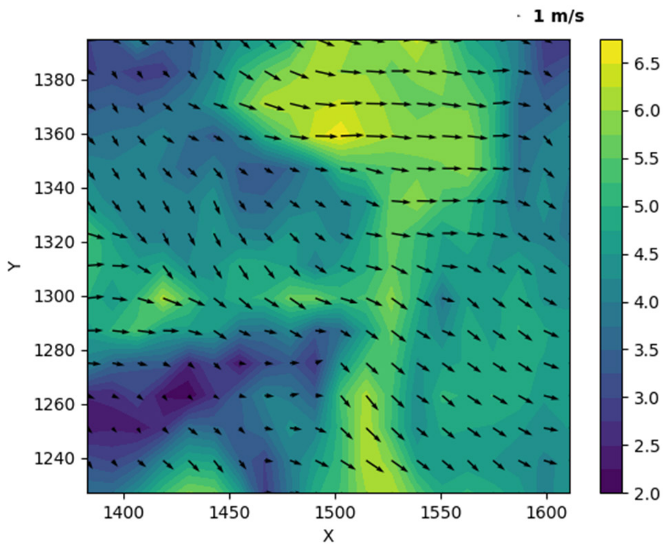


Figure 19: Example of a wind speed and direction intensity-measure field

Earth observation, Sensor data and Geospatial Services for increased resilience of the Historic Areas

In WP6 Unmanned Aerial Systems (UAS) are aiming to provide a comprehensive Cultural Heritage monitoring system in the historic areas both for routine inspection and early detection of damage and degradation and for post-hazard damage inspection of the potentially affected Cultural Heritage assets. The system will integrate data from various remote sensing platforms such as satellites, unmanned aerial vehicles and ground-based monitoring systems in order to cover the specific monitoring needs for the demonstration areas and Tier 1 buildings. All input data fed into this Work Package come from external sources, either provided by local partners when available or from on-line sources as needed. The outputs of the WP6 are used by WP3, (i.e. the routine and the post-disaster monitoring of the Tier 1 buildings), from WP5, (mainly the post-disaster monitoring) and WP7 where all the collected data, for both the routine and the post-disaster monitoring of the buildings, will be available to the end-users. The architectural diagram of the WP6 is presented in Figure 20.

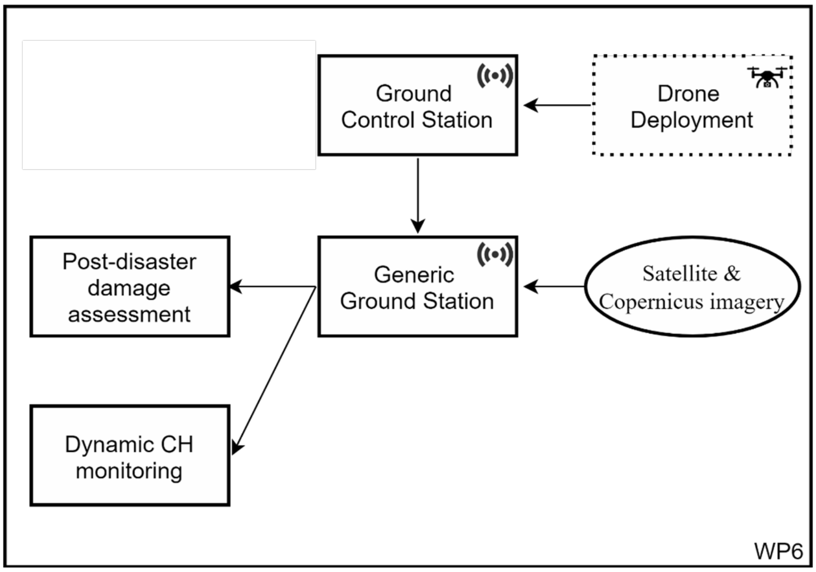


Figure 20: Architectural diagram of WP6

Remote Sensing-based Multiscale Monitoring System (RS-MMS)

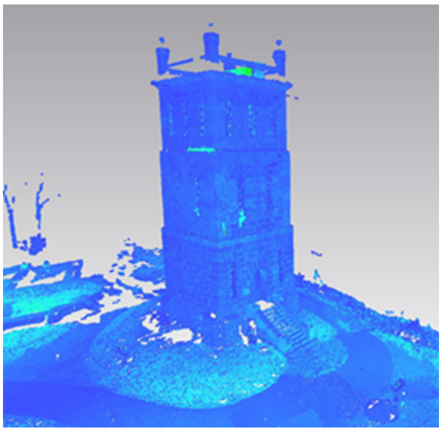
Panagiotis Agrafiotis[6], Andreas Georgopoulos[6], Kleanthis Karamvassis[7], Vassilia Karathanassi[7], Pol Kolokoussis[7], Viktoria Kristollari[7], Margarita Skamantzari[6] and Sevi Tapinaki[6]

The Remote Sensing-based Multiscale Monitoring System (RS-MMS) is one of the basic components of the HYPERION platform. It provides valuable information on Cultural Heritage monuments and emerging hazards as well as for the broader area of the pilot areas (i.e., city of Rhodes, Granada, Venice, and Tønsberg). Furthermore, it aims at rapid post-hazard event damage assessment of the Cultural Heritage assets and the broader area. RS-MMS integrates data from various remote sensing platforms such as satellites, UAV and ground-based, with the focus on the optimal processing of remote sensing data in order to match the specific monitoring needs for historic monuments/areas and hazard scenarios. 3D representations, material degradation maps, land deformation velocity maps, land use changes maps, and maps of inundated areas after a flood event are some of the RS-MMS products..

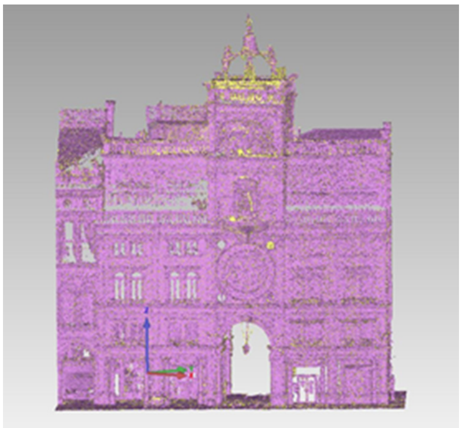
[6] National Technical University of Athens, School of Rural and Surveying Engineering, Laboratory of Photogrammetry
[7] National Technical University of Athens School of Rural and Surveying Engineering, Laboratory of Remote Sensing

Figure 21: Remote Sensing-based Multiscale Monitoring Systems (RS-MMS)

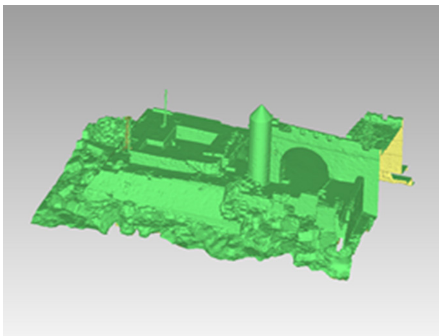
The estimation of the structural deformation is crucial for damage assessment not only for the routine monitoring but mostly after a disastrous event. In this scope, the initial 3D representations of the Cultural Heritage assets were developed by applying geodetic, photogrammetric, and laser scanning methods. The objective was to produce point clouds, textured 3D meshes, light 3D models and sections. The point clouds shown in Figure 22 below will be used as a reference for both the routine and post-disaster monitoring after every 3D documentation to perform comparisons and evaluations of the deviation between them.



Point cloud of the Slottsfjell Tower in Tønsberg (Norway)



Point cloud of the Torre dell' Orologio in Venice (Italy)

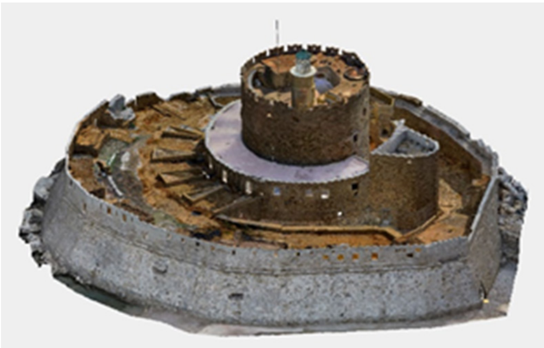


Point cloud of the Naillac Pier in Rhodes (Greece)

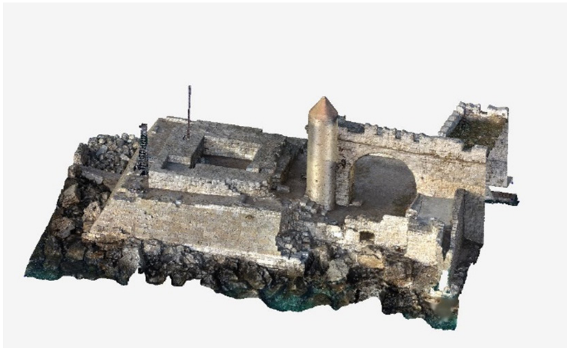
Point cloud of the San Jerónimo Monastery in Granada (Spain)

Figure 22: Point clouds of CH asses in pilot cities using geodetic, photogrammetric and laser scanning methods.

Light 3D models of the Cultural Heritage buildings have been created for further analysis and visualization purposes in combination with various data (Figure 23).



Light 3D model of St. Nikolas Fort in Rhodes (Greece)



Light 3D model of the Naillac Pier in Rhodes (Greece)

Figure 23: Light 3D models of CH buildings

Detailed textured 3D models were produced for specific parts of each Cultural Heritage building in places where hyperspectral data were also acquired (Figure 24). The scope was to integrate the RGB and Hyperspectral data and get results for both the geometry and the material loss for each case. The figures above present the textured 3D model of a specific part of St. Nikolas Fort and the level of erosion by calculating the distance of the points from a plane adjusted to the part of the monument that presents no erosion. The results were very promising and further analysis will be carried out involving machine learning algorithms to automate the entire procedure of material degradation.

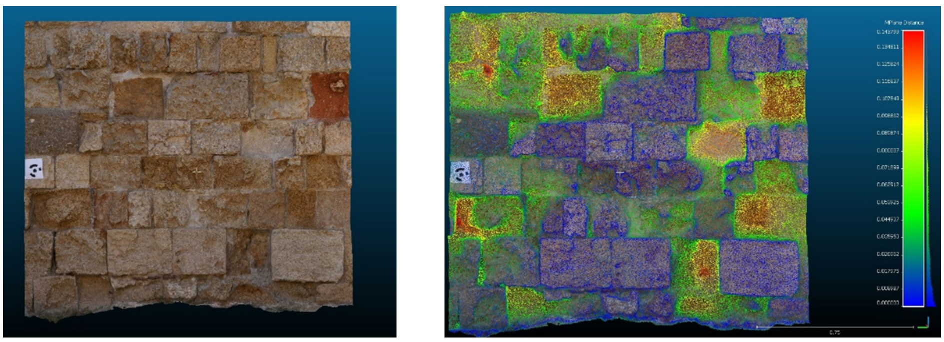


Figure 24: Detailed textured 3D models of specific parts of a CH asset

A spectral unmixing methodology was applied to hyperspectral imagery for building material and deterioration mapping. In Figure 25, the left side presents the materials of a specific part of St. Nikolas Fort in Rhodes, Greece, while in the right side, the deterioration map for a specific part of the Roman bridge in Rhodes, Greece, is depicted.

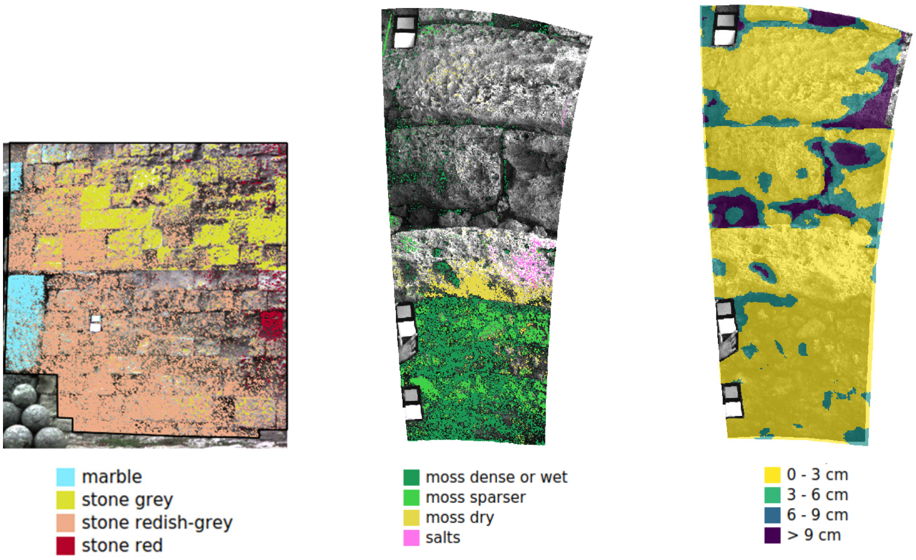


Figure 25: Materials of a specific part of St. Nicolas Fort (left side) and deterioration map for a specific part of the Roman bridge (right side) in Rhodes, Greece

Moreover, a crack detection algorithm was developed by deploying and modifying a Convolutional Neural Network (CNN) to classify the acquired RGB imagery or patches and specifically detect and project the cracks on them as shown below (Figure 26).

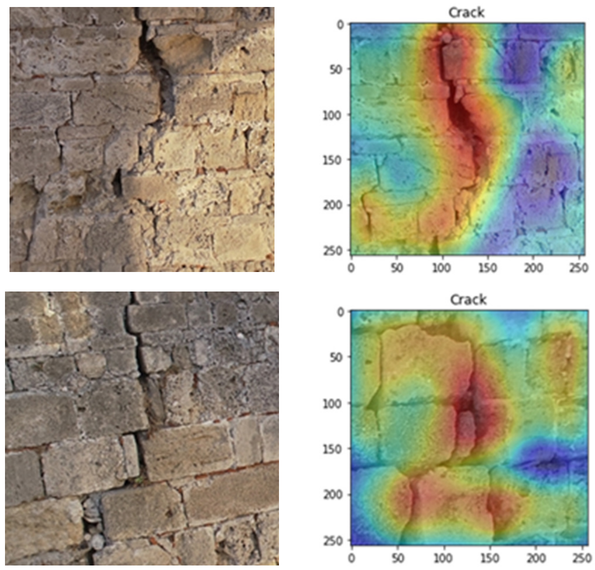


Figure 26: Detection and projection of cracks on walls using a convolutional neural network on RBG images

Land deformation estimation and velocity map production are crucial for pointing out hazards with a slow or gradual onset. A methodology has been developed based on Time-Series Differential Interferometric Analysis, enabling RS-MMS to provide information for better understanding the local ground deformation phenomena and paving the path for an early warning system of expected ground failures. In particular, the adopted technique is based on Stamps and Mintpy functionalities for the detection of millimetre-level surface displacements. The ground deformation patterns of Rhodes pilot area (Greece) are presented in Figure 27. Land uplift is observed in Rhodini area, Rhodes, where part of the central Necropolis with important monumental graves is located.

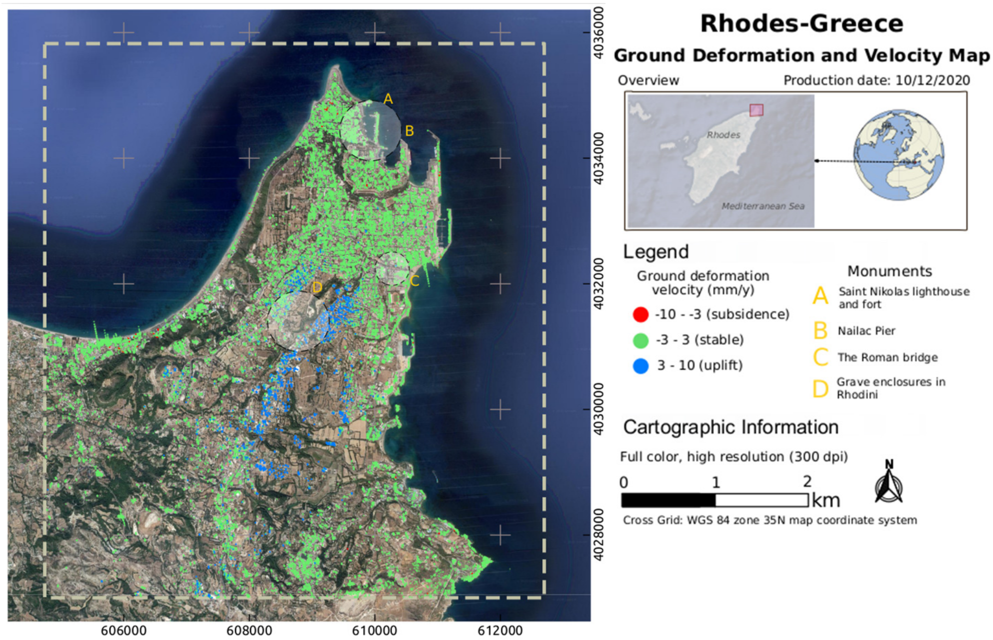


Figure 27: Ground deformation patterns in Rhodes pilot area (Greece)

For the period from January 2016 to November 2019, distinct locations prone to subsidence (red points) and uplift (blue points) are identified. The deformation history for selected scatterers that are close (grey circles) to the Cultural Heritage monuments and present subsidence or uplift is plotted on the right-hand-sided diagrams in Figure 28.

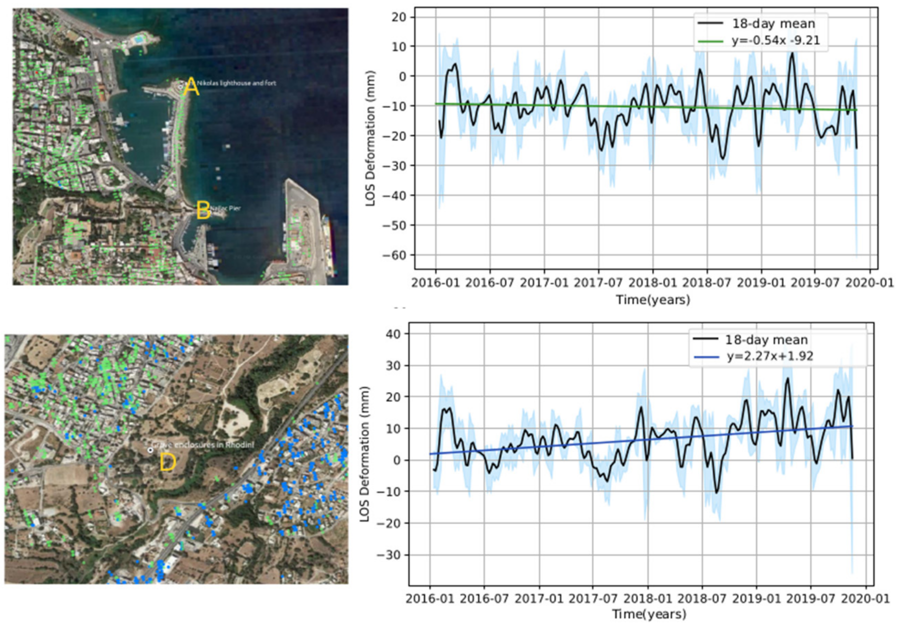
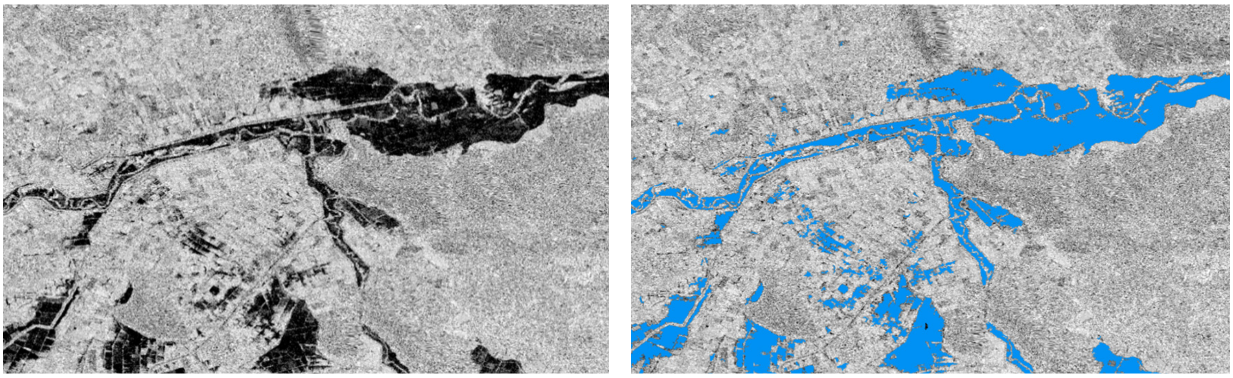


Figure 28: Ground deformation history of locations close to CH assets in Rhodes (Greece)

In the framework of rapid post-disaster damage assessment, RS-MMS outcomes include an innovative method and a free open-source toolbox (Flompy) for floodwater mapping. The method exploits Sentinel-1 time-series information and produces high accuracy (~95%) results in comparison with state-of-the-art ESA`s Emergency Mapping Services (EMS) flood products. In Figure 29, the intensity changes observed in the Sentinel-1 time series (top) and the produced floodwater map (bottom) is shown.



Sentinel-1 intensity changes

Flooded area

Figure 29: Intensity changes observed in the Sentinel-1 time series (right) and the produced floodwater map (left)

The results for the Kragero flood event are illustrated in Figure 30, an area close to the Tønsberg pilot case (Norway). Heavy rains in the Kragero region have raised an orange level flood alert in the area, according to EMS. Many landslides' events are expected, some with considerable consequences, as well as extensive flooding, erosional damage, and flood damage in prone areas.

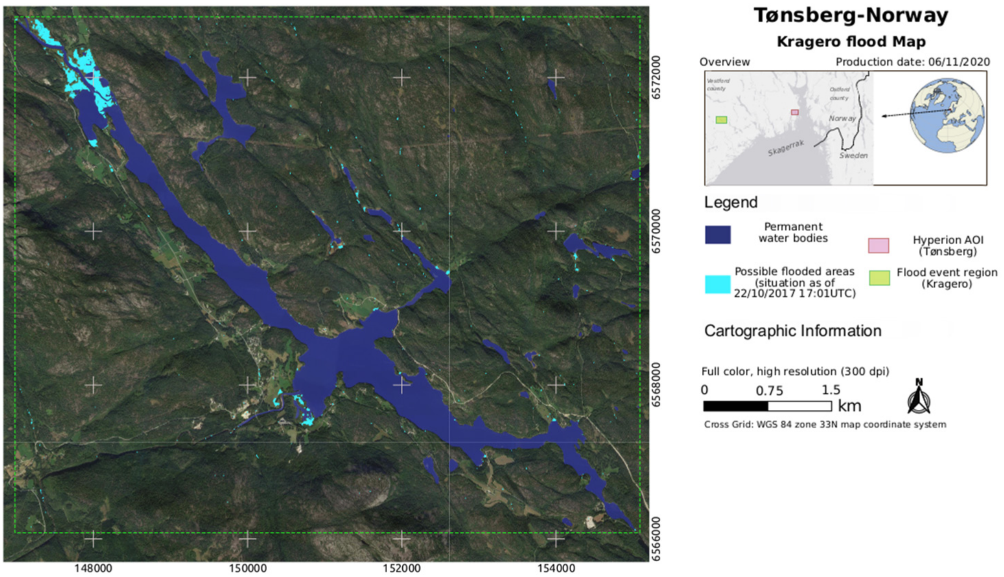


Figure 30: Results for the Kragero flood event close to the Tønsberg pilot area (Norway)

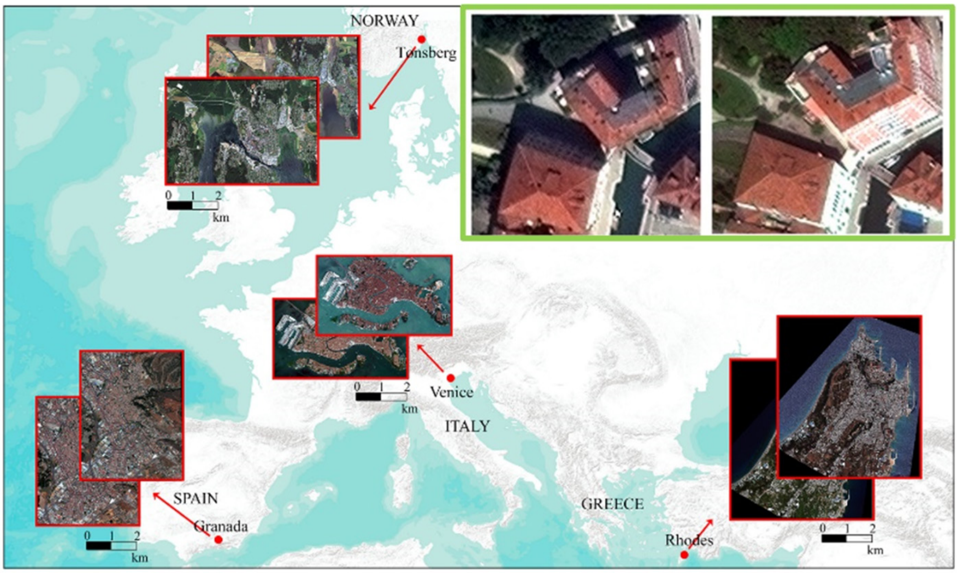


Figure 31: Land change maps produced by the RS-MMS.

Best results were produced by STANet a spatial-temporal attention network trained on a large dataset of professionally annotated building-related changes. This network produced an average omission error of 12% on the four study areas of the project. The STANet output for the entire study area of Tønsberg in Norway is shown in the top row of Figure 32 and a zoomed in sample region in the bottom row. The square shows correctly detected changes.

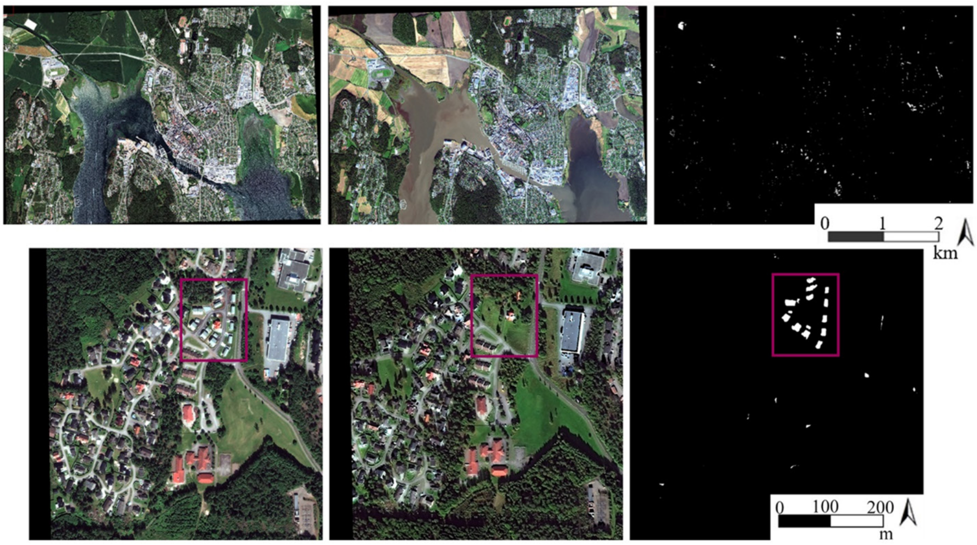


Figure 32: STANet output for the study area of Tønsberg (Norway)

Mapping Torre dell' Orologio (IUAV)

The "Torre dell' Orologio" (Clock Tower) in St. Mark's Square is one of the CH assets (Tier 1) to be studied extensively by the research team of the Hyperion project in Venice, Italy. On July 28th, 2020 staff from the Laboratory for Analysing Materials of Antique origin (LAMA) of Iuav University of Venice (IUAV) and the University of Padova (UNIPD) collaborated for identifying the construction material of the building, namely the properties of the stones, the main deterioration products of the masonry (Figure 33) and, also, for mapping the distribution of the stones. The Clock Tower is an early Renaissance building, located on the north side of the Piazza San Marco at the entrance to the "Merceria". It comprises a tower, which contains the clock, and lower buildings on each side. Both the tower and the clock were constructed in the 15th century. The clock was placed where it could be visible from the waters of the lagoon to give notice to every one of the wealth and glory of Venice.

Figure 33: Graphic processing of the main damages at the Clock Tower building

OSLOMET staff visited the cultural heritage sites and buildings in Rhodes, Greece

On July 29th and 30th, 2020, staff the Oslo Metropolitan University (OsloMet), Professor Dimitris Kraniotis and PhD candidate Petros Choidis, visited the cultural heritage(CH) sites and buildings, which are investigated within the Hyperion project in Rhodes, Greece (Figure 34). They were guided by the staff of the Ephorate of the Dodecanese (EFAD), archaeologist Vasiliki Patsiada and conservator Sotiris Patatoukos, and by Voula Moraitou, representative of the Municipality of Rhodes. The research team visited St. Nikolaos lighthouse and fort, the Naillac tower, the Roman bridge and the grave enclosures in Rodini, all of which are Tier 1 CH assets. During their visit at Agios Nikolaos Fortress in the city of Rhodes the representatives of OsloMet were briefed by Katerina Manousou Della, architect of the Modern Monuments and Modern Monuments Service, on the restoration works carried out by the Ministry of Culture over the last 25 years. The research group from OsloMet defined the critical deterioration mechanisms of the building materials of the case studies and proposed a methodology in order to investigate them. In addition, they proposed the installation of air temperature and air relative humidity sensors in the Fort of Saint Nicholas in order to investigate the climate related damages on artifacts that are hosted inside the building.

Figure 34: Visit of HYPERION project research teams to CH assets in Rhodes, Greece

"Drones for Good" Festival

On September 16th, 2020 the University of Padova (UNIPD) (at the Master course of GIScience) organized an open Festival called "Drones for Good", promoting the use of new geographic technologies and drones for environmental and territorial applications. Almost 100 participants attended the event. Two members of the University of Padova (Matteo Massironi and Jacopo Nava) presented some of the activities of the HYPERION project (Figure 35) and in particular how advanced technology is used for the preservation and the resilience assessments of CH assets.

Figure 35: Sample slide from the presentation to the public (UNIPD)

Micro sampling at Clock Tower in St. Mark's Square

On September 24th, 2020 the research staff from the IUAV and UNIPD carried out sampling of stones at the Clock Tower in St. Mark's Square (Figure 36). The micro-samples have been analysed at the LAMA Laboratory with several analytical techniques (optical microscopy, microFTIR, SEM-EDS and XRPD) to characterise the stones and their decay products.

Figure 36: Illustration of the sampling activities at the Clock Tower in St. Mark's square (sampling spots and micro-samples)

Survey in Venice, Italy by Risk Engineering + Development (RED)

Risk Engineering + Development (RED) conducted a two-day survey in Venice (on October 20th and 21st, 2020) to collect data about the main characteristics and vulnerabilities of the buildings in the city. IUAV and UNIPD assisted RED in this effort, guiding the staff of RED through the "calli" (as the streets of the city are traditionally called) of Venice, contributing in the identification of the buildings' materials and in the data collection. The aim of the survey campaign was to collect information about prefixed characteristics of the assets at risk. The collected data will be used as proxies, together with existing studies from scientific literature, for assessing the vulnerability of the assets belonging to Tier 3. The campaign was structured specifically for Venice, shaping the survey form to be compliant with its building characteristics and accounting for the main perils that can possibly affect it. The survey form, available both in electronic form and hardcopy, included appropriate investigation queries to report the main characteristics of the assets in order to characterize their damageability in the next stages of the project. All this information was combined, producing georeferenced maps and defining a first classification of the assets at risk in Venice. The information collected during the survey will be integrated with data provided from local authorities (e.g. building footprints, their usage, the main networks and infrastructures) to create an exposure database of the city. During two intense on-field working days more than 120 buildings have been mapped and analysed, from the historic center (Rialto bridge, Campo San Polo, Campo Santa Maria Formosa, le Mercerie, Ghetto) to the renovated and more recent areas (Santa Marta and Ca' Foscari University campus of San Giobbe, Giudecca island, Piazzale Roma, train station Venezia Santa Lucia).

Figure 37: Venice site survey

HYPERION in the "Voice of Greece"

The HYPERION's project vision and goals were presented to the public by the project's Coordinator Dr. A. Amditis during his interview in the "The Voice of Greece", a radio show by the Hellenic Broadcasting Corporation, being broadcasted worldwide. Dr. Amditis was invited to discuss the current research and innovative programs of ICCS. The audience had the opportunity to be informed about the research area, the vision, and the expected goals of the HYPERION project.

HYPERION's Official Video Launch

The video of HYPERION project was released to the audience on October 24th, 2020 (Figure 38). Subtitles are available as support for deaf and hard-of-hearing persons. The video is available online on YouTube and most of the social media accounts of the project and the partners' ones: https://www.youtube.com/watch?app=desktop&v=07-1L8Stu9w&feature=youtu.be.

Figure 38: Screenshot from the video of HYPERION

HYPERION at the International transfer of technologies: Semantic transformation of space

The Round table meeting "International transfer of technologies: Semantic transformation of space" was organised by the Ministry of Science and Higher Education of The Russian Federation with participation of the University of West Attica (Greece) and the Southwest State University of Russia. On October 27th, 2020 the round table meeting, open to invited guests and speakers, took place in Athens and Moscow due to the travel restrictions. The main goal of this round table, which was held in a hybrid model (invited speakers from both countries were assembled with physical presence in Athens and Moscow, Figure 39) and with the use of technology were able to communicate and exchange information about the current research developments in both countries (Greece and Russia). Following all the protocols to avoid COVID-19 spread, the scientists had the opportunity to get to know each other better and to further enhance their scientific collaboration. During the meeting distinguished scientists from the two countries presented the recent developments in research and Technology. The HYPERION's program vision, mission and the current results were presented by the project Coordinator Dr. A. Amditis, paving the way for future collaboration with the Russian Federation on Cultural Heritage Preservation. The Presentations were conducted in English, Greek, Russian and a simultaneous translation for the invited auditors in both countries was provided.

Figure 39: Round table "hybrid" meeting in Greece and Russia with simultaneous broadcast

HYPERION's third Plenary meeting

The 3rd Plenary meeting of the project was held remotely on the November 10th and 11th, 2020 (Figure 40). The work packages' leaders presented the progress of the work carried out so far, specifying the difficulties and the delays they faced, during the last six months as a result of the pandemic.After successfully concluding the two-day plenary meeting, the next meeting was scheduled for March 2021, pointing out the possibility of a virtual meeting due to the pandemic.

Figure 40: HYPERION 3rd plenary meeting held virtually

HYPERION at the European Researchers' Night

The last event of 2020, was the participation at the European Researchers' Night. With the aim to bring science and researchers closer to the general public and stimulate interest in research careers – particularly among young people, the European Researchers' Night took place on November 27th, 2020 online. Dr. Angelos Amditis, Research Director at ICCS, I-SENSE Group Director and Project Coordinator of HYPERION, presented his research groups' achievements in several areas including electromobility, citizens' science, cultural heritage preservation and circular economy adoption, during the 2020 Research Night of the National Technical University of Athens. During this fruitful educative talk, HYPERION was introduced to the general public. The European Researchers' Night, funded under the Marie Skłodowska-Curie actions, is a Europe-wide public event that brings researchers closer to the public. It showcases the diversity of science and its impact on citizens' daily lives, stimulating interest in research careers - particularly among young people. In 2019, it attracted 1.6 million visitors across more than 400 cities in Europe and beyond. The video is available online https://www.youtube.com/watch?app=desktop&v=eOynoorsnBM&t=7s%C2%A0 (in Greek) Time Slot (3:43-4:33).

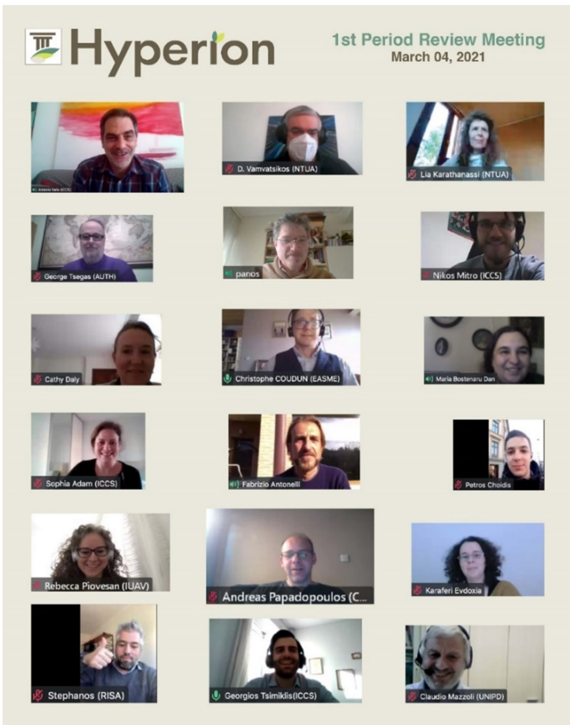


Figure 41: HYPERION first review meeting

HYPERION first periodic review meeting

The first periodic review meeting of HYPERION was held online on March 4th, 2021 (Figure 41). The project's progress was evaluated by three external reviewers: Christophe Coudun (Research Programme Administrator of the European Research Executive Agency (REA)), Maria Bostenaru Dan, who is responsible for the preservation of historic reinforced concrete housing buildings across Europe and Cathy Daly, who is an archaeological, ethnographic conservator and a research specialist in climate change impacts on cultural heritage. The program manager and the work packages' leaders presented the project activities and their progress to the EU delegation.

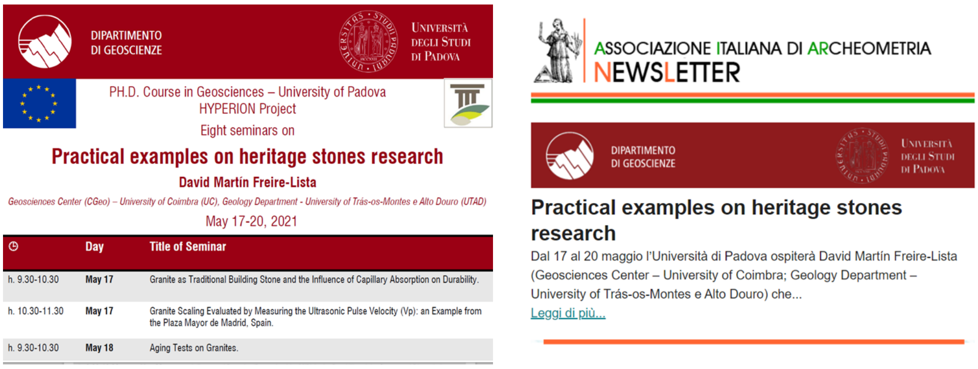
Figure 42: Survey of the Torre dell' Orologio in Venice, Italy by IUAV

Drones' assisted measurements at "Torre dell' Orologio", Venice

On March 5th, 2021, the staff of IUAV carried out a survey at the Torre dell' Orologio on St. Mark's Square in Venice, Italy. The researchers used two drones, which were flying over Piazza San Marco, carrying drone-based photogrammetric devices for the measurements required for photogrammetry.(Figure 42). The support provided by the Municipality of Venice and the Polizia Locale di Venezia is gratefully acknowledged A second visit was, also, carried out two days later with a larger drone carrying an hyperspectral camera..

Short course "Practical examples on heritage stones research"

From 17th to 20th May 2021, eight short course seminars on "Practical examples on heritage stones research" were held online, due to the pandemic, at the Department of Geosciences of UNIPD, as part of the PhD course in Geosciences (Figure 10). The course was held by Dr. David Martín Freire-Lista (Geosciences Center - CGeo - University of Coimbra, UC and Geology Department -University of Trás-os-Montes and Alto Douro, UTAD) and was open to all interested parties. The event was also announced at the Italian Archaeometric Society (AIAr) newsletter, containing a link to the University homepage. The course was sponsored by the HYPERION project and the PhD School in Geosciences.



DIPARTIMENTO DI GEOSCIENZE

UNIVERSITÀ DEGLI STUDI DI PADOVA

PH.D. Course in Geosciences – University of Padova
HYPERION Project

Eight seminars on

Practical examples on heritage stones research

David Martín Freire-Lista

Geosciences Center (CGeo) – University of Coimbra (UC), Geology Department - University of Trás-os-Montes e Alto Douro (UTAD)

May 17-20, 2021

	Day	Title of Seminar
h. 9.30-10.30	May 17	Granite as Traditional Building Stone and the Influence of Capillary Absorption on Durability.
h. 10.30-11.30	May 17	Granite Scaling Evaluated by Measuring the Ultrasonic Pulse Velocity (Vp): an Example from the Plaza Mayor de Madrid, Spain.
h. 9.30-10.30	May 18	Aging Tests on Granites.

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DIPARTIMENTO DI GEOSCIENZE

UNIVERSITÀ DEGLI STUDI DI PADOVA

Practical examples on heritage stones research

Dal 17 al 20 maggio l'Università di Padova ospiterà David Martín Freire-Lista (Geosciences Center – University of Coimbra; Geology Department – University of Trás-os-Montes e Alto Douro) che...

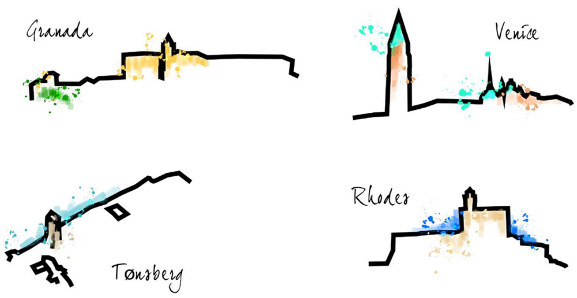
Leggi di più...

Figure 43: Short course "Practical examples on heritage stones research"

Pilot sites

Granada, Spain

Venice, Italy



By Chiara Coletti e Gloria Zaccariello

Tonsberg, Norway

Rhodes, Greece

Publications and conferences

A Modelling Approach for the Assessment of Climate Change Impact on the Fungal Colonization of Historic Timber Structures

Petros Choidis, Dimitrios Kraniotis, Ilari Lehtonen, Bente Hellum

Oslo Metropolitan University—OsloMet, Department of Civil Engineering and Energy Technology, Oslo, Norway;
Finnish Meteorological Institute, Weather and Climate Change Impact Research, Helsinki, Finland

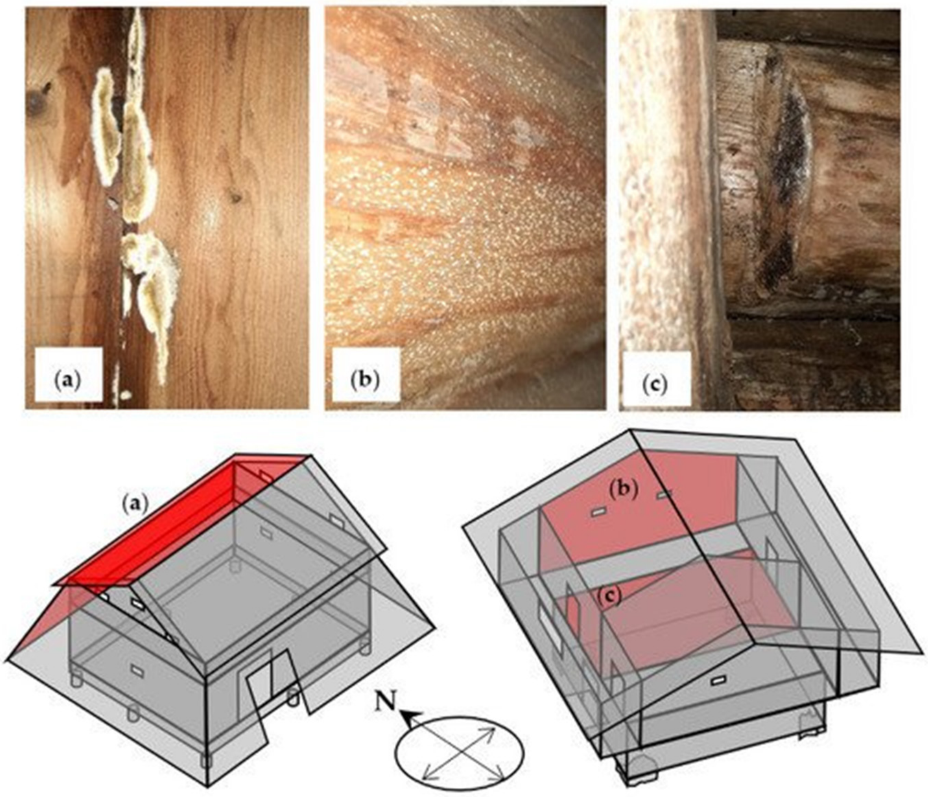


Figure 44: (a) Brown-rot fungi (Coniophora puteana) detected at the positions highlighted with red color at the Fadum storehouse. (b) Scopulariopsis colonies and (c) Myxomycetes detected at the positions highlighted with red color at the Heierstad loft.

Abstract

Climate change is anticipated to affect the degradation of the building materials in cultural heritage sites and buildings. For the aim of taking the necessary preventive measures, studies need to be carried out with the utmost possible precision regarding the building materials of each monument and the microclimate to which they are exposed. Within the present study, a methodology to investigate the mold risk of timber buildings is presented and applied in two historic constructions. The two case studies are located in Vestfold, Norway. Proper material properties are selected for the building elements by leveraging material properties from existing databases, measurements, and simulations of the hygrothermal performance of selected building components. Data from the REMO2015 driven by the global model MPI-ESM-LR are used in order to account for past, present, and future climate conditions. In addition, climate data from ERA5 reanalysis are used in order to assess the accuracy the MPI-ES-LR_REMO2015 model results. Whole building hygrothermal simulations are employed to calculate the temperature and the relative humidity on the timber surfaces. The transient hygrothermal condition and certain characteristics of the timber surfaces are used as inputs in the updated VTT mold model in order to predict the mold risk of certain building elements. Results show a significant increase of the mold risk of the untreated timber surfaces due to climate change. The treated surfaces have no mold risk at all. It is also observed that the most significant increase of the mold risk occurs in the north-oriented and the horizontal surfaces. It is underlined that the mold risk of the timber elements is overestimated by the MPI-ES-LR_REMO2015 model compared to ERA5 reanalysis. The importance of considering the surface temperature and humidity, and not the atmospheric temperature and humidity as boundary conditions in the mold growth model is also investigated and highlighted..

Keywords: hygrothermal performance; timber buildings; cultural heritage; numerical simulations; monitoring and sensors; climate models; fungi identification; mold growth modelling

To download the full issue and read more visit the following link: https://doi.org/10.3390/f12070819

Structural Vulnerability Assessment of Heritage Timber Buildings: A Methodological Proposal

Amirhosein Shabani, Mahdi Kioumarsi, Vagelis Plevris and Haris Stamatopoulos

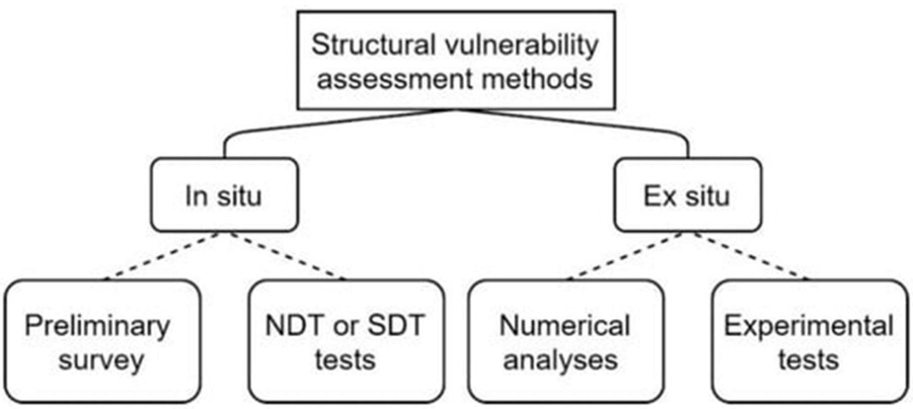


Figure 45: Classification of methods for vulnerability assessments of heritage timber

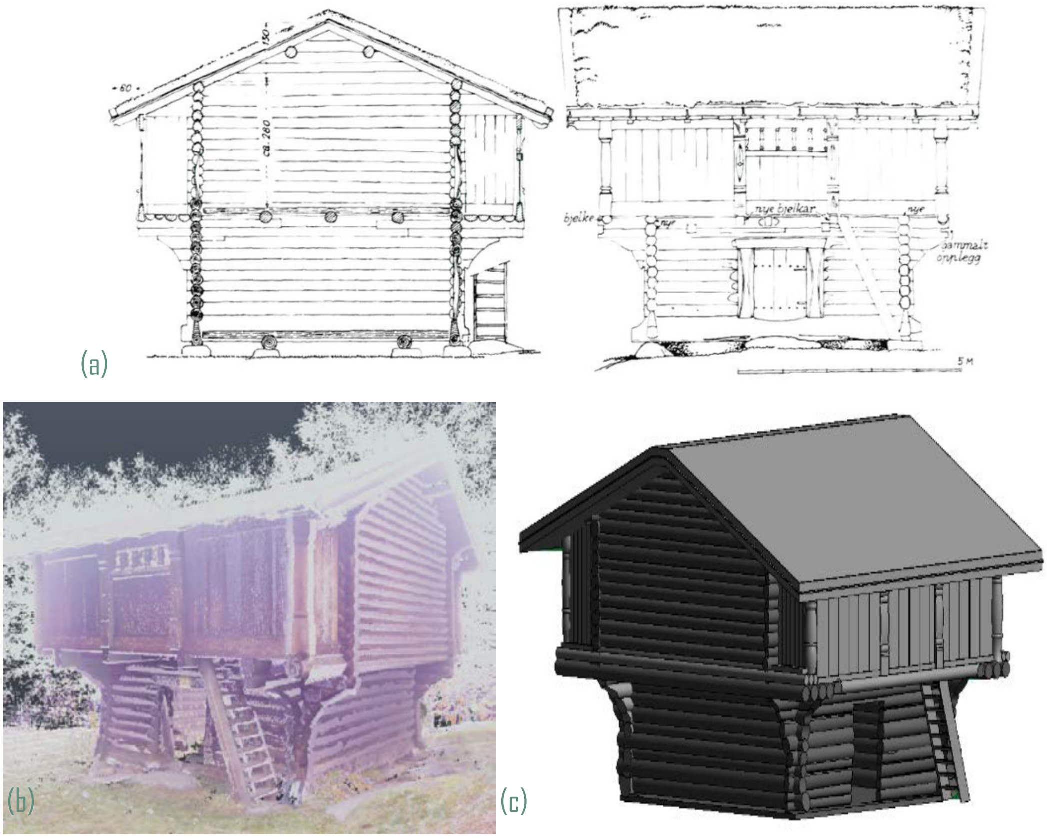


Figure 46: (a) Traditional two-dimensional (2D) view, reprinted from [28]; (b) Point clouds from three-dimensional (3D) laser scanner; (c) 3D drawing view of the Heierstad Loft, Tønsberg, Norway.

Abstract

The conservation of heritage structures is pivotal not only due to their cultural or historical importance for nations, but also for understanding their construction techniques as a lesson that can be applied to contemporary structures. Timber is considered to be the oldest organic construction material and is more vulnerable to environmental threats than nonorganic materials such as masonry bricks. In order to assess the structural vulnerability of heritage timber structures subjected to di_erent types of risk, knowledge about their structural systems and configurations, the nature and properties of the materials, and the behavior of the structure when subjected to di_erent risks, is essential for analysts. In order to facilitate the procedure, di_erent assessment methods have been divided into the categories in situ and ex situ, which are applicable for vulnerability assessments at the element and full-scale level of a case study. An existing methodology for structural vulnerability assessments and conservation of heritage timber buildings is reviewed and a new methodology is proposed..

Keywords: heritage timber buildings; risks and their effects; structural vulnerability assessment; in situ assessment methods; visual inspection; data analysis; ex situ assessment methods; numericalsimulation; experimental test; assessment and conservation methodology

To download the full issue and read more visit the following link: https://doi.org/10.3390/f12070819

State of the art of simplified analytical methods for seismic vulnerability assessment of unreinforced masonry buildings

Amirhosein Shabani, Mahdi Kioumarsi, Maria Zucconi

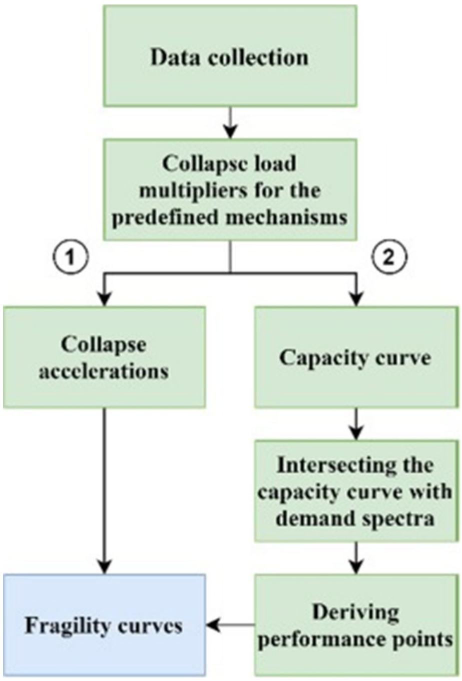


Figure 47: Flowchart of FaMIVE methodology for deriving fragility curves. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).

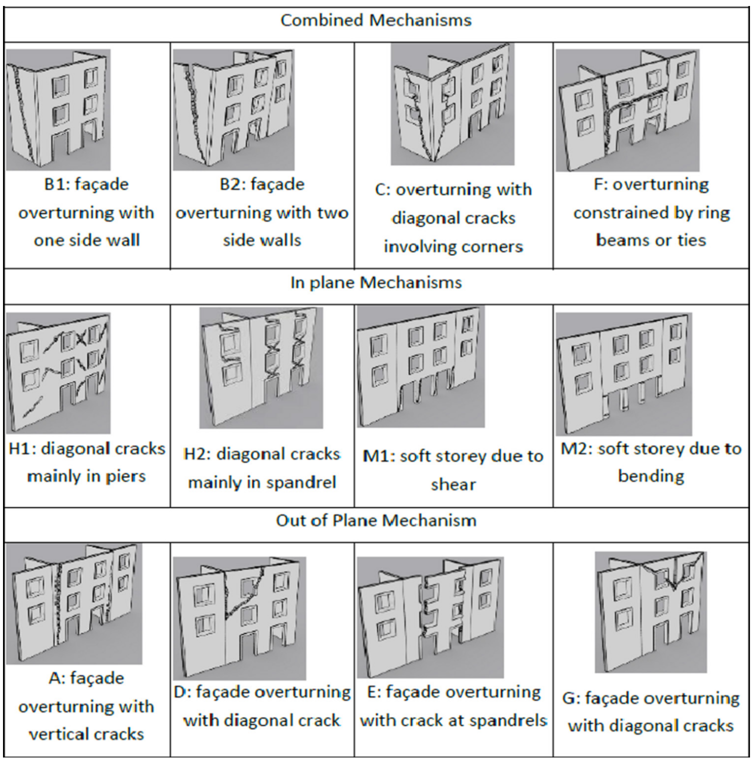


Figure 48: Collapse mechanisms in FaMIVE methodology

Abstract

Cities in the developing world are facing outstanding economic and human losses caused by natural hazards such as earthquakes, and the amount of losses is affected by the quality of preventive measures and emergency management. For this reason, seismic vulnerability assessment is considered a crucial part of a strategy for seismic risk mitigation and for improving the resiliency of cities. Due to the high number of building archetypes for the seismic vulnerability assessment at a large scale, fast, simplified methods have been proposed that can facilitate the assessment procedure with low computational effort. Simplified methods can be categorized into three groups: analytical, empirical, and hybrid methods. In this study, simplified analytical methods for the seismic vulnerability assessment of unreinforced masonry (URM) buildings were reviewed, starting with their classification into three main groups: collapse mechanism-based, capacity spectrum-based, and fully displacement-based methods. Finally, attention was given to the corresponding software packages that were developed to facilitate the assessment procedure.

Keywords: Seismic vulnerability Analytical methods Simplified methods Urban scale Unreinforced masonry buildings Collapse mechanism-based methods Capacity spectrum-based methods Fully displacement-based methods

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Model Type Effects on the Estimated Seismic Response of a 20-Story Steel Moment Resisting Frame

Christos G. Lachanas and Dimitrios Vamvatsikos

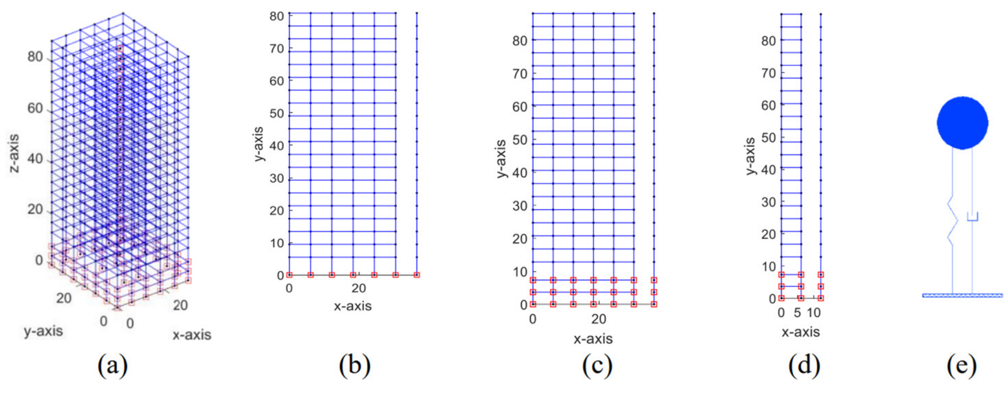

Figure 49: Building models (red circles denote the ground level and the basements): (a) M3Bx model (the central node at each floor is indicated in red). (b) M2Gx model. (c) M2Bx model. (d) M1Bx model. (e) Sxxx model.

Abstract

Finite-element models of varying sophistication may be employed to determine a building's seismic response with increasing complexity, potentially offering a higher fidelity at the cost of the computational load. To account for this effect on the reliability of performance assessment, model-type uncertainty needs to be incorporated as distinct to the uncertainty related to a given model's parameters. At present, only placeholder values are available in seismic guidelines. Instead, we attempt to quantify them accurately for a modern 20-story steel moment-resisting frame. Different types of three-dimensional (3D), two-dimensional (2D) multibay, and 2D single-bay multidegree-of-freedom models are investigated, together with their equivalent single-degree-of-freedom ones, to evaluate the model dependency of the response both within each broad model category, as well as among different categories. In conclusion, ensemble values are recommended for the uncertainty in each model category showing that for the perfectly-symmetric perimeter-frame P-ΔP-Δ sensitive building under investigation, the uncertainty stemming from 3D versus 2D or distributed versus lumped plasticity models is lower than the governing record-to-record variability...

Keywords: seismic performance; model type uncertainty; pushover analysis; incremental dynamic analysis

To download the full issue and read more visit the following link: https://doi.org/10.1061/(ASCE)ST.1943-541X.0003010

Probabilistic identification of surface recession patterns in heritage buildings based on digital photogrammetry

María L. Jalón, Juan Chiachío, Luisa M. Gil-Martin, Enrique Hernández-Montes

(a) (b)

Figure 50: San Jerónimo Monastery: (a) main façade, (b) buttresses.

Abstract

The deterioration of the built heritage is becoming a pressing issue in many countries. The assessment of such a degradation at large (building) scale is key for maintenance priorisation and decision making. This paper proposes a straight forward method to rigorously measure and predict the degradation of heritage building materials. The method is based on a probabilistic Bayesian approach to identify the most plausible surface recession pattern using just digital photogrammetry data. In particular, a set of candidate recession patterns are defined and ranked based on probabilities that measure their relative extent of support to the observed data. A real case study for a sixteenth century heritage building in Granada (Spain) is presented. The results show the efficiency of the proposed methodology in identifying not only the most suitable recession pattern for different parts of the building, but also the probability density functions of the basic degradation parameters representing the identified patterns, such as the depth and the height of the degradation..

Keywords: Bayesian system identification Cultural heritage buildings Surface recession assessment Photogrammetric point cloud

To download the full issue and read more visit the following link: https://doi.org/10.1016/j.jobe.2020.101922

A Preliminary structural survey of Heritage Timber Log houses in TØNSBERG, Norway

Amirhosein Shabani, Haidar Hosamo, Mahdi Kioumarsi and Vagelis Plevris

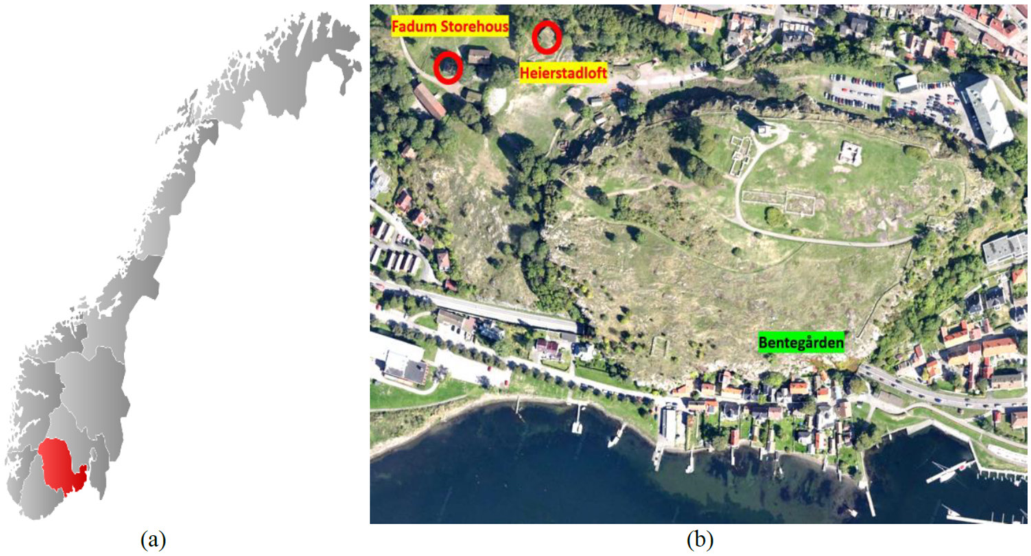

Figure 51: SThe location of (a)Tønsberg in southern Norway, (b) the two case study heritage timber buildings

Abstract

The formulation of a multi-hazard loss model for a given structure is not only of interest for predicting the economic impact of future damages but it can also be of importance for risk mitigation. A methodology to assess the vulnerability of the built environment is a significant component of a loss model. Multi-risk vulnerability of heritage buildings mandates to know more about the history of the construction including aspects of preserving them as assets. Timber as an organic material is more susceptible to decay and the structural assessment of these types of buildings is essential for their preservation. A preliminary survey as a base for the multi-risk vulnerability of the buildings is essential. In this step, the history of the building has to be investigated as well as any intervention to it during its lifetime. For the next step, a damage inspection of structural elements is essential, to be conducted by experts. Afterwards, the configuration of the building such as height, plan view and connections' details should be documented. After the preliminary survey of the building, detailed methods are employed to gather further information about the structure's behavior under different risk scenarios. In this paper, heritage timber buildings in Tønsberg, Norway are selected as case studies for multi-risk vulnerability assessment. The preliminary survey has been implemented by a team of experts and useful data are recorded and explained. Moreover, 3D laser scanners have been used in the survey for obtaining a more detailed and accurate 3D representation of the buildings instead of traditional 2D methods..
Keywords: Preliminary Survey, Heritage Timber Structures, Log House, 3D Laser Scanner, Visual Inspection, Environmental Attack, Vulnerability Assessment

(presented at the **"12th International Conference on Structural Analysis of Historical Constructions SAHC 2020"**)

Hygrothermal performance of log walls in a building of 18th century and prediction of climate change impact on biological deterioration

Petros Choidis, Katerina Tsikaloudakil and Dimitrios Kraniotis

Figure 52: The Fadum storehouse as observed (a) from a satellite view and (b) in situ picture from south-west.

Abstract

Several studies underline the dramatic changes that are expected to take place in nature and environment due to climate change. The latter is also expected to affect the built environment. Particular emphasis is currently given to the impact of climate change on historical structures. Within this context, it is important to use simple methods and novel tools in order to investigate specific case studies. In this study, the climate change impact on the hygrothermal performance of the log walls in a historic timber building is presented. The building under investigation is the Fadum storehouse, also known as 'the coated house', located in Tønsberg, Norway. The storehouse dates to the late 18th century. It has a particular design with the main features of stumps or piles up to which it stands and the 'coating' that covers its outer walls. The main damage of the construction is related to the biological degradation of the wood. The hygrothermal performance of the log walls, as well as the exterior and interior climate, have been monitored and the results have been used to validate a Heat, Air and Moisture transport (HAM) model. The validated HAM model is then used to examine the performance of the log walls for both current and potential future climate conditions. The transient hygrothermal boundary conditions serve as the input parameters to a biohygrothermal model that is used to investigate the biological deterioration of the building components. The findings reveal that currently there is no mould risk for the main body of the construction, which is in accordance with the visual inspection. The passive systems of the building are highly conducive to these results, since they protect it from driving rain and other sources of moisture and eliminate the potential impact of future climate change risk scenarios.

To download the full issue and read more visit the following link: http://doi.org/10.1051/e3sconf/202017215006

3D and Hyperspectral data integration for assessing material degradation in medieval mansonry heritage buildings

P. Kolokoussis, M. Skamantzari, S. Tapinaki, V. Karathanassi, A. Georgopoulos

Figure 53: Detailed 3D Textured Model (RGB).

Figure 54: Detailed 3D Textured Model using HS bands 625 nm, 540 nm, 489 nm as RGB.

Figure 55: Detailed 3D Textured Model using HS bands 823 nm, 710 nm, 696 nm as RGB.

Abstract

Cultural Heritage (CH) is a domain which has been greatly affected by climate change in the past decades. At the same time Information and Communication Technologies (ICT) have been greatly exploited to contribute to the holistic documentation, to support conservation and preservation actions. In order to move further on from the interdisciplinary approach to the holistic approach on Cultural Heritage the fusion of data from various sensors is the next goal. This paper focuses on the exploitation and integration of close-range 3D and Hyperspectral data from four Cultural Heritage buildings of Rhodes in order to assess material degradation. The methodology and data processing for this integration are presented as well as the useful and promising results of this approach which lead to further analysis and future work. The research is conducted within the framework of an EU funded project.

Keywords: Hyperspectral Images, 3D Reconstruction, Material Analysis, Cultural Heritage, Photogrammetry

(presented at the **"XXIV ISPRS Congress, September 2020, Nice"**)

Smart IoT sensors network for monitoring of Cultural Heritage Monuments

Maria Krommyda, Nikos Mitro, and Angelos Amditis

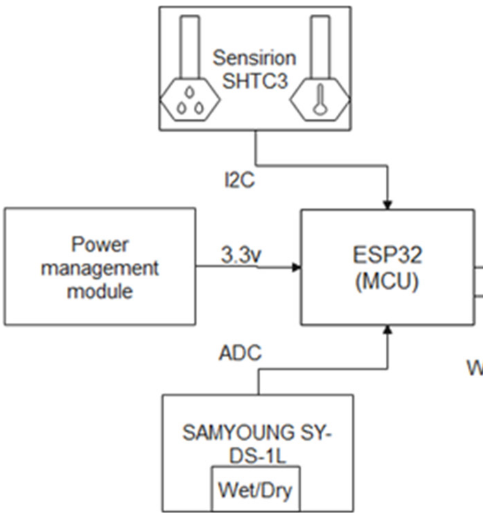

Figure 56: Smart Tag system Architecture

Abstract

The building materials of Cultural Heritage monuments are subjected to continuous degradation throughout the years, mainly due to their exposure to harsh and unexpected weather phenomena related to the Climate Change. The specific climatic conditions at their vicinity, especially when there are local peculiarities such as onshore breeze, are of crucial importance for studying the deterioration rate and the identification of proper mitigation actions. Generalized models that are based on climate data can provide an insight on the deterioration but fail to over a deeper understanding of this phenomenon. To this end, in the context of the EU funded HYPERION project a distributed smart sensor network will be deployed at the Cultural Heritage monuments in four study areas as the solution to this problem. The platform includes smart IoT devices designed to provide environmental measurements close to monuments, a middle-ware to facilitate the communication and a visualization platform where the collected information is presented.

Keywords: Cultural Heritage, monument deterioration, IoT network, environmental monitoring, micro-climate sensors, IoT visualization

HYPERION: understanding and quantifying the effects of climate change on cultural heritage

Chiara Coletti, Luigi Germinario, Fabrizio Antonelli, Renzo Bertoncello, Antonio Galgaro, Lara Maritan, Matteo Massironi, Jacopo Nava, Rebecca Piovesan, Raffaele Sassi, Elena Tesser, Claudio Mazzoli

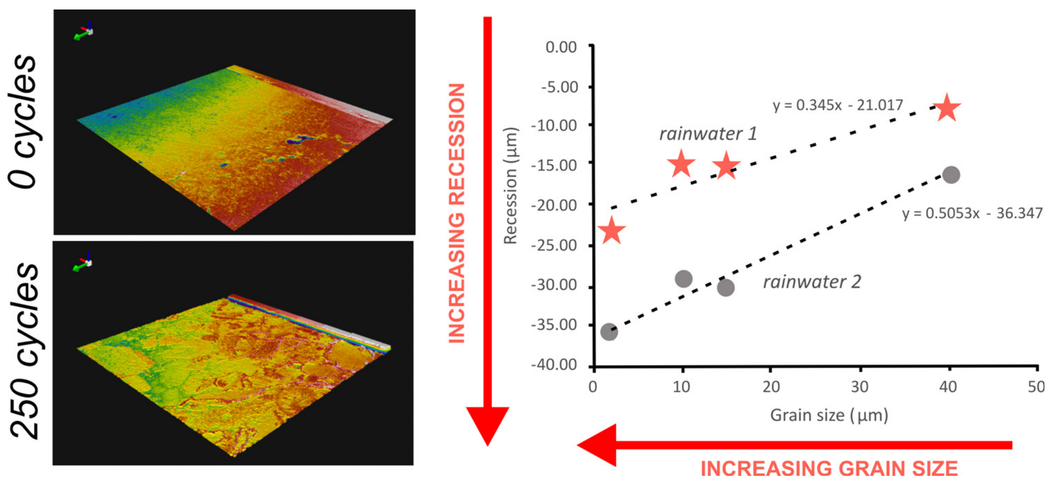

Figure 57: Surface recession measurements during 250 wetting cycles.

Abstract

Climate change is one of the most critical global challenges of our time. During the last century, the anthropic activity had a great impact not only on the environment, affecting even the conservation of cultural heritage. This is becoming a mandatory issue to be tackled by international and local administrations and heritage stakeholders.
Stone is one of the natural materials most utilized in historical monuments. Although stone decay phenomena have been broadly investigated in the past, only few studies are moving towards the understanding and quantification of the short- and long-term effects of climate change. This research direction, however, is essential for supporting sustainable mitigation plans and the city management.
The HYPERION project aims to fill this gap, improving the knowledge of measurable material- and climate-based parameters that influence stone decay rate. The project includes simulations of future scenarios and potential effects of changing climate patterns and air quality, extreme climate events, and multi-hazard circumstances in the historical urban context.
In this contribution, we present the preliminary results of the study of selected building stones used in four European demonstration sites, in Italy (Venice), Greece (Rhodes), Spain (Granada), and Norway (Tønsberg). The basic petrographic and physical-mechanical investigation of the materials is combined with accelerated ageing tests under different environmental stresses (cycles of salt crystallization and freeze-thaw and interaction with rainwaters with different compositions) and field-exposure tests. The expected results will help refining adequate material-specific models of stone surface recession and support structural and hygrothermal simulations about the future decay of cultural heritage.

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