REPORT ASSESSING INNOVATIVE RESTORATION TECHNIQUES, TECHNOLOGIES AND MATERIALS USED IN CONSERVATION

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Table of Context

Introduction

This report focuses on innovative restoration techniques, technologies and materials used in conservation of ruins in particular. The ruins are most often the result of gradual dilapidation which goes through several phases[1]:

- The building has lost most of its wooden parts (timber roof truss, ceiling, timber framing walls), only brick skeletons remain and the building is open to weathering.
- The vaults crashed and the walls cracked, water leaked the walls, and there was a rupture in some places. The openings in the walls grew and the weaker part of the wall fell.
- The masonry is still a whole, but contact with the original terrain level and the relief is lost.
- There were discontinuous ruins in a heap of rubble, vertical cliffs were created.
- All the walls crashed, the castle turned into a construction waste covered with lush vegetation.

Each phase requires special kind of conservation works. Each conservation process include several steps:

- Survey (detailed inspection and reports, relevant graphic documentation and analyses)
- Definition (critical – historical definition)
- Analysis (examination of the resource using scientific methods)
- Strategy and implementation (monitoring, regular inspections, controls)

An overview of all techniques, technologies, materials and tools useable for steps mentioned above would be too extensive. Therefore we focus on innovative techniques and technologies, even so the following review must be necessarily selective. Priority has been given to those methods and procedures that are among the most used in the process of ruin protection and preservation. Preference was given also to the methods used at the workplaces of the members of the RUINS project consortium, as well as to original results of the applied research achieved at these workplaces. For this reason, especially analytical and diagnostic methods are significantly represented in the report.

The individual records are arranged in such a way that the descriptive characteristics of each method are presented first, then the extent of use or application and also the necessary degree of intervention. For a practical assessment a briefly summarizing of their advantages and

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[1] SOKOL, J. – DURDÍK, T. – ŠTULC, J. Ochrana, údržba a stavební úpravy zřícenin hradů [Protection, maintenance and reconstruction of castles ruins]. Praha: Státní ústav památkové péče, 1998. ISBN 8086234010.

disadvantages is namely important. Those interested in more information will appreciate keywords for internet searching, summary of the literature on the subject and links to important websites.

In most cases, the examples of real applications are included which can further clarify the scope of use.

The presented review is selective as we stated above, so it is appropriate not to take it as a final list, but as a material that can be supplemented and updated on the basis of new knowledge and experience. The structure of records is ready to be transferred to a database form in case of need in future for the same reason.

Individual records are listed in alphabetical order in this report, but they can be sorted into different groups for different purposes. One of the possible groupings is as follows:

Survey, recording and presentation methods

Diagnostic methods

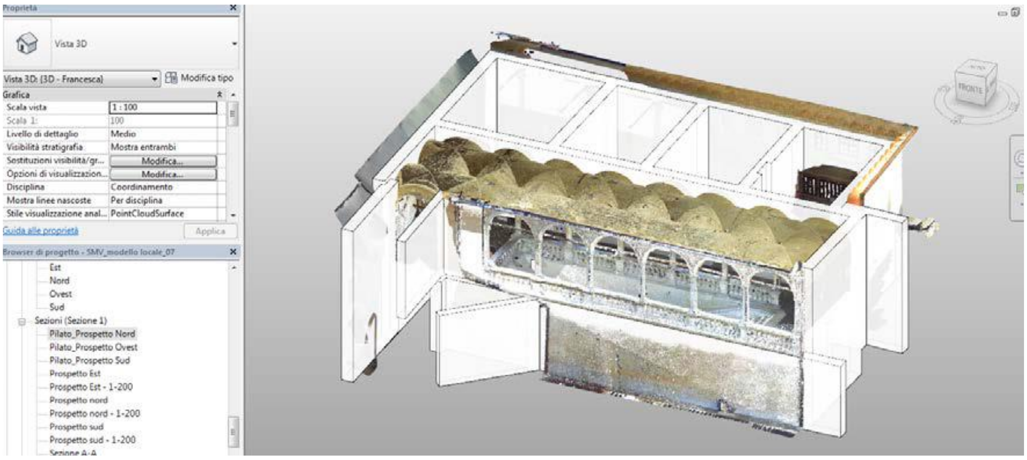
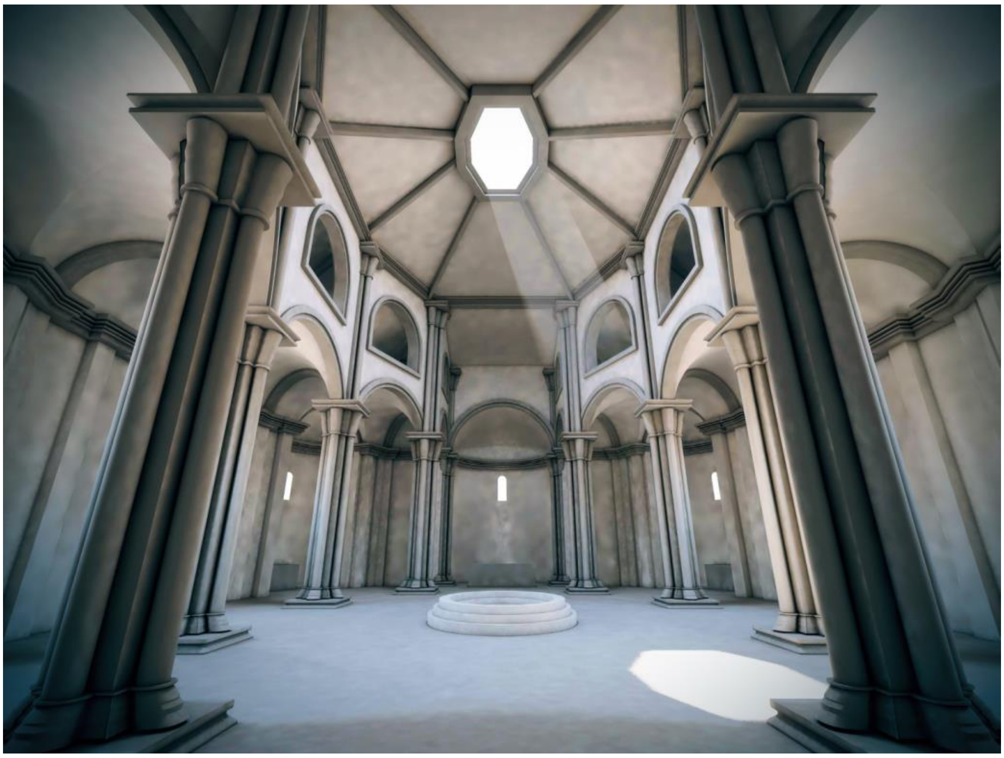
Maintenance and risk management

Modern facilities

Method	**360-degree photography**
Kind	Recording
Basic description	Camera for taking detailed 360-degree photos and videos
Specification	Name: Ricoh THETA V Video footage resolution: 4K (3840 x 1920), 2K (1920 x 960) - 30 fps Photo footage resolution: 5376 × 2688 px Internal memory: 19 GB Weight: 0.121 kg Extra features: BT, USB, Wi-Fi
Range of use	Taking photographs of buildings, structures, and interiors. The device can take full 360-degree photographs.
Intervention rate	Non-invasive
Main advantages	Spherical, 360-degree footage
Negatives or risks	Its use depends on weather conditions (see device specification)
References	
Available at	Lublin University of Technology
Keywords	360-degree camera, spherical camera, pictures, photographs, footage
Recording author	Bartosz Szostak, Lublin University of Technology
Images	

Source of images	Bartosz Szostak, Lublin University of Technology

Method	3D modelling
Kind	Visualization
Basic description	3D modelling is the process of creating a 3D representation of any surface or object by manipulating polygons, edges, and vertices in simulated 3D space. 3D modelling can be achieved manually with specialized 3D production software that lets an artist create and deform polygonal surfaces or by scanning real-world objects into a set of data points that can be used to represent the object digitally.
Specification	There are many 3D modelling software programs on the market. Among the highest rated are: AutoCAD, Blender, SketchUp, 3DS Max, ZBrush. In the last years the use of BIM (Building Information Modeling) or HBIM (heritage Building Information Modeling) is increasing exponentially. Thanks to this particular method the user can view and interact with the model in three-dimensional views as well as orthographic two-dimensional plan, sections and elevation views of the model. In the case of BIM, the distinctive element of this type of parametric model is the integration not only of parameters such as geometry (coordinates), topology (connection relationship between elements) or photometry (visual characteristics of surfaces), already obtainable from many models 3D non-BIM, but also parameters of the internal composition, of the year of construction or of the restoration interventions, of the materials, archival documents, etc.
Range of use	Wide range of use, in the architectural field it can be used both for design and construction (architecture, engineering, technical systems) as well as in facility management. Recently, HBIM is starting to be used for the study, definition and quantification of degradation.
Intervention rate	Non-destructive
Main advantages	The 3D modeling industry has brought many benefits in the architectural field, the main ones are: • Better visualization for all types of buildings • Lower costs • Check for errors that might occur in the drawing process • Minimum errors/revisions in Design and RFI
Negatives or risks	Difficulty in the representation of historical, non-standardized parts of a building
References	LO TURCO, M.: *(2012)* From the geometry of pre-existing to the construction knowledge: an updated recovery from BIM, *DISEGNARE CON.*
Available at	http://disegnarecon.univaq.it/ojs/index.php/disegnarecon
Keywords	3D Modeling, BIM, HBIM
Recording author	Patrizia Borlizzi, SITI

Images	 
Source of images	VERDIANI, G. In: (2017) From the archaeological reality to the digital reconstruction: an architectural drawing challenge, DISEGNARECON.

Examples of application

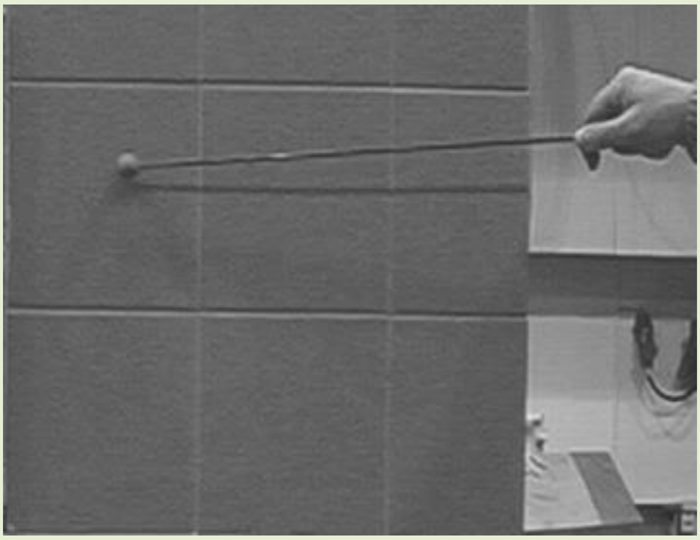
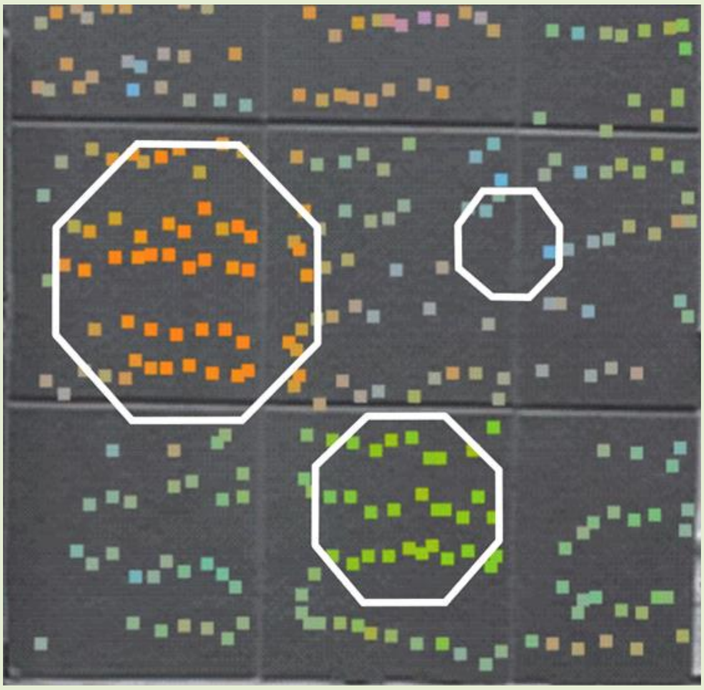
Site Specification	Quartu Sant'Elena
Localization	Quartu Sant'Elena, Cagliari District, Sardinia Region, Italy
Owner and management	University of Cagliari
Affected part	Architectural heritage built during 1900-1930.
Intervention reasons	Collect data and storage elements of liberty and art deco approach through BIM library in order to have
Intervention extent	In the whole city, in particular, were analyzed the door frames, the geometry and decoration on façade in the middle-class neighborhood.
Date of intervention	2015
Time consumption	Not known
Results	Through B.I.M. a library was created of the doors decoration of the city in order to collect data and share information with other worker in the area of restoration.
Evaluation	Exploit the potential of the B.I.M. in the representation of repeating objects serially both within a single building that in more buildings in a large scale territory
References	CICALO', E.: (2016) B.I.M. for representing historical building heritage. The survey of Liberty and Art Deco decorated façades, DISEGNARECON
Images	
Source of images	CICALO', E.: (2016) B.I.M. for representing historical building heritage. The survey of Liberty and Art Deco decorated façades, DISEGNARECON.

Method	3D scanning of details
Kind	Recording
Basic description	Optical, fringe patterns are projected onto the surface of the object. Calibrated 3D sensor head (two cameras + projector) takes pictures of fringe patterns projected onto the surface of the object.
Specification	ATOS Core 200 sensor head. Accuracy: +/- 0,01 mm.
Range of use	Three-dimensional measurement of small components from several centimetres to up to 0,5 m × 0,5 m in size
Intervention rate	Non-destructive method (point spacing)
Main advantages	Fast capture of complex components or textures during automated measurement processes, non-destructive surveying, high accuracy, small size (one case + laptop and tripod) Free analysis software to be installed on infinite number of computers Calibration based on a certified model
Negatives or risks	Fails to work properly in rain and when temperature drops below -5°C.
References	
Available at	Cooperation agreement between Lenso Sp. z o.o. and Lublin University of Technology
Keywords	ATOS, 3D scanning, reverse engineering
Recording author	Maciej Trochonowicz, Lublin University of Technology

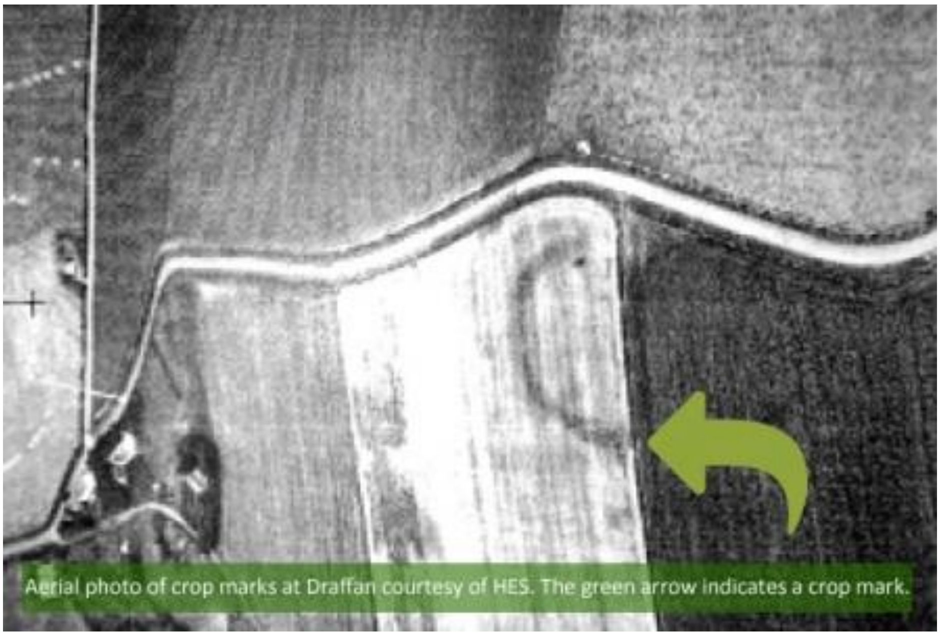
Images

	 
Source of images	Lenso Sp. z o.o.

Method	Acoustic tracing
Kind	Diagnostic
Basic description	The most used method in restoration practice for investigation of rendering defects is based on percussion and recording the places of different acoustic response.
Specification	The method takes advantage of different dynamic and therefore also acoustic characteristics of detached parts, in comparison to the parts with a perfect adhesion. The signal can be analysed simply by an operator or by means of electronic signal analysis. The position of changes is usually marked by chalk directly on the surface and then can be recorded optically (by means of photography or video) or in a semi-automatic way using direct optical record of a moving knocking mass.
Range of use	Detection of detached surface layers of renders and plasters or delamination of surface stone layers
Intervention rate	Non-destructive contact
Main advantages	Fast and low cost method, efficient on any type of surface – rough, glossy
Negatives and risks	No substantial risk, need of manual operation and physical contact
References	DRDÁCKÝ, Miloš F. – LESÁK, Jaroslav 2007: Non-destructive diagnostics of shallow subsurface defects on masonry. In: L. Binda, M. Drdácký and B. Kasal (eds.): *In-Situ Evaluation & non-destructive testing of historic wood and masonry structures* –, NSF/MŠMT/RILEM, ITAM, Praha 2007, pp. 140-147. SKŁODOWSKI, Roman – DRDÁCKÝ, Miloš – SKŁODOWSKI, Marek 2013: Identifying subsurface detachment defects by acoustic tracing. In: *NDT&E International,* 56/2013, pp. 56–64. http://dx.doi.org/10.1016/j.ndteint.2013.02.002
Keywords	Acoustic tracing, surface layers, detachment
Recording author	Miloš Drdácký, ITAM

Images	  Knocking surface with a hard ball on a stick (upper picture), identified subsurface detachment artificially prepared on a testing wall (lower picture). The defective points were found by means of a semi-automatic evaluation of electronically registered sound signals.
Source of images	Miloš Drdácký, Jaroslav Lesák, ITAM 2007

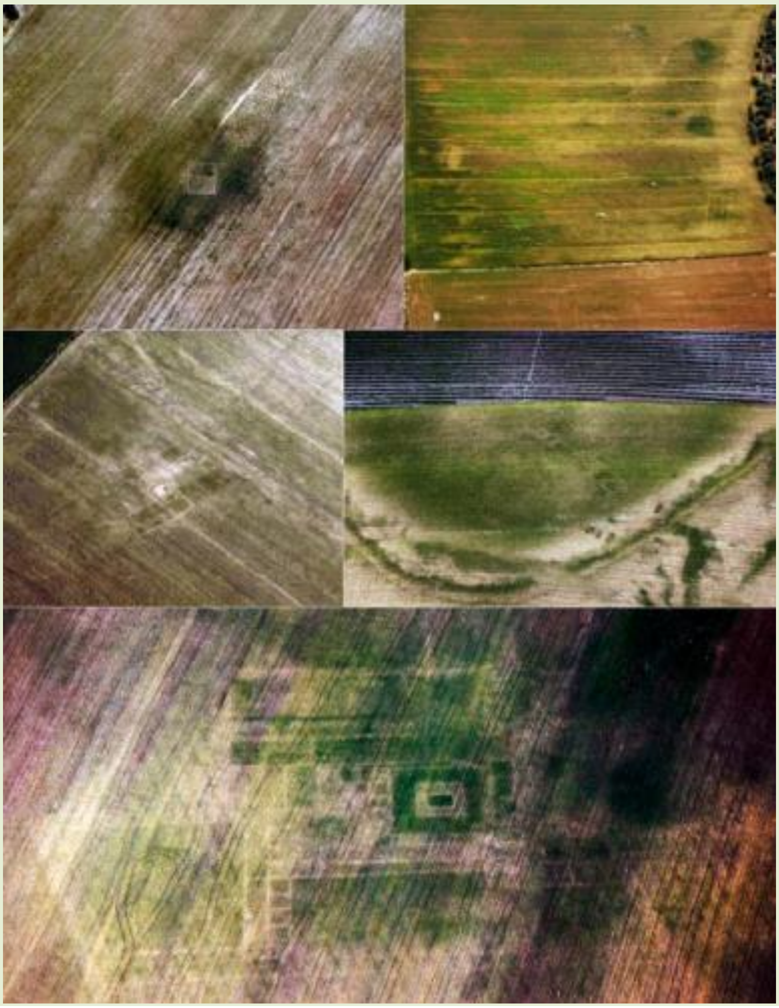
Method	Aerial archaeological prospection
Kind	Recording
Basic description	Archaeological prospection generally refers to non-destructive identification of features and relics buried at archaeological sites. The terms *aerial* or *remotely sensed information* indicate how aerial archaeology works: it uses the distant view. Archaeological sites show up on the ground surface by light-shadow-contrasts (shadow marks), tonal differences in the soil (soil marks) or differences in height and color of the cultivated cereal (crop marks). In that way, settlements, graveyards, fortifications produce specific structures that can be identified easier from a high viewpoint.
Specification	There are two main methods: the one in which the device is piloted by someone and the other one which adopts an automatic pilot. In the last case the device is a fully automatic UAV (Unmanned Aerial Vehicle) platform with a central body where all the electronics and main communication hardware are incorporated. These include the data link antenna, pilot probe, battery and camera compartment on the top face, ground sensor and camera hole on the bottom face, the wing servo connection along the side and the propeller in the backside. The system is connected to a ground control station (GCS), which is able to define all the characteristics of the flight and allows the supervision of the platform during the flights in real time. The device also has an RGB camera that provides the acquisition of images in a red scale.
Range of use	It's a very flexible tool applicable to many types of complex areas with a variety of different features. It can be used in many fields, especially in archaeological excavation areas and architectural complexes, where it offers a detailed generation of three-dimensional (3D) data including the possibility of updating over time.
Intervention rate	Non-destructive
Main advantages	It is a very capable tool for exploring research questions by being able to provide very accurate and precise spectral information as ortho imagery and surface heights as a DSM.
Negatives or risks	High costs when needs to be piloted by a pilot
References	AGÜERA-VEGA F. – F. CARVAJAL-RAMÍREZ, F. – MARTÍNEZ-CARRICONDO, P. J. – SÁNCHEZ-HERMOSILLA LÓPEZ, J. 2018: Reconstruction of extreme topography from UAV structure from motion photogrammetry, In: *Measurement*, 2018, Volume 121, June 2018, Pages 127-138. https://www.sensefly.com/drone/ebee-mapping-drone/
Available at	http://porto.polito.it/2697610/
Keywords	UAV, drone, photogrammetry, aereal laser scanner
Recording author	Patrizia Borlizzi, SITI

Images	 
Source of images	http://www.clydeandavonvalley.org AGÜERA-VEGA F., F. CARVAJAL-RAMÍREZ P., MARTÍNEZ-CARRICONDO, SÁNCHEZ-HERMOSILLA LÓPEZ J.

Examples of application

Site Specification	The Archaeological Prospection of Tuscany
Localization	South Central Tuscany, Italy
Owner and management	Municipalities of Siena, Grosseto and Livorno
Affected part	Panoramic view of the whole Region
Intervention reasons	The aerial survey allows the gathering of data on a regional scale and at the same time carrying out precise analyzes through the repetition of flights and the possibility to vary (albeit within certain limits) the degree of detail.
Intervention extent	The project has among its main objectives the systematic photographic documentation of monumental emergencies and the tracing of Medieval, Classical and Prehistoric Age in the Region. The program has a transversal nature and it's an integral part of wider research projects such as the Archeological Charts of the Provinces of Grosseto, Siena and Livorno.
Date of intervention	2000/2006
Time consumption	The average is of 30-hour flight per year, distributed on 6 years.
Results	In relation to sites and landscapes aerial reconnaissance was found rather effective for both the identification of new sites and for the increase of information at contexts previously known.
Evaluation	Survey products from aerial point of view can be considered as a quick means of documentation for a low-cost mapping, following the updating of excavation procedures.
References	CAMPANA Stefano, FRANCOVICH Riccardo 2005: Progetto Ricognizione Archeologica Aerea della Toscana, Laboratorio di Archeologia dei Paesaggi dell'Università di Siena Rapporto 2000-2005

Images



Source of images http://www.lapetlab.it/testi/ProgettoRicognizioneAereaToscana.pdf

Method	Capacitance moisture measuring
Kind	Diagnostic
Basic description	A popular method for measuring the moisture content in walls involves the electrical capacitance or dielectric constant of the building material.
Specification	Capacitance moisture meters work on the principle of variation of the dielectric constant of a material in presence of water. The dielectric constant of a material is its ability to hold an electric field. Water has a very high dielectric constant: approximately 80.1 at 20°C. By contrast, dry building materials have dielectric constants of less than 5, so capacitance is proportional to the volume of water in the sample.
Range of use	Numerous hand-held meters are commercially available that use this property to estimate the moisture content in a non-destructive manner [14]. Hand-held meters are attenuation devices, composed of a box transmitter with contact and receiver electrodes. The transmitter sends a radiofrequency signal from the surface into the material, and the attenuation in this signal when it arrives at the receiver indicates the moisture content of the material. The meter is usually battery-powered so the signal is weak and does not travel far into building materials. The meter typically consists of two pads that are placed against the wall. The material in the wall forms a capacitor in a circuit between the pads that is highly sensitive to the moisture content of the material
Intervention rate	Non invasive
Main advantages	The easiness of use of the instrument. However, the method has some important limitations. First of all, a careful calibration is necessary for each material and measurement condition; the instrument cannot measure low moisture contents with precision. Moreover, the measured values are influenced by the presence of soluble salts; even if capacitance meters are less affected by the presence of salt than resistance meters, high salt contents have been shown to significantly affect the readings
Negatives or risks	An important limiting factor in the use of this method is the contact between the instrument and the wall: it is important that the meter makes direct contact with the surface, because an air gap between the sensor and surface is likely to affect the reading. From this derives that the instrument might be of difficult use on rough and/or uneven surfaces, as often those of historic walls. Besides, it should be underlined that this method cannot be used to determine the moisture content at a particular location because the measurement location is not precise. All materials in the vicinity of the sensor will affect the reading, so it is difficult to pinpoint the exact source of a high or low measurement
References	
Available at	Restaurateur office in Zagreb

Keywords	
Recording author	Lidija Perić, ZADRA NOVA
Images	

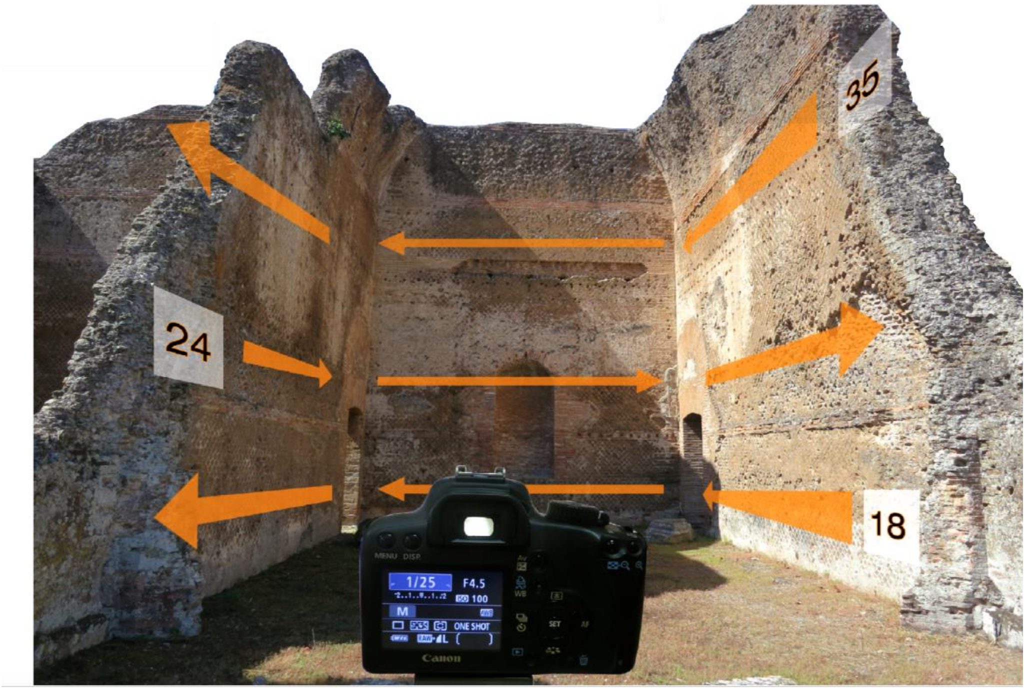
Method	**Production of custom-made lime binders using traditional technologies**
Kind	Remedial
Basic description	A kiln was especially designed for small scale production of lime following the traditional technological features known from the periodic wood fired flare kilns used in Europe during the last two centuries. The use and efficacy of the kiln was assessed on the experimental prototype operated by ITAM AS CR (Válek et al. 2018)
More specification	Maximum charge: 1 t of raw material (limestone). Fuel consumption: 600–700 kg of wood per 500 kg of quicklime (CaO) Burning temperature: 900–1300 °C Duration: 15-20 hours to reach 900 °C followed by 15–20 hours of dwelling time. Cooling phase lasts from 10 to 24 hours.
Range of use	Small-scale production of quicklime (air lime and natural hydraulic lime) and natural cements.
Intervention rate	Technology producing a suitable repair material (mortar binder) for masonry structures. This includes repair of plasters, renders, stuccoes, lime based paints and masonry pointing. The binder can be also used in mortar mixtures for grouting, bedding of masonry units, flooring, stone and other surface repairs.
Main advantages	The custom made lime based binders find use in conservation and restoration projects where a copy of the original binder and its further technological processing is essential. The complete process, i.e. the binder production, mortar preparation and application techniques, allows to replicate original building elements utilising also appropriate historic crafts (Válek 2015). Main advantages: - use of local resources (local limestone) - replication of historic technique (specific production conditions) - replication of lime processing and mortar preparation techniques (specific slaking procedures, hot mixed mortars etc.) - support of traditional skills and crafts - added value as a tourist attraction
Negatives and risks	Need to comply the particular environmental regulations e.g. control of CO_2 emissions. Higher demand on health and safety issues.
References	VÁLEK, Jan 2015: *Lime technologies of historic buildings. Preparation of specialised lime binders for conservation of historic buildings*. Praha: ITAM AS CR, 2015. VÁLEK, J. – SKRUŽNÁ, O. – PETRÁŇOVÁ, V. – FRANKEOVÁ, D. – JIROUŠEK, J. 2018: Development of a small-scale lime kiln and experimental assessment of the produced quicklime. In Hughes, J. J., Valek J. and Groot C. (eds.), *Historic Mortars: Advances in Research and Practical Conservation*. Springer 2018.
Keywords	lime kiln, traditional lime production, lime technology
Recording author	Jan Válek, Petr Kozlovcev (ITAM)

Images	 
Source of images	Jan Válek, Olga Skružná, ITAM

Examples of application

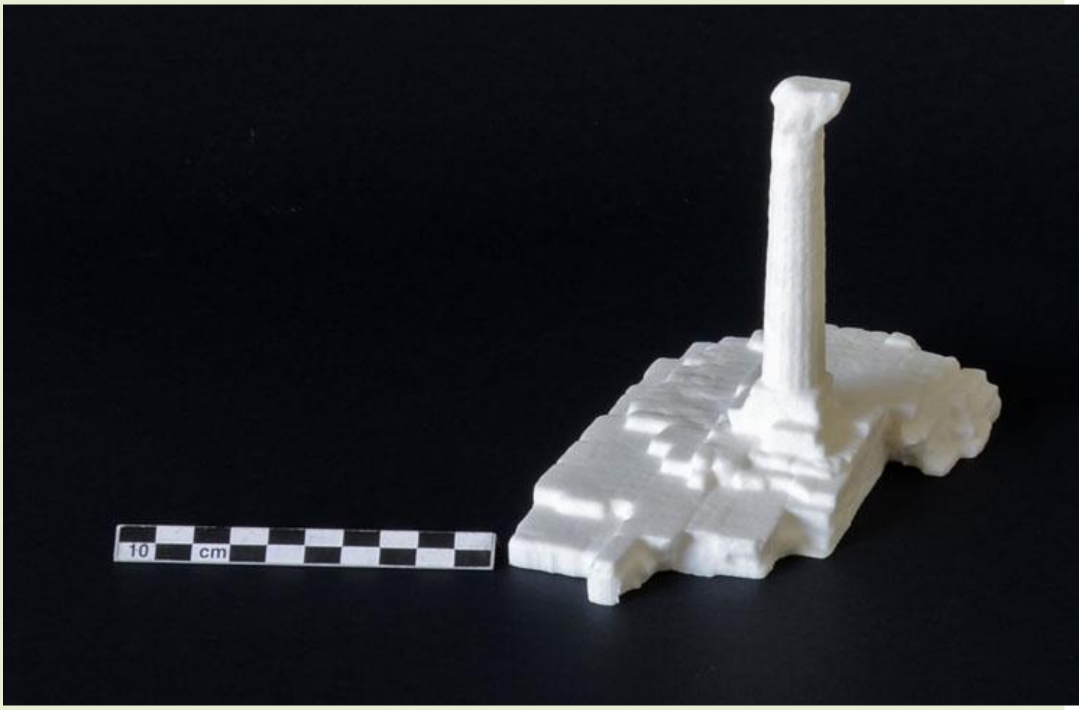
Site Specification	Salajna, spring house
Localization	Salajna, Cheb District, Karlovy Vary Region, Czech Republic (50°1'41.734"N, 12°30'38.386"E)
Owner and management	Private owner
Affected part	Masonry walls and foundations
Intervention reasons	High degree of structural instability and material degradation
Intervention extent	Complete reconstruction utilising traditional materials and techniques. The original masonry material and timber were preserved as much as possible.
Date of intervention	From 24-09-2014 to 22-10-2014
Time consumption	Site specific. In general lime binder production requires – 3 to 4 days.
Results	Restoration of a spring house using the original stone and bricks. Masonry was laid on a lime mortar prepared by traditional craft techniques. Two types of lime burnt in a periodic wood fired kiln were used. Air lime (AL) and natural hydraulic lime (NHL). The bedding mortar was prepared by slaking lime with local sand together in a volumetric ratio AL to NHL to sand 1 : 1 : 7. The spring house was rendered 6 month after its complete reconstruction with a mixture of AL and NHL in ratio of 2 : 1 by volume mixed with 11 portions of local sand. The mix was left to rest with a daily repeated mixing for a few days before its application.
Evaluation	In general suitable. Mortar mixtures well appreciated by the craftsmen. No long term experience with the performance.
References	Not published
Images	
Source of images	Daniel Šufana

Method	Digital photogrammetry
Kind	Recording
Basic description	Photogrammetry is a survey technique that allows to obtain metric information (shape and position) of three-dimensional objects through interpretation and measurement of photographic images. Digital photogrammetry is a well-established technique for acquiring dense 3D geometric information for real-world objects from stereoscopic image overlap and has been shown to have extensive applications in a variety of fields.
Specification	Aerial photogrammetry refers to the collection and processing of imagery captured from an aerial or orbital vehicle. Close-Range photogrammetry (CRP) refers to the collection of photography from the ground or some lesser distance than traditional aerial photogrammetry and is becoming increasing popular and accessible due to new, easy to use software and digital cameras.
Range of use	Photogrammetry, although originally designed to be used in architectural surveying, is currently used for the most part for the topographical survey of the territory, developing mainly in the form of aerial photogrammetry.
Intervention rate	Non-destructive
Main advantages	High geometric accuracy, high level of detail, automation, photorealism, low cost, portability, flexibility
Negatives or risks	Insignificant
References	LUHMAN, Thomas – ROBSON, Stuart – KYLE, Stephen – BOEHM, Jan 2014: *Close Range Photogrammetry: Principles, Techniques and Applications*, De Gruyter, Boston 2014.
Available at	https://www.asprs.org/
Keywords	Digital photogrammetry, passive optical system, Structure from Motion
Recording author	Patrizia Borlizzi, SITI

Images	
Source of images	http://www.microgeo.it/it/prodotti-e-soluzioni/droni-sapr/201568-applicazioni/fotogrammetria.aspx

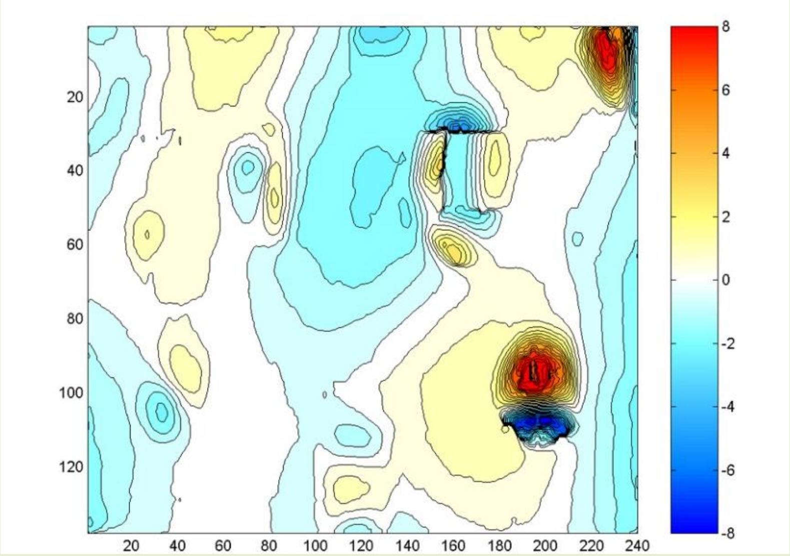
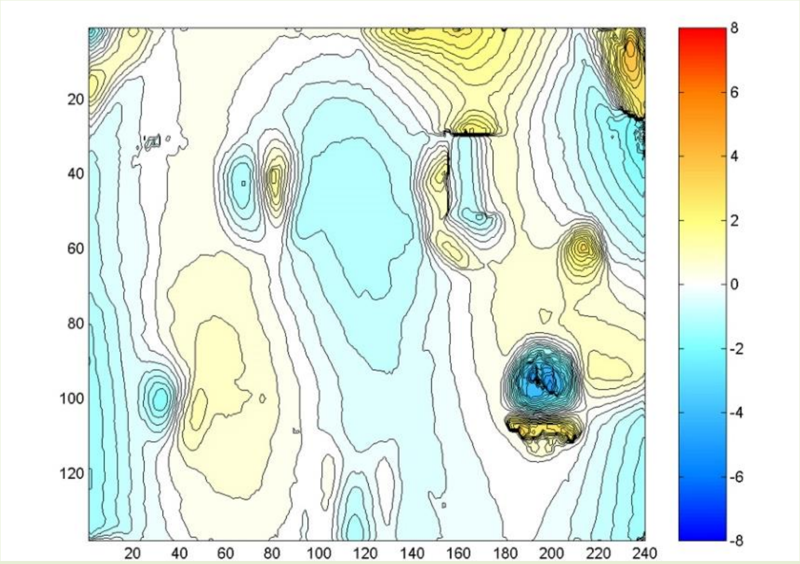
Examples of application

Site Specification	Archaeological Park of Capo Colonna
Localization	Province of Crotone, Calabria (Italy)
Owner and management	Polo Museale della Calabria
Affected part	The sanctuary area
Intervention reasons	Here, on behalf of the Soprintendenza Archeologia of Calabria, photogrammetric surveys from drone have been progressively carried out, as supplementary documentation of the new excavation campaign carried out between 2013 and 2014 and in other areas of the sanctuary, as a verification of the accuracy of the surveys realized over the past decades, with non-instrumental documentation techniques. In particular, numerous photographs and videos of temple A were performed, which documented the progress of archaeological activities in 2013 and 2014.
Intervention extent	Using approximately 150 high resolution images of the column area, zenital and oblique views, created for different purposes, during flights of different moments of the two-year period indicated, in February 2016 a new high-detail 3D model of the preserved area was created in the upper part of the monument.
Date of intervention	2016
Time consumption	Undated
Results	The photogrammetric elaborations have allowed to obtain a dense cloud and a surface defined by mesh. The mesh was covered with a photographic texture taken from the drone, constituting a very detailed documentation of the state of the column and its base. The model lends itself to be displayed also in educational and informative applications. Further processing has made the model suitable for 3D printing, aimed at representing in detail the state of conservation of the monument. 3D printing has been realized, with SLS technique in powder form, in polyamide, in 1: 100 scale of the monument and in a scale of 1:50 of the column with base and capital.
Evaluation	The level of detail is able to give a good approximation of the state of deterioration of the stone boulders of the column and was used for educational purposes and information.
References	http://www.aeropix.it/portfolio/portfolio_lavori/capocolonna-2014-2015/
Images	



Source of images http://www.aeropix.it/portfolio/portfolio_lavori/capocolonna-2014-2015/

Method	2D Laser Doppler interferometry
Kind	Diagnostic
Basic description	The measured surface is excited to vibrate and the surface vibration velocities are measured.
Specification	Dynamic characteristics of the wall-plaster system can be determined across the whole surface area by contactless optical methods. The detached plaster has considerably lower bending stiffness than the wall as well as the layer firmly attached to the bearing brick wall. Therefore, the attached plaster follows the velocities and frequencies of vibrations of the wall, in contrast to the detached parts which vibrate with different frequencies and velocities. This response can be measured optically, and the best results are provided by laser Doppler interferometry. The vibration may be achieved by in principle different methods – by means of acoustic excitation of the detached parts or mechanically through vibration of the whole system.
Range of use	Detection of detached surface layers of renders and plasters or delamination of surface stone layers.
Intervention rate	Non-destructive contactless (in the acoustic excitation variant) or with mechanical (contact) excitation.
Main advantages	Monitoring the surface from large distances – without special surface preparation of the order of meters. Scanning allows for all field measurements and allocates the velocities also on positions on the surface with a resolution to about 1 mm for practical distances.
Negatives and risks	Slow measurements for a high resolution, expensive instrumentation, and health risk for acoustic excitation.
References	DRDÁCKÝ, Miloš F. – LESÁK, Jaroslav 2007: Non-destructive diagnostics of shallow subsurface defects on masonry. In: L. Binda, M. Drdácký and B. Kasal (eds.): *In-Situ Evaluation & non-destructive testing of historic wood and masonry structures* –, NSF/MŠMT/RILEM, ITAM, Praha 2007, pp. 140-147. CASTELLINI, P. – ESPOSITO, E. – PAONE, N. – TOMASINI, E. P. 1999. Non-invasive measurements of damage of frescoes paintings and icon by Laser scanning Vibrometer: experimental results on artificial samples using different types of structural exciters. In: *Non-destructive Testing and Microanalysis for the Diagnostics and Conservation of the Cultural and Environmental Heritage; Proc. VIth Int. Conf.* Roma 1999, pp. 185-198.
Keywords	Differential vibration, acoustic excitation, mechanical excitation, detached surface layer
Recording author	Miloš Drdácký, ITAM

Images	 Vibration modes of plaster defects on the test wall at the excitation frequency of 990 Hz (upper) and with a 90° phase shift (lower). The wall was excited mechanically. 
Source of images	Miloš Drdácký, Jaroslav Lesák, ITAM 2007

Method	Drone photography
Kind	Recording
Basic description	Taking detailed photographs with unmanned flying vehicles, also known as drones (quadcopters). Aerial photography drone is equipped with a camera which allows for taking high resolution videos and photographs. The device allows for taking photographs of areas access to which is limited from the ground. Aerial photography drones are also provided with image stabilizers.
Specification	Name: DJI Phantom 3 Professional Resolution: max. 4096 × 2160 px Weight: 1.28 kg Removable battery with estimated life: 23 minutes
Range of use	Taking detailed photo and video footage of places access to which is limited from the ground.
Intervention rate	Non-destructive
Main advantages	No extra equipment, e.g. scaffolding, jacks, etc., required to take footage
Negatives or risks	The use of the device depends on weather conditions. The person flying the drone must have a special licence; some places are available to drones only upon prior consent.
References	
Available at	Lublin University of Technology
Keywords	drone, photographs, films, 4K
Recording author	Bartosz Szostak, Lublin University of Technology

Images

Source of images	Bartosz Szostak Maciej Trochonowicz \ Lublin University of Technology

Examples of application

Site Specification	Janowiec Castle
Localization	Janowiec, Puławy District, Lublin Region, Poland
Owner and management	Muzeum Nadwiślańskie
Affected part	The entire range of object
Intervention reasons	Site documentation
Intervention extent	Non-invasive
Date of intervention	2017
Time consumption	Not known
Results	A collection of aerial photographs showing hard to reach parts of the ruins.
Evaluation	Photos capturing inaccessible places of the ruined castle were obtained with low economic costs.
References	SZMYGIN, Bogusław – TROCHONOWICZ, Maciej –KLIMEK, Beata – SZOSTAK, Bartosz, *Report on study visit in Janowiec Castle, Poland*. RUINS Project , Lublin 2017.

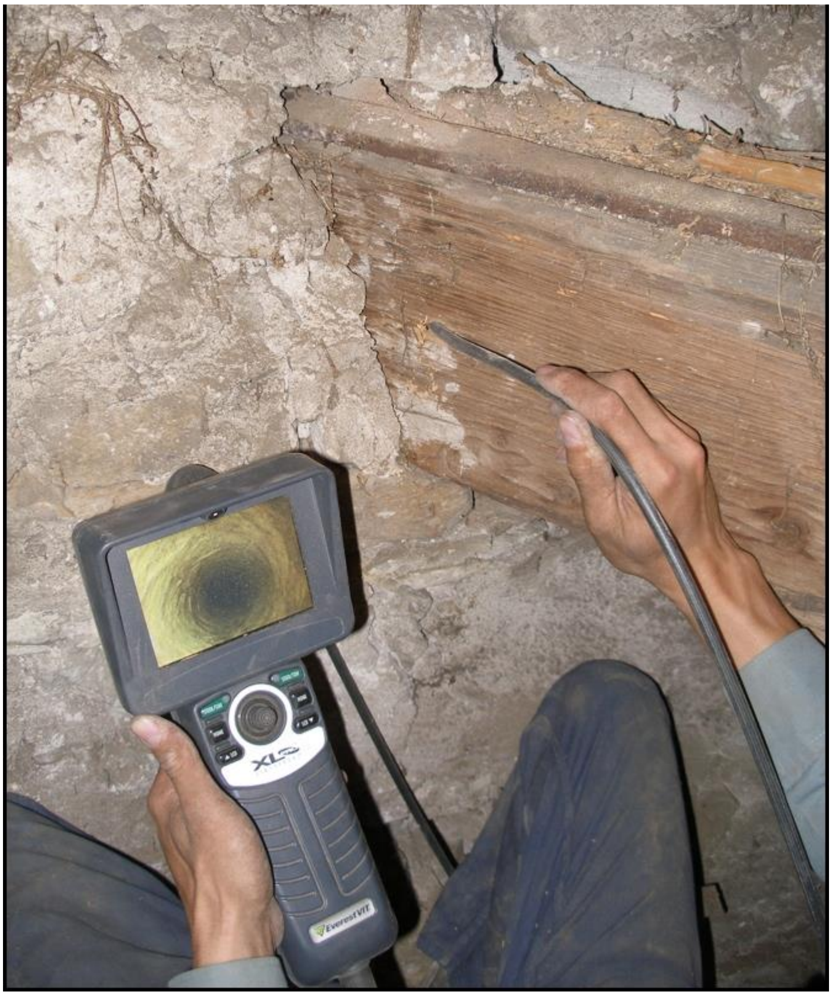
Images	 
Source of images	Bartosz Szostak, Maciej Trochonowicz, Lublin University of Technology

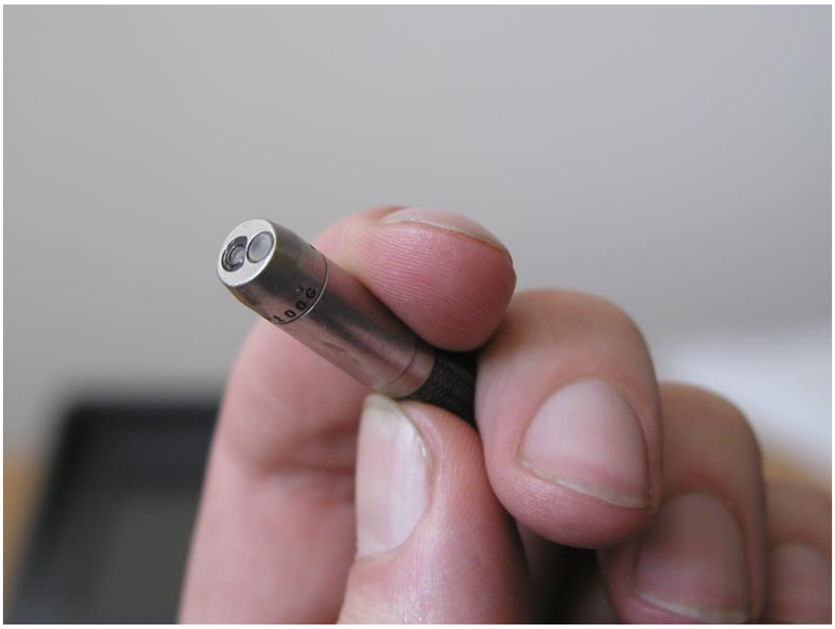
Method	Electronic tacheometry (total station)
Kind	Recording
Basic description	Determining horizontal and vertical positions of points on the earth's surface relative to one another involves conducting pole surveying combined with trigonometric levelling and based on electronic measurement of horizontal and vertical positions. Additionally, it also involves electronic distance measurement. Measurement can be based either on individual points or on groups of points, when automated measurement is concerned. Surveying can be mirrorless.
Specification	Total Station: Trimble S6, Leica TS 06
Range of use	- Determining the shape and size of structures, - Spatial surveying of selected points - Surveying architectural features displayed on wall faces
Intervention rate	Non-destructive method (possibly less invasive, adding measurement points)
Main advantages	Non-destructive Accuracy: 3-4 mm Long distance measurement
Negatives or risks	Fails to work properly in the rain; Sampling requires a grid (a group of sampling points).
References	
Available at	Construction Engineering and Architecture Department Laboratory, Lublin University of Technology
Keywords	Total station, electronic distance measurement, tacheometric surveying
Recording author	Maciej Trochonowicz, Lublin University of Technology
Images	

Source of images	Archive of Construction Engineering and Architecture Department, Lublin University of Technology

Method	Endoscopy (Borescopy, Videoscopy)
Kind	Diagnostic
Basic description	Sensorial method for examining inaccessible spaces and cavities by means of an optical endoscope or a remote controlled miniature video camera.
Specification	The simplest devices include optical endoscopes designed for direct, non-recordable observations. In this case, it is only an exploratory too and not a documentation. They can, for example, determine the state and extent of preserved decorations on old wooden ceilings covered with younger plaster ceilings. The base for most sophisticated devices is a miniature camcorder with its own light source. Simple inspection cameras on a 2-5 m long cable are sufficient for the most common surveys. These devices can have their own LCD display, which can be viewed in real-time. At the same time, the captured video can be stored in digital form for further processing or connected directly to the laptop.
Range of use	With endoscopic camera devices, inaccessible spaces of varying sizes, from small cavities, cracks and joints through narrow gaps between adjoining constructions to complex underground corridors and systems, can be explored. Surveys of larger areas that are difficult to access, such as chimney and ventilation shafts, drainage channels, crypts, etc. use more complex equipment for movement and panoramic scanning.
Intervention rate	Non-destructive or less invasive (a hole with a diameter 8 mm)
Main advantages	Simple and operative, easy to operate
Negatives or risks	Insignificant, when inspecting larger cavities the operator must protect thin cable from to get stuck in a crack or narrowed hole.
References	SHUEREMANS, Luc: Structural Assessment of Masonry in Ruinous State, In: *International Conference Series on Historic Structures*, HS 2010 (https://lirias.kuleuven.be/bitstream/123456789/277167/1/IC-LS10d-Historic+Structures-Ruins+and+fortresesses.pdf) https://uk.trotec.com/fileadmin/downloads/Optische_Inspektion/BO26/TRT-BA-BO26-TC-001-EN_2015-08-07.pdf
Available at	CET ITAM AS CR
Keywords	Borescope, boroscope, endoscope, videoscope
Recording author	Jiří Bláha, ITAM

Images





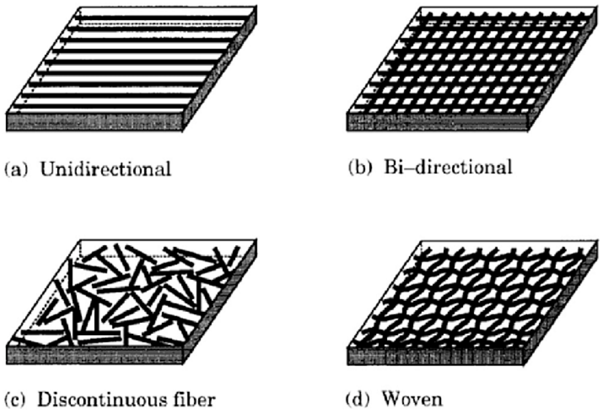
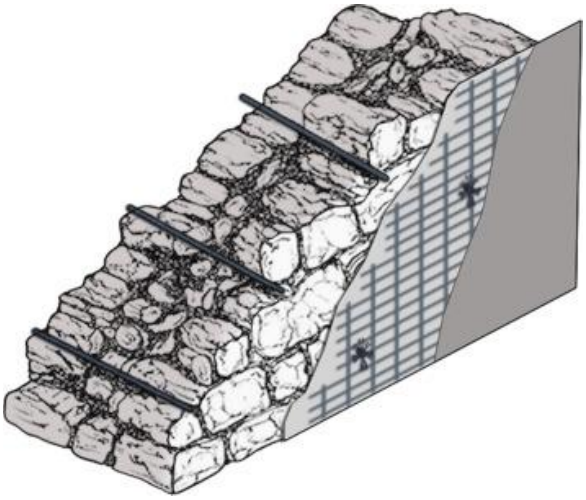
Source of images	Michal Kloiber, Jiří Bláha, ITAM

Examples of application

Site Specification	Zámek Telč (Telč Chateau)
Localization	Telč –Inner Town Nr. 1, Vysočina Region, Czech Republic
Owner and management	National Heritage Institute
Affected part	Beer cellar in former brewery
Intervention reasons	Archaeological: exploring of hidden underground spaces
Intervention extent	A hole Ø 20 mm in a mortar gap of the masonry joint
Date of intervention	2018-01-29
Time consumption	1 hour
Results	Finding a corridor leading to a stone door frame of late medieval origin
Evaluation	The complementary arguments for further decisions regarding a possible displacement of the recent separating wall have been acquired in a nondestructive way.
References	Not yet published

Images	 
Source of images	Michal Kloiber, ITAM, 2018

Method	Fiber reinforced composites
Kind	Remedial
Basic description	Composite materials based on high strength organic and inorganic fibers (made of glass, aramid or carbon, with a diameter in the range 5-25 µm) in combination with polymeric matrices (epoxy, polyester, vinyl ester, etc.).
Specification	Bonding made of FRP laminates can be applied to the surface of the masonry parallel to the directions of the maximum principal tensile stresses, thus having a role of tensile reinforcement.
Range of use	May be applied either in a reversible manner in the form of circumferential externally attached tendons in a color matching that of the external surface of the structure, or as epoxy-bonded laminates to the facades of masonry buildings which cannot be strengthened by concrete jacketing.
Intervention rate	Invasive, reversible.
Main advantages	Low weight (which is approximately 4 times less than that of steel), very high strength, and excellent chemical resistance, not corrodible, reversibility.
Negatives and risks	Purchase price which is 2-4 times higher compared with steel.
References	BANI-HANI, K. – BAKARAT, S. 2006: Analytical evaluation of repair and strengthening measures of Qasr al-Bint historical monument - Petra, Jordan. In: *Engineering Structures,* 2006. **28**(10): p. 1355-1366. BERGAMO, O. – RUSSO, G. – DONADELLO, S. 2014: Retrofitting of the Historic Castagnara Bridge in Padua, Italy, with Fibre Reinforced Plastic Elements. In: *Structural Engineering International*, 2014. 24(4): p. 532-543. COSENZA, E. – IERVOLINO, I. 2007: Case study: Seismic retrofitting of a medieval bell tower with FRP. In: *Journal of Composites for Construction*, 2007, 11(3): p. 319-327. FEO, L. – LUCIANO, R. – MISSERI, G. – ROVERO, L. 2016: Irregular stone masonries: Analysis and strengthening with glass fibre reinforced composites. In: Composuites Part B: Engineering Volume 92, 2016, pp. 84-93. MICELLI, F., et al. 2014: Mechanical behaviour of FRP-confined masonry by testing of full-scale columns. In: *Materials and Structures*, 2014. 47(12): p. 2081-2100. SCHOBER, K.U., et al. 2015: FRP reinforcement of timber structures. In: *Construction and Building Materials,* 2015. 97**:** p. 106-118. SIVARAJA, S.S., et al. 2013: Preservation of Historical Monumental Structures using Fibre Reinforced Polymer (FRP) - Case Studies. *2nd International Conference on Rehabilitation and Maintenance in Civil Engineering* (Icrmce), 2013. 54: p. 472-479.
Available at	Wide offer of various materials on the market
Keywords	FRP, reinforcement, retrofitting, strenghtening
Recording author	Wei Zhang, CET ITAM

Images	 Various types of fiberreinforced composite lamina  
Source of images	TAWFIK, Bassem – LEHETA, Heba – ELHEWY, Ahmed – ELSAYED, Tarek 2016: Weight reduction and strengthening of marine hatch covers by using composite materials. In: *International Journal of Naval Architecture and Ocean Engineering* 9(2), 2016. https://schnellcontractors.com FEO, L. – LUCIANO, R. – MISSERI, G. – ROVERO, L. 2016: Irregular stone masonries: Analysis and strengthening with glass fibre reinforced composites. In: Composites Part B: Engineering Volume 92, 2016, pp. 84-93.

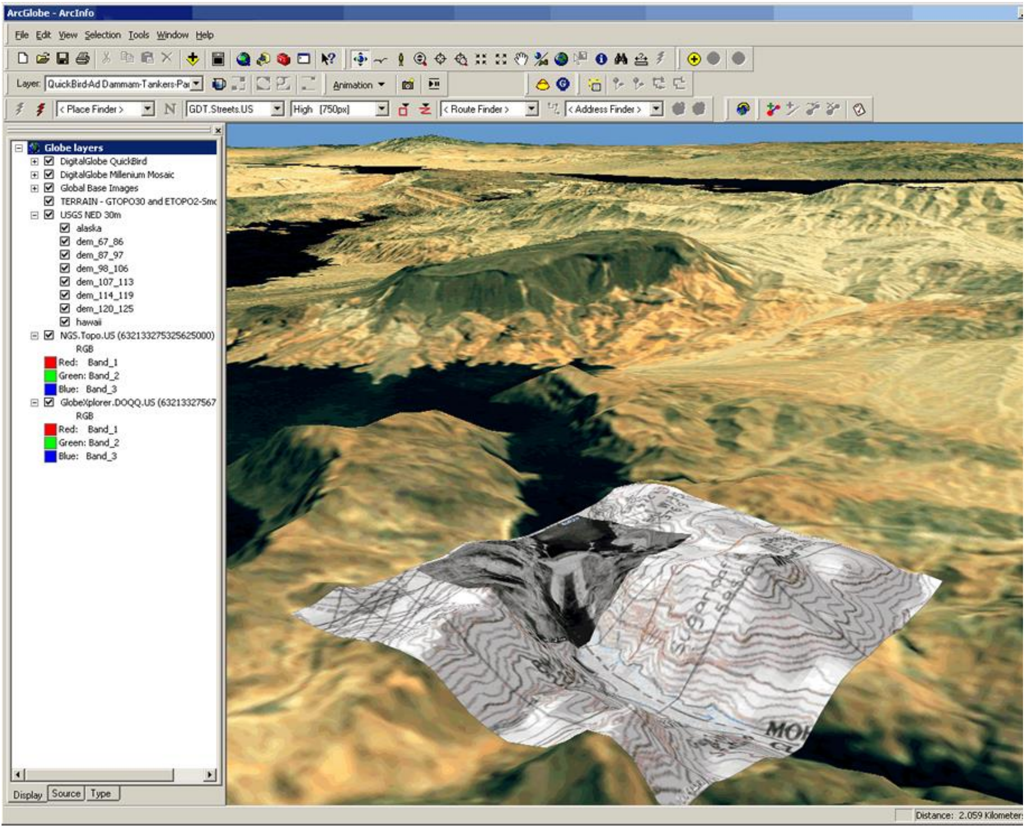
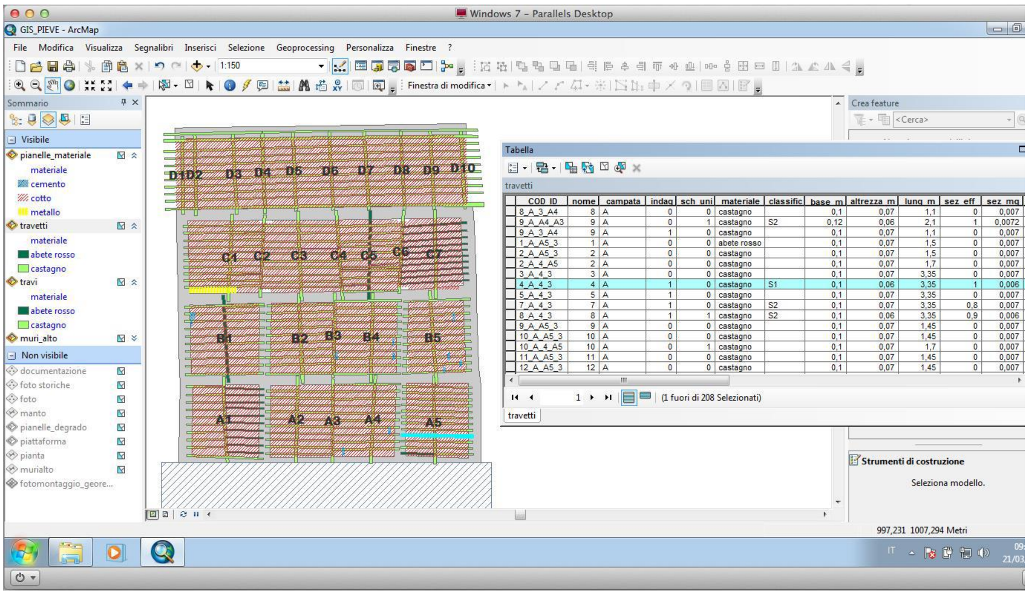
Method	**Fourier-transform infrared spectroscopy and micro-FTIR spectroscopy**
Kind	Diagnostic
Basic description	***A technique used to obtain an infrared spectrum of a solid, liquid or gas. The*** FTIR offers quantitative and qualitative analysis for organic and inorganic samples. The micro-FTIR is more recent technique that improved the potential in the field of diagnostic and conservation of art works.
More specification	***When IR radiation is passed through a sample, some radiation is absorbed by the sample and some passes through (is transmitted). The resulting signal at the detector is a spectrum representing a molecular 'fingerprint' of the sample. The different chemical structures (molecules) produce different spectral fingerprints.***
Range of use	The FTIR is usually used for characterization of composition (e.g. of geological samples, such as coal, shale, fluid and melt inclusions, silicate glass, minerals, and microfossils) and degradation of the different specimens, to establish the structural relationship between degradation phases and the substratum, to evaluate the effect of cleaning treatments performed by conservators, to **identification of compounds and contaminants** inside the sample. Micro-FTIR is used for samples that are too small to be chemically analysed by conventional FTIR techniques. This technique can collect IR signals at high spatial resolution, and has great potential for the characterization of compositionally complex samples. ***In the last few years, the use of the portable FTIR for non-invasive identification of pigments and organic binders in wall paintings and in contemporary artworks, significantly increased.***
Intervention rate	Sampling is required.
Main advantages	The reliability of the measurements even with an extremely small amount of sampled material is very high. FTIR can be particularly used for identification of organic compounds. It is possible to analyse micro-samples, and performing in situ investigations.
Negatives or risks	Specificity and interpretability of FTIR spectra may be limited due to overlapping bands, and detection limits depend largely on the compounds studied.
Available at	CET ITAM AS CR Construction engineering Laboratory in Lublin University of Technology
References	STUART, B. 2004: *Infrared spectroscopy: Fundamental and applications*. Google Scholar 2004.
Keywords	FTIR, Fourier-transform, Infrared, spectroscopy, μ- FTIR
Recording author	Dita Machová, CET, Petra Mácová, CET

Images	 
Source of images	Petra Mácová, CET ITAM Archive of Construction Engineering and Architecture Department, Lublin University of Technology

Examples of application

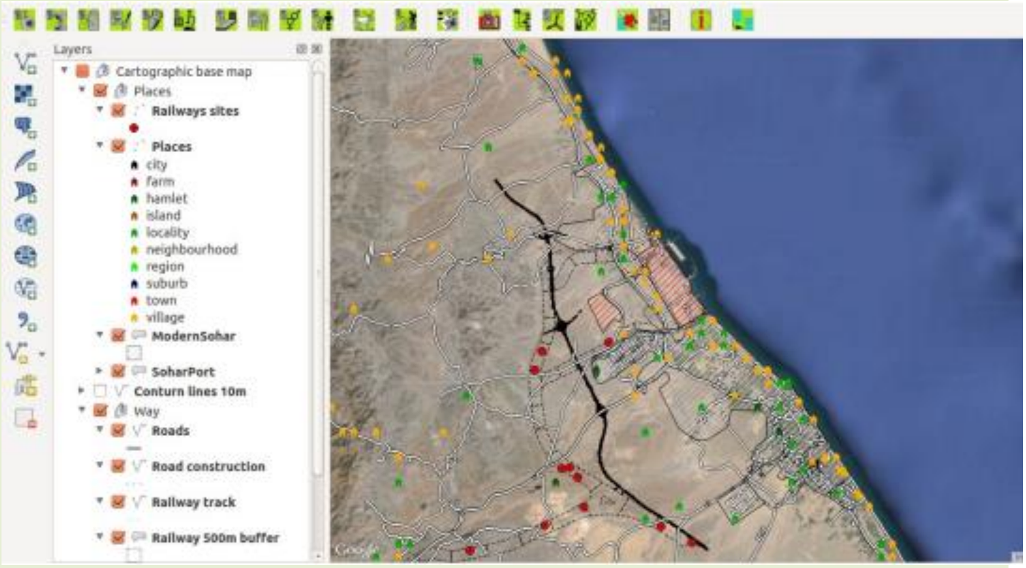
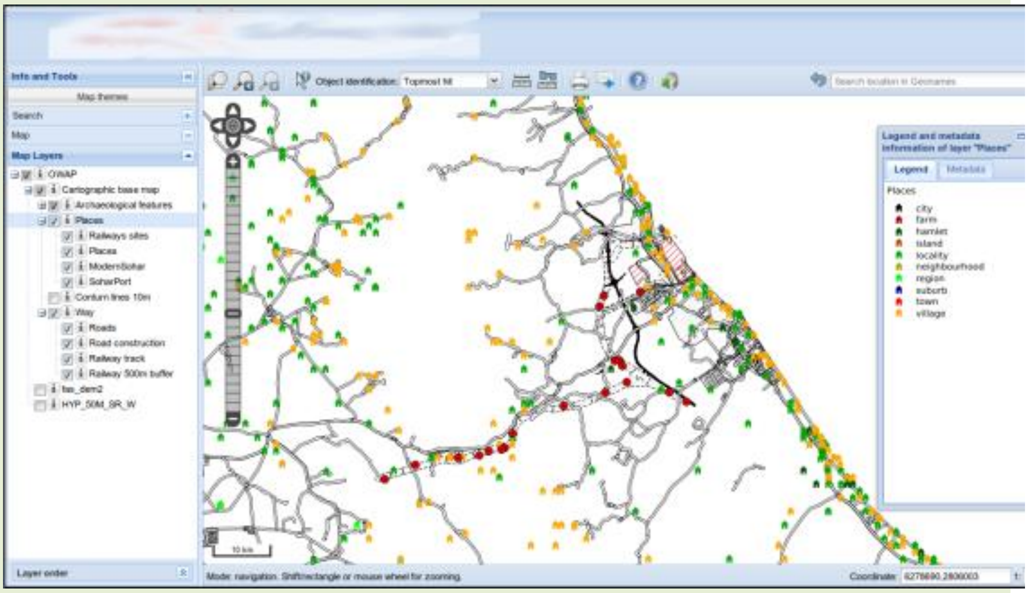
The diagnostic analysis of the degradation process of the monument stone was studied. The qualitative distribution maps of degradation products, obtained by means of micro-FTIR revealed that the degradation process is present deep inside the stones also if it is not visible macroscopically.	La Russa, Mauro Francesco, et al. 2009: The use of FTIR and micro-FTIR spectroscopy: an example of application to cultural heritage. *International Journal of Spectroscopy* 2009.
Deteriorated wall paintings which were applied at ceiling and walls of halls and rooms were examined by Fourier Transform Infrared Spectroscopy (FTIR) analysis to determine the origins of archaeological raw materials.	**Bader, Nabil A. – Waeel, B. Rashedy 2014: Analyticsl study of paint layer in mural painting of Krabia school (19 th c.), Cairo, Egypt. *Mediterranean Archaeology & Archaeometry* 14.2 (2014).**
FTIR was used to determine the inorganic and organic compounds present in encrustation covering the marble.	**Maravelaki-Kalaitzaki, P. 2004: Characterization of weathering crusts from monuments in Athens, Greece. *Air pollution and cultural heritage*, Balkema, Londres (2004): 71-78.**
The presence of both organic and inorganic compounds in the brick and mortars samples was determined by means of a FTIR spectroscope.	**Pineda, P.– M. D. Robador,M.D. – Perez-Rodriguez, J.L. 2013: Characterization and repair measures of the medieval building materials of a Hispanic–Islamic construction. *Construction and Building Materials* 41 (2013): 612-633.**

Method	Geographic Information System
Kind	Visualisation
Basic description	A geographic information system (GIS) is a system designed to capture, store, manipulate, analyze, manage, and present spatial or geographic data. Remote Sensing techniques supply various kinds of data (physical, environmental, cartographic, anthropic, etc.) related to the archaeological site; then these data are organized by GIS into thematic layers to be visualized, processed and analyzed.
Specification	A characteristic, common to all GIS software, is the capacity of managing multi-layer and multi-scale georefenced geographic data: this potential makes GIS applications ideal for managing archaeological data. Given the nature of most archaeological data, GIS technology is probably the most flexible and complete system for analyzing the spatial context of historical and pre-historical data.
Range of use	Data visualization, creation of large-scale databases for organising, analysing and sharing the products of their field research. The use of GIS in the management of information related to the restoration project is functional to the realization of a dynamic archive, able to fully identify the various pathologies and to evaluate the possible variations over time, allowing to identify any worsening in the matter constituting the architectural palimpsest.
Intervention rate	Non-destructive
Main advantages	Articulated mapping and easily updated over time
Negatives or risks	Insignificant
References	SCIANNA, A. – VILLA, B. 2011: GIS applications in archaeology. In: *Archeologia e Calcolatori* XXII/2011. Pp. 337-363.
Available at	http://www.archcalc.cnr.it/indice/PDF22/AC_22_Scianna_Villa.pdf
Keywords	GIS, archaeology
Recording author	Silvia Soldano, SITI

Images	 
Source of images	https://it.pinterest.com/pin/212795151120241152/ https://www.researchgate.net/publication/266397350_Il_contributo_del_GIS_nel_progetto_di_restauro_La_copertura_della_Pieve_di_Novi?enrichId=rgreq-53bbf43b91aa3d75034a449390609690-XXX&enrichSource=Y292ZXJQYWdlOzI2NjM5NzM1MDtBUzoxNDkxNzk1Nzc5MzM4MjRAMTQxMjU3ODU5MTQ2MQ%3D%3D&el=1_x_3&_esc=publicationCoverPdf

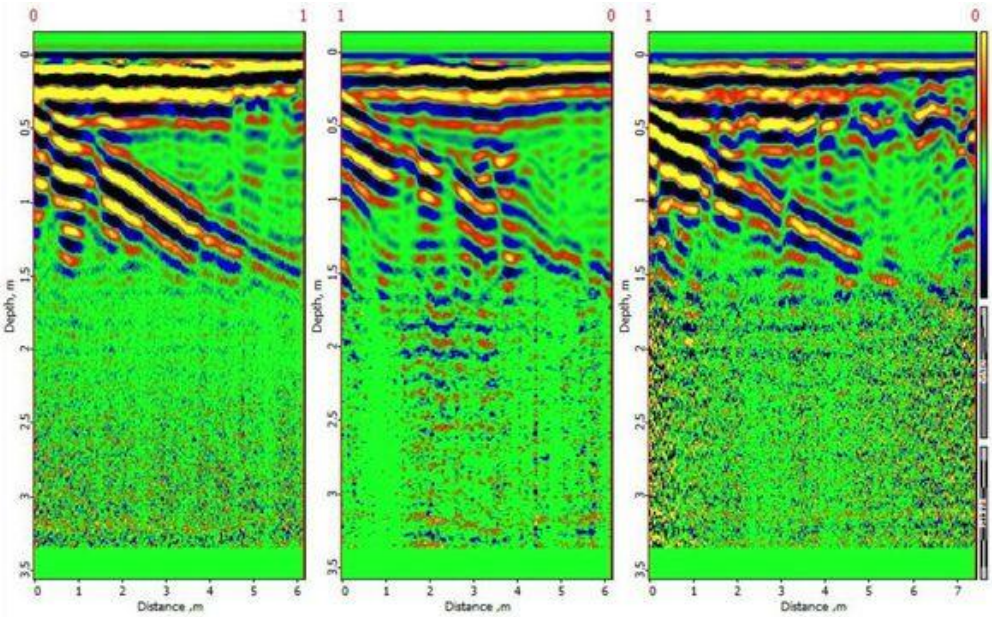
Examples of application

Site Specification	The cave of Fumane, Verona
Localization	Fumane, Verona District, Veneto Region, Italy
Owner and management	University of Fumane
Affected part	In this archaeological site laid problems of an archival nature, stratigraphic and of representation for the continuation of research.
Intervention reasons	Development and implementation of a management and analytical system through open source of archaeological database tools.
Intervention extent	The data thus organized, classified and themed consent fast management of the archaeological data, spatial analysis of the materials and an increase of the information.
Date of intervention	2010-15
Time consumption	Unknown
Results	The IT research line is aimed at managing and communicating archaeological data.
Evaluation	The WebGIS module is a management tool that will allow, at 4 protected levels of access (by login): • the cartographic and thematic visualization of the territory • the location and census of archaeological sites (extra site) • the location with the relative features of each individual site excavated and in progress of excavation (intra site) with relative progress of the state of the works • search and query of features • pdf printing in various scales with personalized templates • data download in shape file format • sending reports of areas at archaeological risk
References	COCCA Enzo, PERESANI Marco 2015: Il GIS nell'ambito di sistemi innovativi per la gestione del dato archeologico. Sviluppo e implementazione di un sistema gestionale e analitico con strumenti open source di banche dati archeologiche. *Caso studio Grotta di Fumane*; Anni 2010-15; Università degli Studi di Ferrara

Images	 
Source of images	http://eprints.unife.it/1014/1/tesi%20Cocca.pdf

Method	Ground-penetrating radar (GPR)
Kind	Diagnostic
Basic description	Geophysical method that uses high-frequency radar pulses to image the subsurface (10-1000 MHz). A GPR transmitter emits electromagnetic energy into the ground. When the energy encounters a buried object or a boundary between materials having different permittivity, it may be reflected or refracted or scattered back to the surface. A receiving antenna can then record the variations in the return signal. These variations can be observed on a screen and recorded in form of time diagram, i.e. linear (vertical) profile showing how parameters of the studied structure change. Amplitude of the reflected electromagnetic pulse is proportional to the magnitude of the reflection coefficient at the boundary of two different environments. It increases proportionally to the increase in the contrast of the dielectric constant on both sides of the reflecting border.
Specification	Zond-12e two ground-penetrating georadar sets with antennas of the range 100 MHz (range in favourable conditions, 30–50m) to 1 GHz (thin layers, e.g. plaster, coating). Use of a specific antenna is determined by a sounding task. Higher sounding frequency means better resolution, but with more significant electromagnetic wave attenuation in the environment, resulting in lower sounding depth; and vice versa - lower frequency may lead to a larger penetration depth at the sacrifice of poorer resolution. Moreover, lower frequency produces larger initial insensitivity area ("blind" zone) of a georadar. Portable digital subsurface sounding radar device carried by a single operator. Data transmission: through Wi-Fi or Ethernet to PC.
Range of use	- determining the depth and the outline of lithologic borders - determining the structure of the soil (layer thickness, cracks) - determining location of cracks and cavities in the soil and rocks - determining location of subsoil, sewers, aquifers, leaks and moist places - surveying underground and building utility lines - detecting forgotten underground rooms, corridors, crypts - detecting engineering structures, i.e. foundations, walls, etc. - monitoring internal composition of engineering structures - looking for layer cracks and location of archaeological structures
Intervention rate	Non-destructive method
Main advantages	Fast and accurate method allowing for locating, identifying and measuring subsurface structures.
Negatives or risks	Depending on antennas being used, sounding depth of the electromagnetic wave may be limited. Limited usefulness in water environment, areas of high salinity, and moist sedimentary rocks, e.g. loam, clay.
References	
Available at	Construction engineering Laboratory in Lublin University of Technology
Keywords	Ground-penetrating radar (GPR), geophysical method
Recording author	Lucjan Gazda, Lublin University of Technology

Images



Tunnel sounding (along). Zond-12e GPR - antenna 500 MHz.

Source of images

https://geo-matching.com
http://www.bjdihou.com

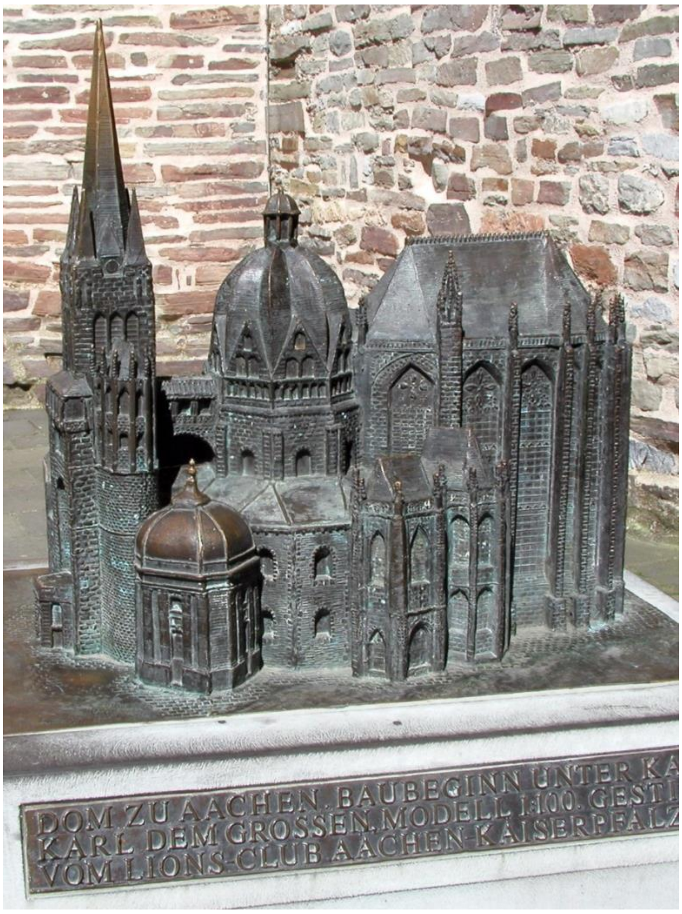
Method	Hidden roofs
Kind	Remedial
Basic description	Flat or low pitched roofs which are situated lower than the wall top level is. They may also have a form of roof terrace or green roofs.
Specification	Structural composition and type may vary. A reinforced concrete is usually preferred as main constructive material.
Range of use	Where it is not desirable to let the rainwater penetrate into the interior of a former building. Inside intentional ruins in romantic gardens and parks.
Intervention rate	Invasive because such a roof must be firmly connected to walls.
Main advantages	The appearance of the building remains as it is. Interior structures (ceilings, vaults, paintings) are sufficiently protected. Hidden roofs can also stabilize leaning or deformed walls.
Negatives or risks	The drainage of water from precipitations must be reliable; also in case of torrential rain. Ducts and filter grids need regular inspections and an adequate maintenance.
References	SCHUBERT, Alfréd 1998: Opravy hradů, městských hradeb a jiných neúplně dochovaných staveb. Požadavky památkové péče a jejich řešení. Instadsetzungen von Burgen, Stadtmauern und andren unvollständig erhaltenen Bauwerken. Anforderungen der Denkmalpflege und ihre technische Ausführung. In: *Zříceniny historických staveb a jejich památková ochrana*. Příloha časopisu ZPP 58, 47-57.
Available at	Individual design
Keywords	Parapet roofs, green roofs, terraces
Recording author	Jiří Bláha, ITAM
Images	 Parapet roof on listed building: Old College, Aberystwyth University, Wales
Source of images	http://www.rmpolymers.co.uk

Examples of application

Site Specification	Hrad Landštejn (Landstejn Castle Towers)
Localization	Landštejn Nr. 2, Jindřichův Hradec District, South Bohemia Region, Czech Republic
Owner and management	Národní památkový ústav (National Heritage Institute)
Affected part	Top part of the main tower (donjon) and northern tower
Intervention reasons	Stabilisation of stone masonry and making the top of the main tower accessible to visitors of the castle.
Intervention extent	Wall tops were built up to the highest preserved level and aligned to the horizontal level.
Date of intervention	1990
Time consumption	Not known
Results	The higher (southern) tower top serves as a lookout terrace. The northern tower has a green roof hidden behind the parapet wall.
Evaluation	As the roofs of the main part of the castle were not reconstructed, the castle still looks like a ruin from distant views. In comparison with the older state of the castle, the current wall tops walls look unnatural – too straight.
References	
	

Images	 
Source of images	Profimedia.CZ a.s. / Alamy Stock Photo

Method	Information panels / Interpretation boards
Kind	Modern facilities
Basic description	Information panels create a group of small size permanent installations designed for an economical and attractive way of displaying information for visitors.
Specification	Information panels primarily offer a more complete picture of the site, its history, or local attractions. The technical solution can take various forms like: • Stand-alone boards from different materials • Tables on the wall made from different materials • Posters made of synthetic fabrics • Paving tiles with texts, maps or pictures • Stand-alone posts/totems; combination with audio guide is possible • Visualization or way finder models with texts • Haptic scale models for blind people Information Panels can be combined with other forms of heritage interpretations (webpages, smart devices applications, leaflets, etc.)
Range of use	Usable for the most of immovable historical objects including ruins and archaeological sites.
Intervention rate	Depending on locality and specific technical solution, but mostly none or minimal (concrete base blocks of posts, fastening screws or anchors when placed on the walls).
Main advantages	Simple and mostly relatively inexpensive in situ publication of basic information about the object. Maps and visualizations of original state can be easily compared with actual state of the ruin.
Negatives or risks	Regular maintenance is needful. It could be endangered by vandalism, especially in outlying localities. Inappropriate technical solutions, designs, or locations may disrupt genius loci of a site or spoil photographs wished by visitors. Transparent material for boards minimizes visual impact but such panels are harder to read.
References	*The ICOMOS Charter for the Interpretation and Presentation of Cultural Heritage Sites*, 2008 http://icip.icomos.org/downloads/ICOMOS_Interpretation_Charter_ENG_04_10_08.pdf *Interpretation Handbook and Standard: Distilling the essence*. Wellington: Department of Conservation, 2005. ISBN 0-478-22572-5. *Irish Walled Towns Network: Bored of boards! Ideas for interpreting heritage sites.* The Heritage Council, 2016 https://www.heritagecouncil.ie/content/files/bored_of_boards_1mb.pdf
Available at	Wide offer on the market, usually custom production
Keywords	Heritage interpretation, information panel, interpretation board
Recording author	Jakub Novotný, ITAM

Images	 Transparent information board on the wall of the St. James Church in Jihlava (CZ)  Haptic model of the cathedral in Aachen (Germany)
Source of images	Jakub Novotný, Jiří Bláha, ITAM

Examples of application

Site Specification	Jihlava Town Fortification
Localization	Jihlava, Vysočina Region, Czech Republic
Owner and management	City of Jihlava
Affected part	A touristically accessible circuit to the remnants of the mediaeval town fortifications.
Intervention reasons	Heritage interpretation intended for visitors to the city; basic information on the history of town fortification.
Intervention extent	9 panels with 4 masonry screws on each panel.
Date of intervention	2013
Time consumption	Not known
Results	Information system enables tourists to follow a trail on the history of the town fortifications.
Evaluation	Interpretation panels designed in sober colours provide information in Czech, English and German languages.
References	https://www.jihlava.cz/en/vismo/o_utvar.asp?id_org=100405&id_u=1049&p1=2679 http://jihlava.maps.arcgis.com/apps/MapSeries/index.html?appid=996898a939ae40309f4d1bc1e20e1db7 The trail guidebook in Czech on: https://issuu.com/jihlava/docs/pevnost-cz

Images	 

Source of images

Jakub Novotný, ITAM

Method/Technology/Material	**Ion chromatography or ion-exchange chromatography (IC/IEC)**
Kind	Diagnostic
Basic description	**The method is used for water chemistry analysis, especially for salt concentration (t**he knowledge of salts concentration in masonry is crucial for selection of the most suitable way of the damaged construction renovation).
More specification	**The IC measures concentrations of ionic species by separating them based on their interaction with a resin. Ionic species separate differently depending on species type and size. Sample solutions pass through a pressurized chromatographic column where ions are absorbed by column constituents. As an ion extraction liquid, known as eluent, runs through the column, the absorbed ions begin separating from the column. The retention time of different species determines the ionic concentrations in the sample.**
Range of use	**Porous building materials, such as stone, brick and mortar are prone to** the **ingress of moisture and damage from salt crystallization. The IC is used to identify the water soluble salts as cations and anions** from a wide range of solid samples, such as bricks, mortars, cements.
Intervention rate	Sampling is required but volume of sample is small.
Main advantages	It can be used for the analysis of cations and anions. Ion chromatography provides accurate quantitative analyses. It offers short time of analysis, simple pre-treatment.
Negatives and risks	**Only ion concentrations can be determined, and complete salt-phases are determined by deduction, which is only possible for simple systems.**
References	Weiss, Joachim 2016: *Handbook of Ion Chromatography, 3 Volume Set*. Vol. 2. John Wiley & Sons, 2016.
Keywords	Ion chromatography, IC, Ion exchange chromatography, IEC
Recording author	Dita Machová, CET
Images	

	
Source of images	Dita Machová, CET

Examples of application

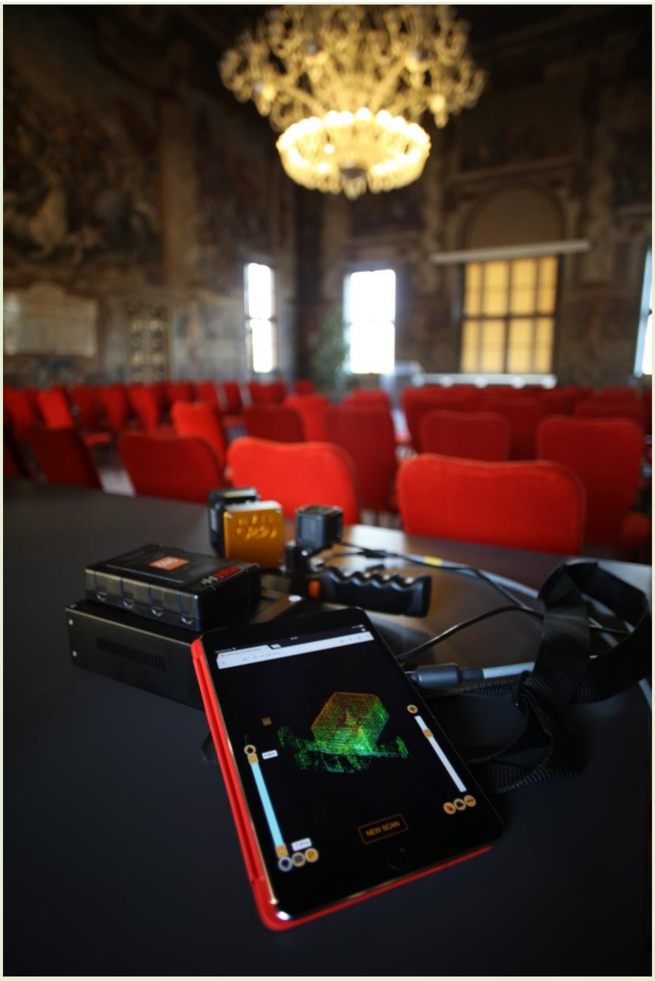
The nature of salt content in stone material was identified by ion chromatography technique, the ion content was determined qualitative and quantitatively. Chromatography is also reliable to assess the efficacy of salts removal methods in cultural heritage.	Alvarez de Buergo, M. – Lopez-Arce, P. – Fort, R. 2012: Ion chromatography to detect salts in stone structures and to assess salt removal methods. *EGU General Assembly Conference Abstracts*. Vol. 14. 2012
Ion Chromatography was used to identify the soluble salts present in the samples (from historic building) as cations and anions.	**Lopez-Arce, P., et al. 2009: Treatment of rising damp and salt decay: the historic masonry buildings of Adelaide, South Australia. *Materials and structures* 42.6 (2009): 827-848.**

Method	Laser scanning
Kind	Recording
Basic description	A range based surveying technique that measures the distance from a target by illuminating the target with pulsed laser light and measuring the reflected pulses with a sensor technology.
Specification	The laser scanners are tools that can measure at very high speed the position of hundreds of thousands of points, which define the surface of the surrounding objects. What we get from this relief is a very dense set of points that is called a *point cloud*. Basically there are 3 measurement principles with laser scanners, TOF (Time Of Flight) laser scanners, phase difference laser scanners and triangulation laser scanners. The combination of multiple laser scans allows to obtain a more precise result and to create a complete three-dimensional model that describes the geometry of the embankment with a high degree of accuracy. This active optical system can be used without any light.
Range of use	3D scanning is used in archeology but also for mobile mapping, surveying, scanning of buildings and building interiors. In addition to surveying and cataloging, the laser survey of an archaeological site allows the creation of a navigable three-dimensional model useful for creating a virtual excavation museum that can be consulted online by users. The high precision of the relief also allows the faithful reproduction of objects through the use of numerical control machines.
Intervention rate	Non-destructive
Main advantages	Allow to examine both natural and manmade environments with accuracy, precision, and flexibility. Laser scanner technology represents the most precise methodology to date for the cataloging of valuable archaeological assets, allowing the planning of the recording, analysis and archiving of data in a totally innovative way and proposing three-dimensional georeferenced digital surveys that can be connected to specific databases in in order to create easily questionable GIS.
Negatives or risks	Insignificant
References	MOUSSA W., ABDEL-WAHAB, M. & FRITSCH D., (2012): An automatic procedure for combining digital images and laser scanner data. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*. Melbourne, Australia, XXXIX-B5, 229–234. https://www.int-arch-photogramm-remote-sens-spatial-inf-sci.net/XXXIX-B5/229/2012/isprsarchives-XXXIX-B5-229-2012.pdf
Available at	Geomatic Laboratory for the Cultural Heritage of Politecnico of Turin
Keywords	Laser scanner, active optical system, LIDAR
Recording author	Patrizia Borlizzi, SITI

Images	 
Source of images	http://www.3dtarget.it/eu/it/laser-scanner/prodotti-laser-scanner/terrestri/demo-usati/faro-focus-3d-ms120-detail.html http://www.microgeo.it/it/prodotti-e-soluzioni/20151-laser-scanner.aspx

Examples of application

Site Specification	Pescara del Tronto, (Italian earthquake 2016)
Localization	Ascoli Piceno, Marche, Italy
Owner and management	TASK Force and DIRECT (Disaster Recovery Team) of Politecnico di Torino
Affected part	Whole village
Intervention reasons	Survey and recording of the damage and testing integrate techniques throw photogrammetry and Handheld Laser scanner (ZEB-REVO RT By GEOSLAM).
Intervention extent	3 different blocks with different complexity.
Date of intervention	2016-10-25
Time consumption	Acquisition: 10-15 min; Elaboration: 30 min for each one acquisition.
Results	The point cloud is quite dense and the acquisition of the result is faster than traditional techniques can offer.
Evaluation	Allow to build a point cloud in real time through the tablet supplied with the handheld scanner.
References	CHIABRANDO, Filiberto, SAMMARTANO, Giulia, SPANO' Antoni: *A comparison among different optimization levels in 3D in multi-sensor models. A test case in emergency context*: 2016 Italian Earthquake.

Images	 
Source of images	Geomatic Laboratory for the Cultural Heritage of Politecnico of Turin

Method/Technology/ Material	**Lead capping**
Kind	Remedial
Basic description	The metal sheets can protect wall tops or other horizontal surfaces where soft capping is not suitable (Měřínský – Plaček – Vlach 2009, 25).
More specification	Possible to use on tops of high and thin walls, where soft capping is not suitable. Lead metal plates are anchored by copper bands. It is necessary to choose appropriate thickness of metal plates and way of its anchoring. (Měřínský – Plaček – Vlach 2009, 25; Vinař 2011, 58-59). For capping also titan – zinc plates are possible to use, copper parts should be omitted where causing colouring of walls with green blurs (Schubert 1998, 54).
Range of use	For high and thin walls (Měřínský – Plaček – Vlach 2009, 25). Use of copper is not recommended.
Intervention rate	Minor, just the top layer of masonry is affected.
Main advantages	Effective protection of walls, minimal maintenance demands, neutral colour shade.
Negatives and risks	Necessary to choose proper material resistant to windstorms for not to endanger visitors of the site. Sometimes unnatural when viewed from above.
References	VINAŘ, Jan 2011: Hrad Rokštejn. Oprava a konzervace v letech 2002 až 2010. Die Burg Rokštejn. Ihre Restaurierung und Konservierung in den Jahren 2002 bis 2010. *Archaelogia historica* 36/2011/1, 51-60. MĚŘÍNSKÝ, Zdeněk – PLAČEK, Miroslav – VLACH, Roman 2009: Hrad Rokštejn. *Zpravodaj Stop*. Časopis společnosti pro technologie ochrany památek 11/2009/4, 17-29.
Keywords	Pigments, expression of ruin, colors, mortar
Recording author	Stanislav Vohryzek, ITAM

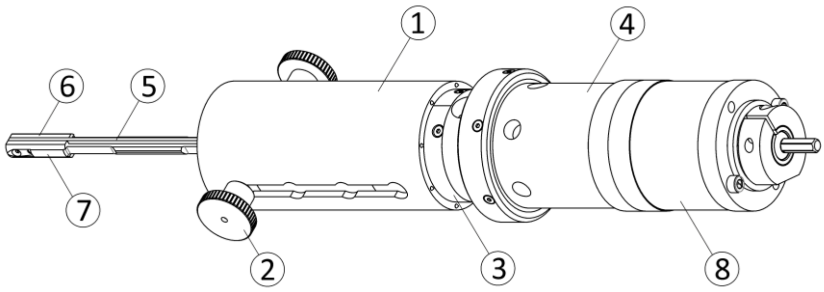
Example of application

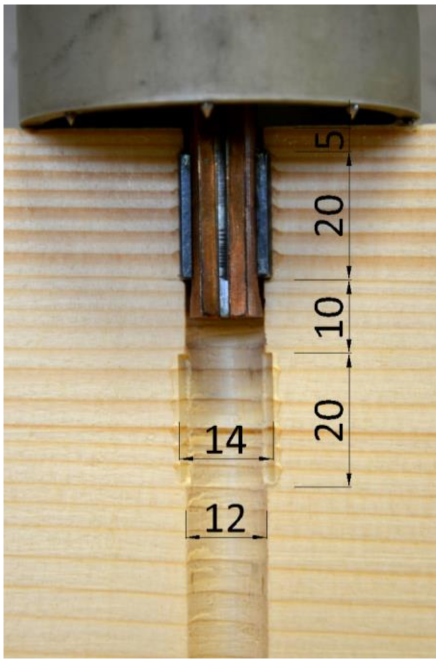
Site Specification	Hrad Rokštejn (Rokštejn Castle)
Localization	Brtnice, cadastral Přímělkov, Vysočina Region, Czech Republic
Owner and management	Town Brtnice
Affected part	Partially ruined palaces of lower (first picture) and upper castle (second picture).
Intervention reasons	Wall top protection from weather effects (rain and snow).
Intervention extent	High situated and with difficultyaccessible parts of walls, protection of plasters of the upper castle (second picture)
Date of intervention	Between 2002-2008 (see photos), later repaired
Time consumption	Not known
Results	On lower palace a part of lead cap has been damaged in strong windstorm (first picture), later repaired.
Evaluation	Satisfactory
References	VINAŘ, Jan 2011: Hrad Rokštejn. Oprava a konzervace v letech 2002 až 2010. Die Burg Rokštejn. Ihre Restaurierung und Konservierung in den Jahren 2002 bis 2010. *Archaelogia historica* 36/2011/1, 51-60. MĚŘÍNSKÝ, Zdeněk – PLAČEK, Miroslav – VLACH, Roman 2009: Hrad Rokštejn. *Zpravodaj Stop*. Časopis společnosti pro technologie ochrany památek 11/2009/4, 17-29.
Images	

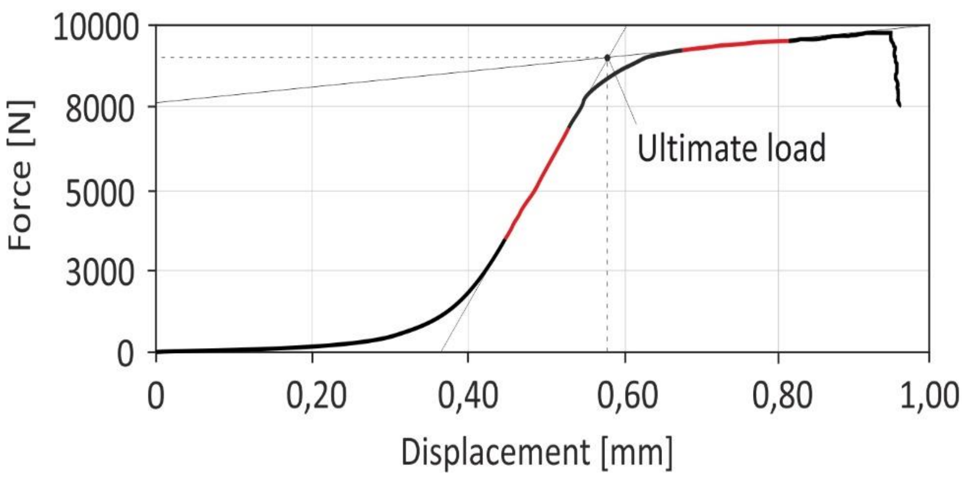
Source of images	Stanislav Vohryzek, NPÚ, 2008

Method	Loading jack for compression strength measuring
Kind	Diagnostic
Basic description	A portable device to measure mechanical properties of wood using small size jack inserted in a pre-drilled hole and designed to determine the current mechanical properties: strength and modulus of deformability in compression parallel to the grain. In the test, the dependence of the force on deformation is measured while symmetrically arranged jaws are being pushed apart in a radial borehole with a 12 mm diameter (Drdácký and Kloiber, 2013)
Specification	The device has been developed by ITAM AS CR for the specific needs of field surveys. During the measurement, the force is scanned and recorded. It is calibrated to the real force of the jaws pushing apart and simultaneously related to the measured distance of jaw displacement. The correlations between the compression strength parallel to the grain and the strength of standard specimens is determined in compliance with EN 408 range in the interval $R2 = 0.7–0.9$ based on the wood species. The relations were described by usable linear regression models (Kloiber et al., 2015). The modulus of elasticity cannot be calculated directly from the diagram; the modulus of deformability was established using the angle of the curve fit through the linear part of the force record and deformation. Commonly, the measurement is performed at four different depths below the surface. The holes into the material to be tested are carefully drilled at selected places to enable further assessment of the timber condition, e.g. the timber quality based on the obtained core, sawdust, as well as video inspection.
Range of use	Developed for the purpose of on-site inspections. Designed only for soft wood species commonly used in timber constructions (roofs, ceilings, log walls), namely spruce, fir, pine and larch. Requires 150 × 150 mm free area for drill.
Intervention rate	Semi-destructive (less invasive)
Main advantages	Thanks to wireless connection with a laptop gives results immediately. The holes can be used for future measurements.
Negatives or risks	In the case of decorated ceiling beams, the holes must be sealed after the testing.
References	DRDÁCKÝ, Miloš – KLOIBER, Michal 2013: In-situ compression stress-deformation measurements along the timber depth profile. In *Structural Health Assessment of Timber Structures,* Book Series: Advanced Materials Research 778, 2013, 209-216. Trans Tech Publications, Switzerland. KLOIBER, Michal – DRDÁCKÝ, Miloš – TIPPNER, Jan – HRIVNÁK, Jaroslav 2015: Conventional compressive strength parallel to the grain and mechanical resistance of wood against pin penetration and microdrilling established by in-situ semidestructive devices. In: *Materials and Structures,* 48(10): 3217–3229,
Available at	ITAM AS CR
Keywords	defectoscopy, material testing, soft wood
Recording author	Jiří Bláha, CET

Images







Source of images	Michal Kloiber, ITAM

Examples of application

Site Specification	**Stříbro, house Nr. 305**
Localization	Stříbro Nr. 16, Tachov District, Plzeň Region, Czech Republic
Owner and management	Private owner
Affected part	Timber log rooms embedded in brick wall town house.
Intervention reasons	Detailed survey of log walls built in two different time periods (1490/91 d, 1731/31 d) as known from dendrochronological dating.
Intervention extent	Semi-destructive
Date of intervention	2016-12-06
Time consumption	3 hours
Results	The mediaeval timber walls in room A can continue to perform their structural function. The deformed walls on the northern and eastern side of the room B (Baroque) would require such a heavy repair, coupled with the significant amount of replacement of the original material that a complete exchange would appear to be a more appropriate solution.
Evaluation	The on-site application of loading jack helped to determine actual bearing capacity of the preserved log walls. It has been acquired in a less-invasive way.
References	BLÁHA, Jiří – KLOIBER, Michal – HRIVNÁK, Jaroslav 2016: *Stavebně-technický průzkum roubených stěn domu čp. 305 ve Stříbře* (okr. Tachov). Research report. CET Telč 2016 KAREL, Tomáš – KRATOCHVÍLOVÁ, Alžběta 2017: Nález roubené konstrukce pozdně gotického domu ve Stříbře (Ruská, čp. 305). In: *Průzkumy památek II/2017*, 69-78.
Images	

Source of images	Jaroslav Hrivnák, ITAM, 2016

Method	Local replacement of masonry
Kind	Remedial
Basic description	Conservation of current situation, consolidation, elimination of cause of decay, mainly harmful influence of atmospheric water. Using new masonry to restore the face of wall, mainly near ground level. Sometimes also a repair of overhanging walls threatened to fall down (Sokol – Durdík – Štulc 1998, 13).
More specification	In advance it is necessary to make detail survey and photographic records of the preserved state by specialist. Copies of plans should be given not only to supervisor but also to masons (Schubert 1998, 50). Unstable wall should be replaced by minor parts. The stability of stones is checked up only with hand or by tapping. Using pickaxe or hammer could cause destabilization of more stones than necessary. The unstable stones should be carefully dismantled, cleaned and reinstated in their mortar bed in their precise original position. During repair of more stone layers, stones should be removed and after cleaning of joints returned to original place in opposite sequence. It is necessary to use all material from dismantled part of wall. As it is never possible to replicate exactly an old masonry, at least all bigger stones must be placed to their original location (Žižka 2011, 19; Schubert 1998, 50-51). The new wall should keep the character of original masonry, its composition and irregularities. The joints should be filled with mortar as narrow as possible. The repaired areas should be integrated to original masonry, some distinguishing features are useful by larger replacements. The new wall faces should be anchored to core of the wall by larger stones (Žižka 2011, 19-21). Joints need to be filled with small pinnings (Schubert 198, 48). Wall overhangs are possible to conserve using underpinning with blind arches. It is possible to make supports in whole thickness of wall or only in part of it. It's necessary to choose material precisely and think out of work order (Žižka 2011, 19). The used material comes usually from destructions in hillsides, ditches, interiors. Use all material of all types and scales – not only big, but also small stones, including even fragments of stone and bricks (Žižka 2011, 28).
Range of use	To be used only where no other alternative is. Preferably to repairs of recent collapses. Filling of holes, where water can accumulate. Supporting stabilization of smaller parts of walls remained. It is not necessary to repair already lost lintels or to strengthen the wall heads with bond beam (Schubert 1998, 51).
Intervention rate	Destructive, invasive (Vinař 1998, 64)
Main advantages	Preservation of the external appearance. Elimination of shape

	deformation of walls or vaults, strengthening of masonry with a new mortar, possibility to use hidden fixing elements like non-ferrous metal strips and bars (Vinař 1998, 64).
Negatives and risks	Loss of authenticity, loss of significant traces of original handwork alteration or loss of original plasters, renders or brickwork pointing. In case of true imitation there may be difficult to distinguish authentic and repaired sections. It's necessary to familiarize masons with demanded character of masonry and to make some probes on bigger samples. Sometimes necessary to dismantle and rebuilt entirely unsatisfactory masonry different to sample (Žižka 2011, 19 and 21). Risk of mason's tendency to use stones of a same size or to make wall as unusual as possible – to lay stones on shorter side or at an angle of 45° or to fill wide joints only with mortar (Schubert 1998, 50) When using a raw material from castle is necessary to make consultations with archeologist in order not to disturb accumulations of debris characteristic for particular castle sites. It is also important to not endanger the plants which are typical for ruins (Žižka 2011, 28). During the repair of walls is necessary to preserve all evidences of older stages of buildings (joints, walled or preserved traces after window's and door's lining, holes showing position of former ceiling joists or scaffolding, consoles of parapet walks including rests of their timber supports, rests of drainages, chimneys and toilets shafts, warm air heating ducts, traces of building's development as imprints of displaced construction on walls, gables or plasters (Sokol – Durdík – Štulc 1998, 13-14; Schubert 1998, 47-48).
References	RAZÍM, Vladislav: Zříceniny hradů a městské hradby v současné praxi památkové péče, PSČ 24/2010/2, 10-17. SCHUBERT, Alfréd: Opravy hradů, městských hradeb a jiných neúplně dochovaných staveb. Požadavky památkové péče a jejich řešení. In: Zříceniny historických staveb a jejich památková ochrana. Příloha časopisu ZPP 58, 47-57. SOKOL, Jan – DURDÍK, Tomáš – ŠTULC, Josef: Ochrana, údržba a stavební úpravy zřícenin hradů, Příloha časopicu ZPP 58/1998. Praha. Vinař, Jan: Opravy a zpevňování zdiva zřícenin. In: Zříceniny historických staveb a jejich památková ochrana. Příloha časopisu ZPP 58 58-69. ŽIŽKA, Jan: K technologii a stavebním postupům při opravách torzálně dochovaných staveb, PSČ 25/2011/2, 18-36.
Keywords	Wall face, conservation, masonry
Recording author	Stanislav Vohryzek, ITAM

Examples of application

Site Specification	Hrad Lukov (Lukov Castle)
Localization	Lukov, Zlín Region, Czech Republic
Owner and management	Lukov municipality
Affected part	Castle entrance gate
Intervention reasons	Stabilization of middle of east face wall of gate
Intervention extent	Middle third of east face wall of gate
Date of intervention	1987-1989
Time consumption	Unknown
Results	Stabilization of east side of the gate
Evaluation	New masonry, low quality of masons skills, not proper material – cement mortar.
References	Kohoutek, Jiří: Hrady Brumov a Lukov – výzkum a následná rekonstrukce. AH 30/2005, 225-233. Vrla, Radim: Hrad Lukov, zpravodaj Stop. Časopis společnosti pro technologie ochrany památek 11/2009/4, 4-16.
Images	
Source of images	Stanislav Vohryzek, NPÚ, 2006

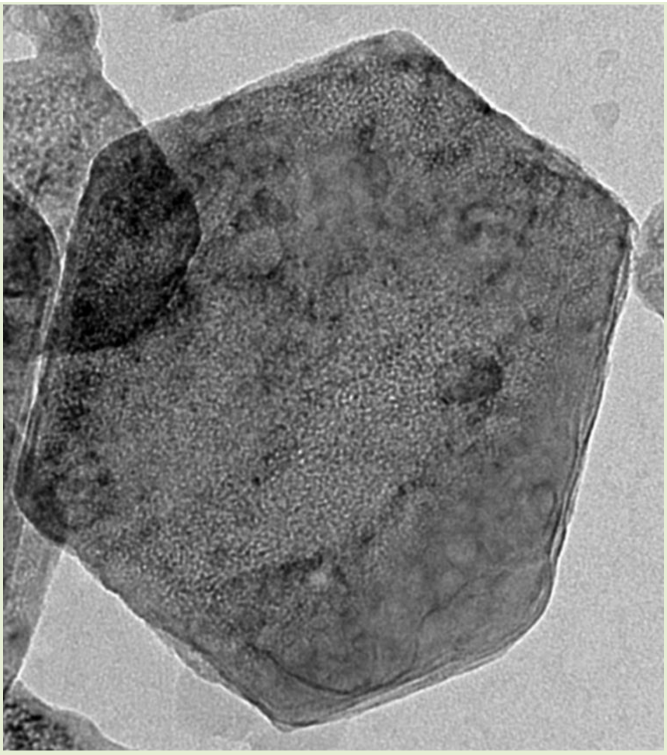
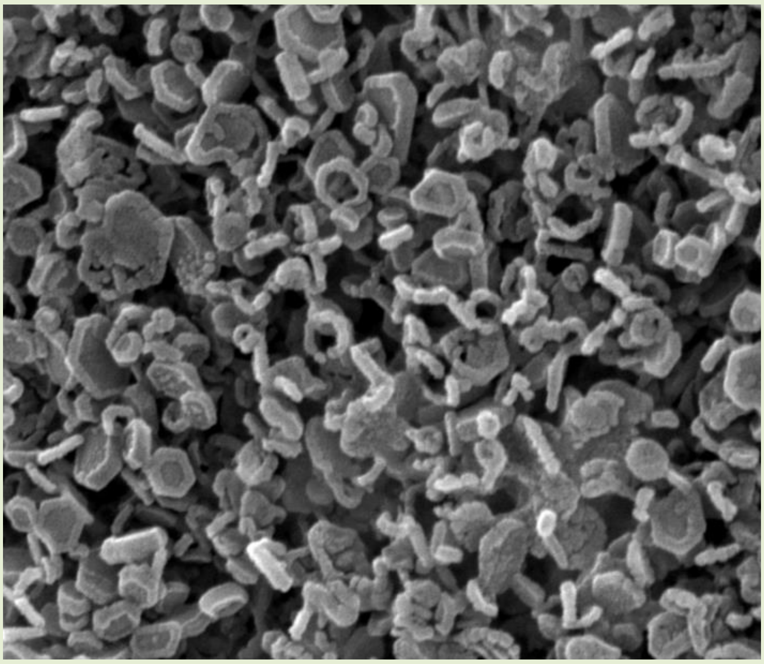
Site Specification	Hrad Lukov (Lukov Castle)
Localization	Lukov, Zlín Region, Czech Republic
Owner and management	Lukov municipality
Affected part	Western front of the West palace, right new masonry behind original masonry.
Intervention reasons	Filling of a wide vertical crack leading to risky stability of wall (Vrla 2009, 9-10).
Intervention extent	Considerable. New mixed masonry, structure of new mortar is similar to original, mortar spread across parts of the surface of the stones. The new wall face is spread is distinguish by shrinking back from original wall (Kohoutek 2005, 231; Vrla 2009, 9-10).
Date of intervention	1996
Time consumption	?
Results	Stabilization of west side of west palace.
Evaluation	Considerable change, fulfils technical demands, corresponds with character of ruin (Vrla 2009, 9-10).
References	Kohoutek, Jiří: Hrady Brumov a Lukov – výzkum a následná rekonstrukce. AH 30/2005, 225-233. Vrla, Radim: Hrad Lukov. Zpravodaj Stop. Časopis společnosti pro technologie ochrany památek 11/2009/4, 4-16.
Images	
Source of images	Stanislav Vohryzek, NPÚ, 2006

Site Specification	Hrad Lukov (Lukov Castle)
Localization	Lukov, Zlín Region, Czech Republic
Owner and management	Lukov municipality
Affected part	The parapet part of inner face wall of northeast wall of castle corner.
Intervention reasons	Reconstruction of loopholes (Vrla 2009, 9-10).
Intervention extent	Reconstruction of loopholes. New wooden lintels, restitution of missing window lining and window sills using old bricks and slightly adjusted lime mortar, spread on the wall face by trowel. (Vrla 2009, 10).
Date of intervention	2002-2003
Time consumption	Not known
Results	Stabilization of parapets.
Evaluation	Favourable, preserved expression of ruin, used raw materials can naturally aging (Vrla 2009, 10).
References	Vrla, Radim: Hrad Lukov. Zpravodaj Stop. Časopis společnosti pro technologie ochrany památek 11/2009/4, 4-16.
Images	
Source of images	Stanislav Vohryzek, NPÚ, 2006

Abbreviations:

AH	Archaeologica historica
PSČ	Památky středních Čech
ZPP	Zprávy památkové péče

Method	Nanolime treatment
Kind	Remedial
Basic description	Dispersions of colloidal $Ca(OH)_2$ nanoparticles (~ 30–300 nm in size) in alcohols often used for the consolidation of various types of cultural heritage objects.
Specification	The strengthening effect is caused by the carbonation reaction. – multistep process that may be simplified present as reaction o $Ca(OH)_2$ with carbon dioxide resulting in calcium carbonate and water. During the nanolime carbonation, amorphous calcium carbonate, monohydrocalcite, vaterite, aragonite and calcite were detected and their formation/transformation is strongly dependent on the curing conditions such as relative humidity and temperature.
Range of use	Consolidation of wall paintings and stones or conservation of paper, canvas and wood.
Intervention rate	Non-destructive
Main advantages	High surface areas, high reactivity, high concentrations, chemical compatibility with limestones, usage of non-aqueous system.
Negatives and risks	Partial back migration of nanoparticles causing white haze formation.
References	LOPEZ-ARCE, P. –GOMEZ-VILLALBA, L. S. –MARTINEZ-RAMIREZ, S. –ALVAREZ DE BUERGO, M. – FORT, R. 2011: Influence of relative humidity on the carbonation of calcium hydroxide nanoparticles and the formation of calcium carbonate polymorphs. In: *Powder Technol.* 205, 2011, pp. 263–269. BAGLIONI, P., CHELAZZI, D., GIORGI, R. 2015: *Nanotechnologies in the Conservation of Cultural Heritage*. Springer, Netherlands, 2015. RODRIGUEZ-NAVARRO, C. – ELERT, K. – ŠEVČÍK, R. 2016: Amorphous and crystalline calcium carbonate phases during carbonation of nanolimes: implications in heritage conservation. In: *CrystEngComm* 18, 2016, pp. 6594–6607.
Keywords	Nanolime, $Ca(OH)_2$, calcium carbonate.
Recording author	Radek Ševčík, CET ITAM

Images	 TEM image of Ca(OH)2 nanoparticle.  Partially carbonated Ca(OH2) nanoparticles observed under SEM.
Source of images	TEM: RODRIGUEZ-NAVARRO, Carlos – ELERT, Kerstin – ŠEVČÍK, Radek 2016: Amorphous and crystalline calcium carbonate phases during carbonation of nanolimes: implications in heritage conservation. In: *CrystEngComm* 18, 2016, pp. 6594–6607. SEM: Radek Ševčík, CET ITAM

Examples of application

Site Specification	**Leuben chateau**
Localization	Leuben, Nordsachsen District, Saxony Region, Germany
Owner and management	Noble family of Sahr-Schönberg
Affected part	Exterior plasters of the chateau
Intervention reasons	Consolidation
Intervention extent	Eastern facade, deteriorated dolomitic lime plaster and lime stucco.
Date of intervention	2012
Time consumption	Not known.
Results	Strengthening of mortar, grouting of voids, completion of plaster losses, paint layer consolidation with the usage of modified CaLoSiL (nanolime)/CaLoSiL-Mikro mixtures.
Evaluation	The modified application techniques and composition of CaLoSil nanosols have been tested and demonstrated successfully.
References	DAEHNE, A. – HERM, C. 2013: Calcium hydroxide nanosols for the consolidation of porous building materials - results from EU-STONECORE. In: *Heritage Science* 1, 11, 2013.
Images	 Leuben castle, eastern facade, tympanum, left part of test area 1: detail of the demonstration area for fine stucco consolidation before (left) and after (right) treatment.
Source of images	DAEHNE, A. & HERM, C. Calcium hydroxide nanosols for the consolidation of porous building materials - results from EU-STONECORE. Herit. Sci. 1, 11, 2013 .

Method/Technology/Material	**Nuclear magnetic resonance (NMR) spectroscopy**
Kind	Diagnostic
Basic description	*The NMR is used to study the structure of molecules, the interaction of various molecules, the kinetics or dynamics of molecules and the composition of mixtures.*
More specification	*Many nuclei have spin and all nuclei are electrically charged. If an external magnetic field is applied, an energy transfer is possible between the base energy to a higher energy level (generally a single energy gap). The energy transfer takes place at a wavelength that corresponds to radio frequencies and when the spin returns to its base level, energy is emitted at the same frequency. The signal that matches this transfer is measured in many ways and processed in order to yield an NMR spectrum for the nucleus concerned. Because of superconducting magnets which are offering maximum sensitivity, the device is very large. Currently, mobile stray-field NMR is a method of growing interest, it is small and inexpensive.*
Range of use	*The NMR is used for determining the content and purity of a sample as well as its molecular structure, for studying physical properties at the molecular level such as conformational exchange, phase changes, solubility, and diffusion. The NMR was used for detection of moisture in historical walls, or for studying protective and consolidating treatment. NMR devices can also be small and inexpensive if permanent magnets are used, and samples need not be placed within the magnet but can be examined externally in the stray magnetic field.*
Intervention rate	*Non-destructive and versatility method.*
Main advantages	*The NMR can provide quantitative study of molecules in solution and in solid state, a wide variety of NMR parameters are correlated to material properties. Portable instrument allowing to measure the water content of materials, on site and in a totally non-destructive way.*
Negatives and risks	*NMR is inherently insensitive compared with other analytical techniques. Conventional instrumentation is large and expensive. Portable NMR cannot accessed large depths of samples.*
References	*Proietti, Noemi – Donatella Capitani – Valeria Di Tullio 2018: Nuclear Magnetic Resonance, a Powerful Tool in Cultural Heritage. Magnetochemistry 4.1 (2018): 11.*
Keywords	*NMR; portable NMR*
Recording author	*Dita Machová, CET*

Images	
Source of images	*Capitani, Donatella, et al. 2009: An integrated study for mapping the moisture distribution in an ancient damaged wall painting. Analytical and bioanalytical chemistry 395.7 (2009): 2245-2253.*

Examples of application

The NMR technique was used for evaluation of the pore-space structure in various types of building materials.	*Brai, M., et al. 2007: Validity of NMR pore-size analysis of cultural heritage ancient building materials containing magnetic impurities. Solid state nuclear magnetic resonance 32.4 (2007): 129-135.*
Portable NMR allows one to assess the state of conservation of wall paintings and to quantitatively map the moisture distribution in the outer layers of a wall painting as well as in historical masonry.	*Proietti, Noemi, et al. 2015: MOdihMA at Sforza Castle in Milano: Innovative Techniques for MOisture Detection in Historical Masonry. Built Heritage: Monitoring Conservation Management. Springer, Cham, 2015. 187-197.*
With NMR were investigated the penetration depth of treatment, the occurrence of in-homogeneities in treated material, and changes of the open porosity possibly occurring in treated stone.	*Di Tullio, Valeria, et al. 2011: NMR depth profiles as a non-invasive analytical tool to probe the penetration depth of hydrophobic treatments and in-homogeneities in treated porous stones. Analytical and bioanalytical chemistry 400.9 (2011): 3151-3164.*

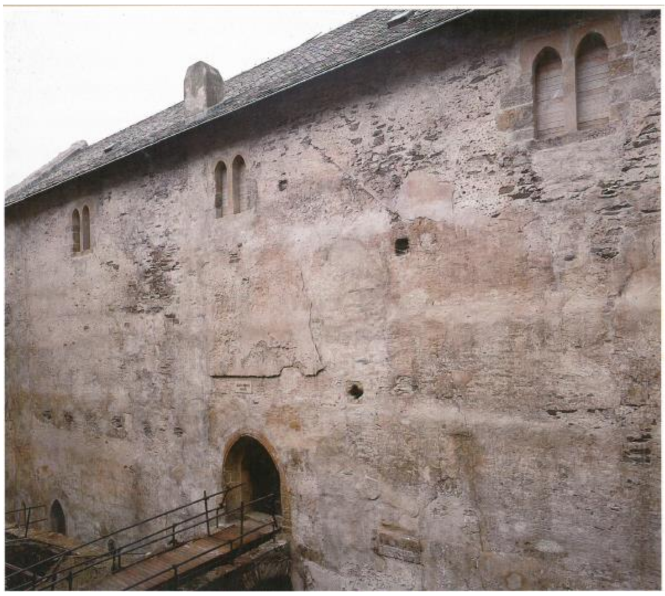
Method	Optical microscopy
Kind	Imaging method
Basic description	The technique employed to closely view a sample through the magnification of a lens with visible light.
More specification	The optical microscopy, also sometimes known as a light microscope, uses one or a series of lenses to magnify images of small samples with visible light. The lenses are placed between the sample and the viewer's eye to magnify the image so that it can be examined in greater detail.
Range of use	The method provides basic information about the morphology of the material surface. It permits direct visual evaluation of species on an investigated object, based on the characteristic macroscopic features. For example, the device allows to characterize of small cracks on the surface, locating faults and degraded parts. In addition, identification and characterization of algal and cyanobacterial communities can be carried out through observations by **optical microscope**. Basic variant designed for low magnification observation of a sample is **stereoscopic microscope.** It is helpful for bigger objects, which is not possible observed at the optical microscope, but features visibility is not as good. Another of technique of optical microscopy is **polarized light microscopy**. Polished sections as well as thin sections of rock or ore are analyzed either by transmitted or reflected light. Polarized light, when traveling through a crystal is split up into two waves of different velocity which are resolved by a second polarization process just before the polarized light passes through the object lenses. The interference of these two waves gives characteristic colors which help to identify minerals. **3D Digital Video Microscope combines multiple functions at once.** It is an optical inspection microscope used to image objects with rough surfaces or irregular topology, do optical comparisons, measure feature sizes in 2 or 3 dimensions, generate 3D profiles, and view objects from multiple perspectives. The microscope can be used on a tripod or handheld, to study both the morphology of untreated surfaces and the petrographic analysis in the transmitted polarized light. It can helps with controlling the effects of conservation and restoration, and interventions on the microstructure of material.
Intervention rate	Sampling is required.
Main advantages	Enable basic material characterization, description of changes, sample amount is not large, universal use.
Negatives and risks	Sample preparation is difficult, especially for a polarized light microscopy.
References	Murphy, Douglas B. *Fundamentals of light microscopy and electronic imaging*. John Wiley & Sons, 2002.
Keywords	optical microscopy, stereoscopic microscope, polarized light microscopy, **3D digital video microscope**

Recording author	Dita Machová, CET
Images	 Polarizing microscope, stereoscopic microscope, 3D Digital Video Microscope.
Source of images	Dita Machová, CET

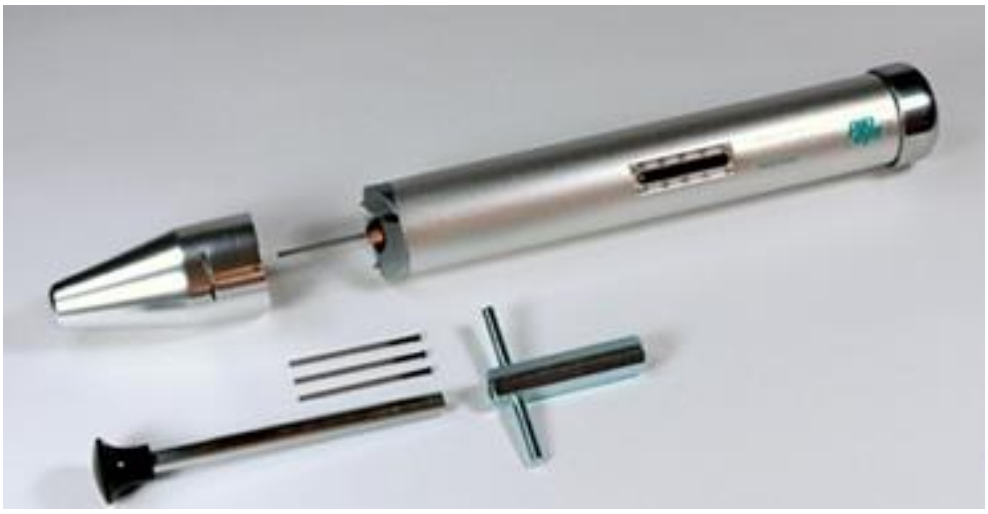
Method	Patination
Kind	Remedial
Basic description	Used in order to decrease visual expression of colours of new restored parts, mainly on mortar or plaster surfaces (Schubert 1998, 53).
More specification	A way to moderate expression of new mortar or plasters in order to preserve overall impression of monument. New mortar has often distinctive grain-size distribution or could be too shining, which can be changed with added pigments. It is better to prepare smaller amount of mortar for specific parts of repaired masonry with different shade (grey, grey-ochre, brown, shades of ochre). Such practice can reduce final corrections and patination (Girsa 1994, 113). It's necessary to distinguish between grouting mortar and plasters (Žižka 2012, 27)
Range of use	Colouring of mortars and plasters during mixing process. Final patination. Patination of calcic leaches of older repairs using cement binder appeared unsuccessful (Girsa 1994, 113; Schubert 1998, 53; Sokol 2012, 81)
Intervention rate	Non-destructive
Main advantages	Attaining of integrated expression of ruin, decrease need of final patination, avoid of artificial colours, longer duration.
Negatives and risks	Choosing unstable pigments. Controversial when natural aging of materials is expected. Risk of contrived result, theatrical impression.
References	GIRSA, Václav 1994: Obnova dvorních průčelí purkrabského paláce. Wiederherstellung der Fassade des Burggräflichen Palais der Burg Bezděz – Ein konkreter Beitrag zur Diskussion über der Denkmalskonservierung, *Zprávy památkové péče* LIV, 109-116. SCHUBERT, Alfréd 1998: Opravy hradů, městských hradeb a jiných neúplně dochovaných staveb. Požadavky památkové péče a jejich řešení. Instandsetzungen von Burgen, Stadtmauern und andren unvollständig erhaltenen Bauwerken. Anforderungen der Denkmalpflege und ihre technische Ausführung. In: *Zříceniny historických staveb a jejich památková ochrana*. ZPP 58, 47-57. SOKOL, Petr 2012: Gutštejn – průzkumy a stabilizace hradní zříceniny. Gutštejn – surveys into and stabilisation of the castle ruins. *Památky západních Čech* II-2012, 72-86. ŽIŽKA, Jan 2011: K technologii a stavebním postupům při opravách torzálně dochovaných staveb. Zu der Technologie und den Bauvorgängen bei der Instandsetzung der Bauwerktorsos. *Památky středních Čech* 25/2, 18-36.
Keywords	Pigments, expression of ruin, colours, mortar
Recording author	Stanislav Vohryzek, ITAM

Examples of application

Site Specification	Hrad Gutštejn (Gutštejn Castle)
Localization	Konstantinovy Lázně, Okrouhlé Hradiště, Plzeň Region, Czech Republic
Owner and management	National Heritage Institute (NPÚ)
Affected part	South palace
Intervention reasons	Attempt to patinate older calcite leach from phase reconstruction from year 2009 and older reconstruction using cement binding
Intervention extent	Upper part of south and west front of the South Palace
Date of intervention	2011
Time consumption	Not known
Results	Patinating of calcite leach was successful, patination of mortars with cement binding without apparent results (picture shows state before intervention).
Evaluation	Patination of mortar with cement binding can't be recommended.
References	SOKOL, Petr 2012: Gutštejn – průzkumy a stabilizace hradní zříceniny. Gutštejn – surveys and stabilization of the castle ruins. *Památky západních Čech* II-2012, 72-86.
Images	
Source of images	Sokol 2012, 77
Site Specification	Hrad Bezděz (Bezděz Castle)

Localization	Bezděz, Liberec Region, Česká Lípa District, Czech Republic
Owner and management	National heritage institute (NPÚ)
Affected part	South and east front of the Burgrave's palace.
Intervention reasons	Conservation of the palace, removal of unnatural traces of destruction and recently added constructions.
Intervention extent	Visual correction of disturbing parts and constructions, modern bricking in. Inorganic pigments BAYFERROX (black, yellow, Chlumčany ochre), then for uniting of shades fine glazing pigment agent Porosil ZV 20 (Girsa 1994, 112-115).
Date of intervention	Summer 1993
Time consumption	Not known
Results	Visual impact optimal, the authenticity is compromised
Evaluation	Conservation attitude, minimum compromise
References	GIRSA, Václav 1994: Obnova dvorních průčelí purkrabského paláce. Wiederherstellung der Fassade des Burggräflichen Palais der Burg Bezděz – Ein konkreter Beitrag zur Diskussion über die Denkmalskonservierung, *Zprávy památkové péče* LIV, 109-116.
Images	
Source of images	Girsa 1994 (cover of ZPP LIV/1994/4)

Method	Pilodyn wood penetrometer
Kind	Diagnostic
Basic description	Pilodyn tester is designed for estimating the density and structural strength of wood; it contains a spring that is pre-loaded to a constant tension. When triggered, the spring drives a blunt steel pin, initially touching the log surface, into the wood.
Specification	The device has a scale (from 0 to 40 mm) for measuring the depth the pin penetrates into the wood. Since the maximum depth of penetration is 40 mm, the readings reflect wood properties of the surface layer. The tester is loaded with the ramrod and then pressed firmly onto the test surface. The impact pin is shot into the wood by pressing the trigger cover. The depth of penetration can be read straightaway in mm on the scale mounted on the tester.
Range of use	Complementary tool used usually in combination with micro-drilling or with other more sophisticated methods. Can be used for both living and dead wood.
Intervention rate	Non-destructive (minimally invasive)
Main advantages	Light and operative, requires minimal maintenance, simple to use with no charging (mechanical loading), simple mechanical indicating scale.
Negatives or risks	It can refer about surface layer of wooden element only. Can be dangerous when spring is released unintendedly.
References	http://www.ferret.com.au/c/hylec-controls/pilodyn-wood-density-meter-from-hylec-n852069#voGXgW8GyhpUxYhx.99 MÄKIPÄÄ, Raisa – LINKOSALO, Tapio 2011: A non-destructive field method for measuring wood density of decaying logs. In: *Silva Fennica* 45(5): 1135–1142.
Available at	ITAM AS CR
Keywords	Penetrometer, wood density
Recording author	Jiří Bláha, CET

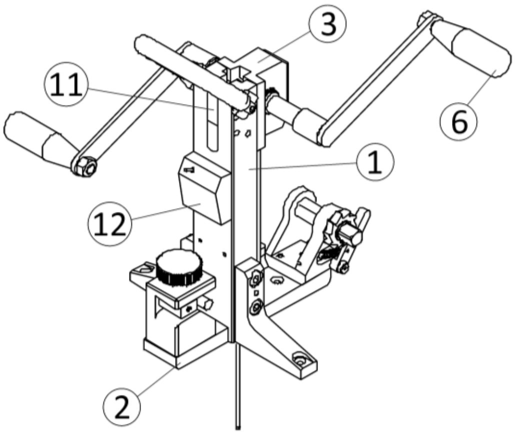
Images	 
Source of images	http://www.ferret.com.au Jiří Bláha, ITAM

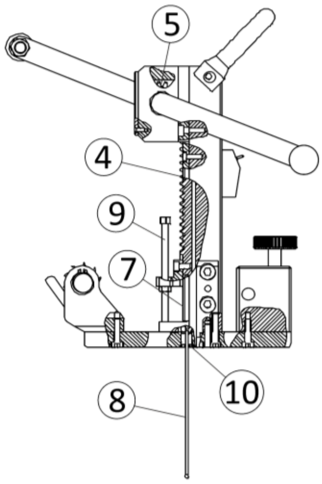
Examples of application

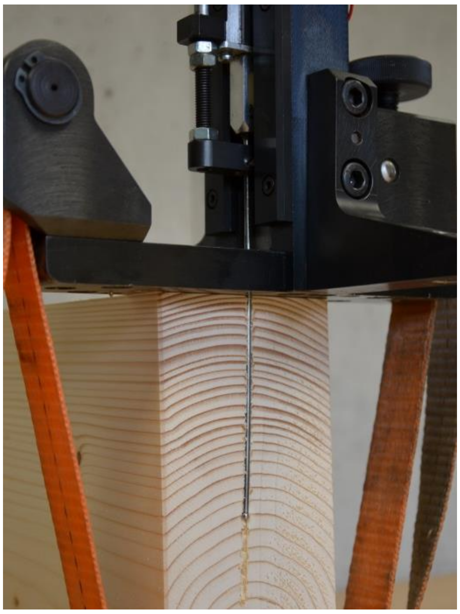
Site Specification	Church of St. John the Baptist
Localization	Dešná, Jindřichův Hradec District, South Bohemia Region, Czech Republic
Owner and management	Catholic church
Affected part	Roof timber frame
Intervention reasons	Evaluation of technical condition, mapping od hidden decay..
Intervention extent	Non-destructive (minimally invasive)
Date of intervention	2006
Time consumption	1 hour
Results	Pilodyn penetrometer was use as complementary tool for mapping the extent of hidden damage.
Evaluation	Penetrometer helped to determine boundary between healthy and damaged parts in vicinity of local damages as shown on the photograph.
References	
Images	
Source of images	Jiří Bláha, ITAM, 2006

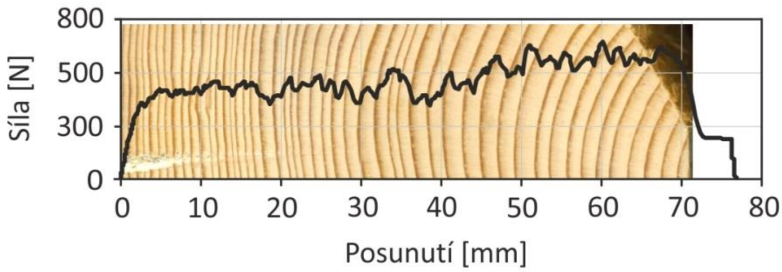
Method	Pin pushing indentor
Kind	Diagnostic
Basic description	Measuring of mechanical resistance against a tool (pin) penetration into wood.
Specification	The force of user's arms turning the double crank is transferred to the pinion. The pin pointed with a semi-round tip passes through the tool base in bronze grommets which reduce friction of the moving pin. The instrument is equipped with a displacement sensor, which consist of a displacement gauge fixed to the movable part and a coded strip fixed in a groove in the rear wall of the toothed rack. In the rear of the movable part there is a wireless data transmitter that is electronically connected with the displacement gauge; there is also a wireless connection between the wireless data transmitter and a USB receiver of the recording PC with SigVis software specially developed for recording and for to analyse the measuring outputs.
Range of use	Developed for the purpose of on-site inspections. Designed only for soft wood species commonly used in timber constructions (roofs, ceilings, log walls), namely spruce, fir, pine and larch.
Intervention rate	Semi-destructive (less invasive)
Main advantages	The manual operation of the tool saves energy which is appreciated especially in remote locations. Thanks to wireless connection with a laptop gives results immediately.
Negatives or risks	Results can be affected by inhomogeneity of wood or its decay.
References	KLOIBER, Michal – TIPPNER, Jan – HEŘMÁNKOVÁ, Věra – ŠTAINBRUCH, Jakub 2012: Comparison of results of measuring by current NDT methods with results obtained through a new device for wood mechanical resistance measuring. In: *Proceedings of the 8th International Conference on Structural Analysis Historical Constructions,* 10/2012, Wroclaw, Poland. ISSN 0860-2395, pp. 2035-2043. KLOIBER, Michal – TIPPNER, Jan – HRIVNÁK, Jaroslav – PRAUS, Luděk 2012: Experimental verification of a new tool for wood mechanical resistance measurement. In: *Wood Research* 57(3): 2012, Slovakia. pp. 383-398.
Available at	ITAM AS CR
Keywords	Defectoscopy, density, indentor, material testing, soft wood
Recording author	Jiří Bláha, CET

Images









Source of images	Michal Kloiber, ITAM

Method	**Repair of plaster and render based on material and technological copy of the original**
Kind	Remedial
Basic description	Use of material prepared according to the existing original. Adequate local sources of raw materials should be identified and compared with the commercially available products. In justified cases, lime can be burnt in a small kiln to replicate the historic production process allowing the use of historically appropriate mortar and application processes. The aim is to utilise the relevant traditional techniques of lime slaking and mortar production as much as possible. The availability of the appropriate material is important for the material compatibility issues and also for the cases where a specific appearance is required.
Specification	Analyses include lime binder characterisation, mineralogical and chemical composition, mainly the degree of hydraulicity and MgO content, aggregate mineralogy, particle size distribution, mixing ratio, additives and admixtures, presence of lime lumps, underburnt particles etc. Original building element (render/plaster) features must be thoroughly surveyed, number of layers and coats as well as like specific features relevant to the application technology including tool traces etc. Provenance identification of local sources of raw materials if possible. Lime binder preparation – small scale production replicating the appropriate historic technology (Válek 2015). Assessment of compatibility of the newly produced mortar. Practical evaluation of the newly produced mortar on test panels. Testing of application methods is also based on observation of authentic historic details and period written and pictorial sources (documents about architecture, manuals, accounting books from the time of construction etc.).
Range of use	Repair and reconstruction of renders and plasters.
Intervention rate	Where the replication of material and its application techniques is essential.
Main advantages	Material compatibility with historic original. The complete process, i.e. the binder production, mortar preparation and application techniques, allows to replicate original elements utilising appropriate historic crafts [1]. Aesthetic compatibility – colours and structure (appearance). Preservation of traditional and historic crafts.
Negatives and risks	Local resources of raw materials do not exist or cannot be identified. Material characterisation is not conclusive in terms of a practical use. Limited application for highly degraded masonry, i.e. the original material has its physical properties highly altered (risk of incompatibility).
References	Válek, J. 2015: *Lime technologies of historic buildings. Preparation of specialised lime binders for conservation of historic buildings*. Praha: ITAM AS CR, 2015. Wichterlová, Z. – Waisserová, J. – Skružná, O. – Válek, J. 2018: Reconstruction of the Sgraffito Technology Used North of the Alps during the Renaissance Reveals a New Shading Technique. In: *Proceedings of International Conference Sgraffiti.* 2-4 November 2017, Horneman Institute, Hildesheim, Germany.
Keywords	Render, plaster, lime mortar, repair material, analysis and design
Recording author	Jan Válek, Olga Skružná, Petr Kozlovcev, ITAM

Images	 
Source of images	Jan Válek, Olga Skružná, ITAM

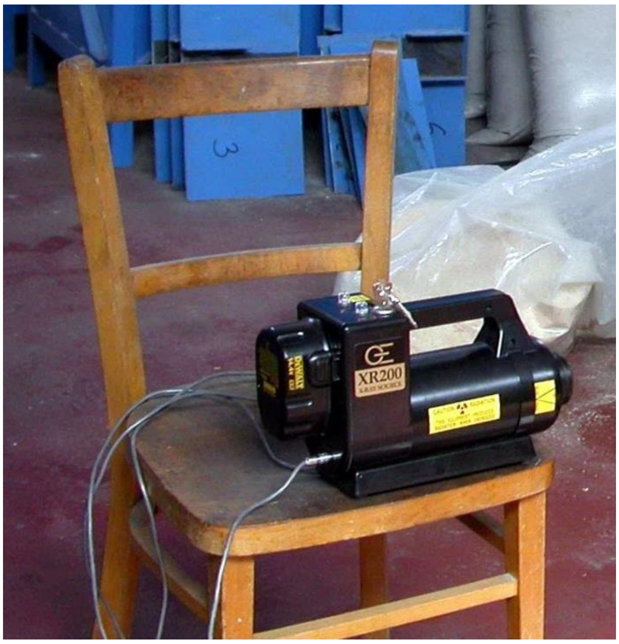
Examples of application

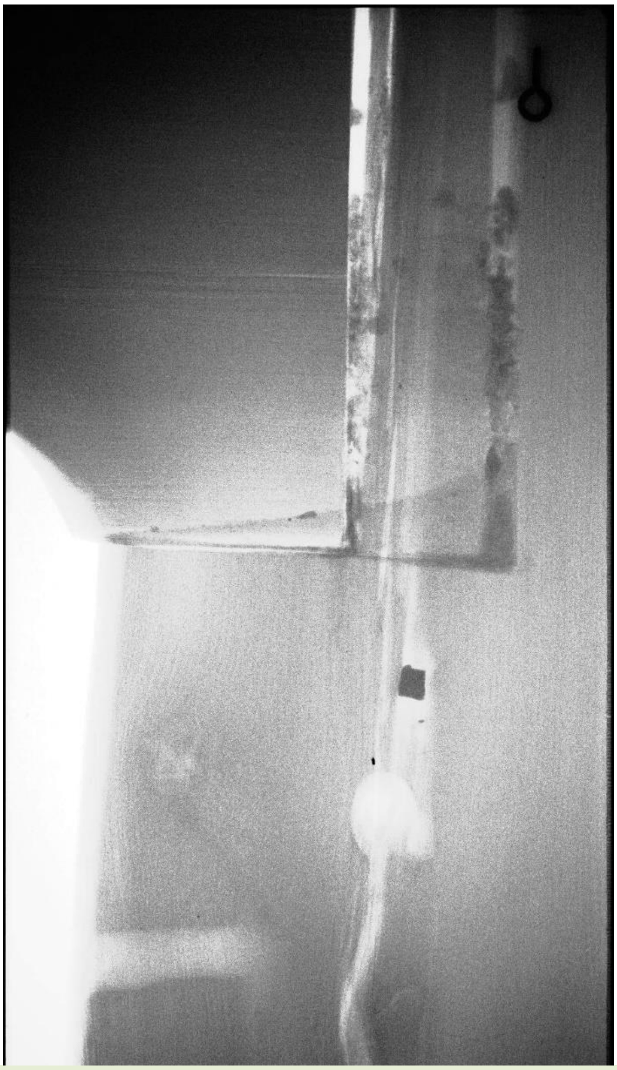
Site Specification	Slavonice, house No. 545
Localization	Slavonice, Jindřichův Hradec District, South Bohemia Region, Czech Republic
Owner and management	Private owner
Affected part	SW wall of the house
Intervention reasons	Experimental restoration of missing parts of a sgraffito motif depicting Processing of Landsknechts (mercenary soldiers). The replication of the material allowed reconstruction of the original artistic technique.
Intervention extent	Repaired area: 4 × 3 m
Date of intervention	From August to September 2017
Time consumption	2 months of preparation, sampling, analysing, examination of raw materials, lime production 1 months of restoration work
Results	Restored sgraffito (16th century). Reconstructed parts were executed with mortars using the local raw materials and contemporary historic procedures. Contribution to knowledge of historic sgraffito technique – trowel-shaded sgraffito – tested with mortars from local sources, processed in the traditional way.
Evaluation	Prepared mortar mixtures were well appreciated by the craftsmen. The restored area has a consistent entire appearance; the original planes are nevertheless well distinguishable.
References	Wichterlová, Z. – Waisserová, J. – Skružná, O. – Válek, J. 2018: Reconstruction of the Sgraffito Technology Used North of the Alps during the Renaissance Reveals a New Shading Technique. In: *Proceedings of International Conference Sgraffiti.* 2-4 November 2017, Horneman Institute, Hildesheim, Germany.

Images	 
Source of images	Jan Válek, Olga Skružná, ITAM

Method	Portable X-ray Generator
Kind	Diagnostic
Basic description	A light battery powered pulsed generator with phosphor plates for multiple use in X-ray recording.
Specification	Pulsed X-rays generate a high intensity X-ray burst (pulse) in a very short period of time (10 to 50 nanoseconds depending on the model). The Phosphor Recording Device enables repeat recording and easy image digitization. The recording plate consists of a very thin layer of phosphorus crystals, connected to each other and deposited on a plastic mat. Phosphoric crystals absorb and store X-ray energy in the form of a hidden image. The amount of energy absorbed is proportional to the X-ray intensity to which the crystals were subjected. The stored energy is then released from the crystals by red laser irradiation. The crystals get into an unstable state and radiate the blue visible light upon transition to the basic steady state. This light is recorded by a scanner that converts it into images that can be further processed. The scanner is the largest part of the entire device; it has an approximate size of 40×50×27 cm and weighs about 15 kg. Its power consumption is up to 100 watts and can be connected to a laptop computer via a USB cable. Recording boards are not completely erased while reading in the scanner, and some crystals still retain some energy. This information can be completely erased by exposure to daylight. After deleting the previous information, the recorder may be reused. Outputs are in the form of digital images exported in standard formats. Using common editing programs, they can be combined into larger units.
Range of use	The device allows looking under the surface of walls, ceilings, uncovering invisible joints, repairs, hidden defects, etc. Preferably, the X-ray recording shows the differences between two materials with a significantly different density. A typical example of use is the detection of hidden reinforcement or anchoring elements in timber structures or plastic stucco ornaments.
Intervention rate	Non-invasive
Main advantages	Light and operative, simple to operate, minimal maintenance.
Negatives or risks	The unit produces radiation only when it is pulsing. Time delay button and remote cable allow the operator to move a safe distance from the unit when it is in operation. The use may be regulated by national regulations.
References	ANTHONY, Ronald W. – DRDÁCKÝ, Miloš – JIROVSKÝ, Ivo – KASAL, Bohumil 2003. X-ray diagnostics of historic timber structures [in Czech]. In Proceedings of the Historic structures conference. High Tatras, Slovakia 2003
Available at	ITAM AS CR
Keywords	X-ray, defectoscopy, pulsed generator
Recording author	Jiří Bláha, CET

Images

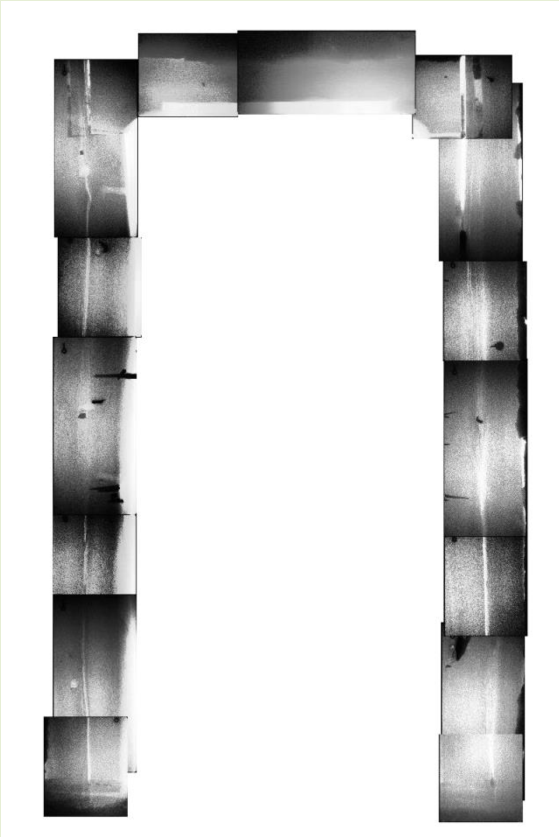




Source of images	Jiří Bláha, CET

Examples of application

Site Specification	**Hrad Pernštejn (Pernštejn Castle)**
Localization	Pernstejn Nr. 16, Vysočina Region, Czech Republic
Owner and management	National Heritage Institute
Affected part	Wooden doorframe in the Clock Tower
Intervention reasons	Dendrochronological dating and detailed survey
Intervention extent	Non-invasive
Date of intervention	2003-09-02
Time consumption	3 hours
Results	Accurate detection of joint shape and dimensions of the additional metal elements.
Evaluation	The on-site application of portable X-ray helped to thoroughly describe the composition and actual condition of the wooden doorframe from 1480-1497. It has been acquired in a nondestructive way.
References	BLÁHA, Jiří – KYNCL, Tomáš – ANTHONY, Ronald W. 2005: Komplexní nedestruktivní průzkum pozdně gotického dřevěného portálu v Hodinové věži na hradě Pernštejně. In: *Dějiny staveb 2004*, sborník příspěvků z konference v Nečtinech, Plzeň 2005, s. 165–170. ANTHONY, Ronald W. 2005: Investigation of historic timber structures using portable X-ray technology. In: Conservation of historic wooden structures: proceedings of the international conference, Florence, 2005. Vol. 1 and 2 p. 289-293.

Images	  
Source of images	Jiří Bláha, ITAM, 2003

Method	Pull-off testing
Kind	Diagnostic
Basic description	Tensile strength measuring. The test involves pulling off a disc previously attached for this purpose to the surface being analysed. The force required to pull the disc from the surface, together with the carrier, is measured.
Specification	Dyna Pull-off instrument has discs with 50-mm in diameter and uses epoxy resin as a fixing adhesive. At least three pull-off tests are usually required to get a valid indication of bond strength for a test area
Range of use	Measuring tensile strength and coating adhesion.
Intervention rate	Destructive (invasive) method. The force applied to the pull stub is gradually increased until failure or, if nondestructive testing is desired, a specified (sufficient) value is reached. A common practice is to cut the coating around the pull stub to isolate the test area from the surrounding coating and minimize the damage of coating outside the tested area.
Main advantages	Mobile and versatile device which can be used on-site.
Negatives or risks	Needs access to places to be tested. It can refer about the coating adhesion or homogeneous surface layer only. Cleaning the coating with chemicals or solvents before testing can alter the coating integrity.
References	BONALDO, Everaldo – BARROS, Joaquim – LOURENÇO, Paulo 2005: Bond characterization between concrete substrate and repairing SFRC using pull-off testing. In: *International Journal of Adhesion & Adhesives* 25 (2005) 463–474.
Available at	Lublin University of Technology
Keywords	Pull-off, adhesion, tensile strength, bond strength
Recording author	Bartosz Szostak, Lublin University of Technology

Images	 
Source of images	Bartosz Szostak, Lublin University of Technology

Method/Technology/Material	Raman spectroscopy (RS)
Kind	Diagnostic
Basic description	Raman spectroscopy is a versatile method for analysis of a wide range of samples.
More specification	*The **RS** based on inelastic scattering of monochromatic radiation. During this process energy is exchanged between the photon and the molecule such that the scattered photon is of higher or lower energy than the incident photon. The difference in energy is made up by a change in the rotational and vibrational energy of the molecule and gives information on its energy levels.* *The **micro-Raman spectrometers** which represents spectroscopy combined with microscopy, allows the investigator to detect and quantify the molecular chemistry of microscopic samples.* *Infrared spectroscopy is a complementary technique to Raman spectroscopy and is discussed in many cases for completeness.*
Range of use	*It can be used for both qualitative as well as quantitative purpose,* for identification of specific compounds within a wide range of specimens, **organic and inorganic**, for identification of particulate contaminants, high-resolution depth profiling and subsurface analysis on transparent and semi opaque samples, characterization of coatings, multi-layer laminates, thin films, inclusions and subsurface defects. Micro-Raman spectroscopy is an exceptional tool for investigating the chemistry of interfaces, each structure is analysed in situ. Many reviews papers have extensively described and compared portable Raman spectrometers for cultural heritage analysis, a portable Raman spectrometer relies on a compromise between the available features and the real needs of the project at hand.
Intervention rate	The RS requires no sample preparation, is non-invasive and non-destructive.
Main advantages	For most samples there is no need for any sample preparations. It is able to record spectra of inorganic and organic materials. It has the high spatial resolution. It is possible to analyse micro-samples, and performing in situ investigations.
Negatives and risks	The RS cannot be used for metals or alloy, fluorescence of impurities or of the sample itself can hide the Raman spectrum. Some compounds fluoresce when irradiated by the laser beam.
References	Smith, Ewen – Geoffrey Dent 2013: *Modern Raman spectroscopy: a practical approach*. John Wiley & Sons, 2013.
Keywords	Raman spectroscopy, Micro-Raman spectroscopy
Recording author	Dita Machová, CET

Images	
Source of images	Petra Mácová, CET

Examples of application

A perspective on recent applications and new frontiers in sampling modalities, data processing, and instrumentation of Raman spectroscopy.	*Casadio, Francesca – Daher, Céline –Bellot-Gurlet, Ludovic 2016: Raman spectroscopy of cultural heritage materials: overview of applications and new frontiers in instrumentation, sampling modalities, and data processing. Topics in Current Chemistry 374.5 (2016): 62.*
An approach to evaluate parameters and apply of a portable Raman spectrometer, characterisation of mobile Raman instrumentation for art analysis.	*Lauwers, Debbie, et al. 2014: Characterisation of a portable Raman spectrometer for in situ analysis of art objects. Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy 118 (2014): 294-301.*

Method	Regular preventive inspections
Kind	Maintenance
Basic description	Regular inspection and maintenance regime with feedback coupled with the public subsidy system.
Specification	Site inspections produce reports containing detailed status report with photographs and recommendations regarding: - works to be carried out to insure an optimal accessibility and safety - works to be carried out in view of the preservation - special attention required in view of durable maintenance - urgent works of repair - on-site advice - maintenance schedule: long term maintenance planning Report could be used as an instrument to apply for maintenance grants
Range of use	Suitable for all kinds of building monuments, especially appreciated in difficult-to-reach areas, such as roofs, towers and castle ruins.
Intervention rate	Non-destructive
Main advantages	It can significantly reduce the cost of necessary repairs
Negatives or risks	Work on heights requires special security equipment. It is possible to use forklift platforms or drones which, however, increases the purchase price.
References	http://www.promonumenta.sk http://www.monumentenwacht.be/ https://www.monumenten.nl/onderhoud-en-restauratie/monumentenwacht
Available at	Some European countries: The Netherlands, Belgium, Slovakia
Keywords	Monumentenwacht, Pro Monumenta
Recording author	Jiří Bláha, CET
Images	

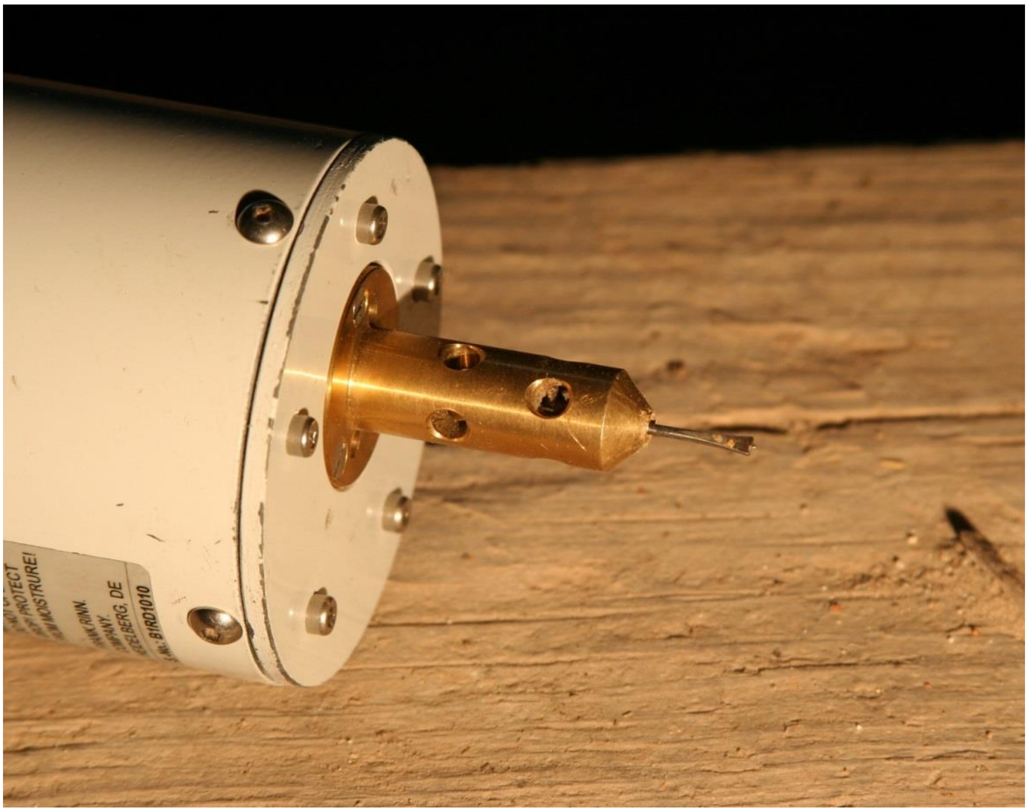
Source of images	PRO MONUMENTA Slovakia Monumentenwacht Zuid-Holland

Method	Resistance moisture measuring
Kind	Diagnostic
Basic description	One of the most popular techniques for determining the moisture content of building materials is based on measurements of the electrical resistance of the materials.
Specification	Resistance meters work on the principle of decrease of the electric resistance of a material in presence of water. Hand-held resistance meters use two probes or pins, which are pushed in the material or wall surface. Some meters come with long pins requiring drilling of small holes into the wall. These instruments measure the resistance of a material to an electric direct current (dc). Since liquid water with impurities is a good conductor, the higher the moisture content of the material is, the lower is the electrical resistance. The presence of soluble salts significantly affects the measured values.
Range of use	This method can be successfully used for the measurements of moisture content in wood, while it is much less suitable in masonry walls. This is because of multiple reasons: - calibration is well established for most types of wood, since the measurements are reproducible if the material is consistent; differently, in the case of masonry the absence of homogeneity of the materials complicate the calibration. - the pins can easily penetrate into wood, while they cannot straightforwardly be pressed into brick or stone elements.
Intervention rate	Non invasive
Main advantages	Advantages of the methods are given by its non-invasiveness, the low cost of the instruments and the simplicity in using the method.
Negatives or risks	Limits of the methods are given by the fact the measured values are strongly influenced by the presence of salt, the contact pressure applied to the pins, the temperature, the hardness and the irregularities of the materials. Moreover, the instrument measures only the outer layer of the material, which is strongly affected by the conditions at the surface as occurrence of surface condensation, evaporation etc.
References	
Available at	Restaurateur office in Zagreb
Keywords	
Recording author	Lidija Perić, ZADRA NOVA
Images	

	
Source of images	

Method	Resistograph
Kind	Diagnostic
Basic description	Resistograph is an electronic high-resolution needle drill resistance measurement device designed for inspections of timber constructions.
Specification	A thin, long needle is driven into the wood. The electric power consumption of the drilling device is measured, recorded and printed. Resistograph devices are different from other resistance drills because they provide a high linear correlation between the measured values and the density of the penetrated wood. They are used for inspecting trees and timber in order to find internal defects, and to determine wood density and growth rates.
Range of use	50 cm drilling depth. A time required depends on the number of measurements.
Intervention rate	Semi-destructive (minimally invasive)
Main advantages	Designed for on-site use. Besides connection to a PC it offers an integrated thermo printer providing immediately outputs in a 1: 1 scale.
Negatives or risks	The length of the case (cca 60 cm) is sometimes limiting for measurement in desired direction.
References	RINN, F. – SCHWEINGRUBER, F.H. – SCHÄR, E. 1996: RESISTOGRAPH and X-ray density charts of wood comparative evaluation of drill resistance profiles and X-ray density charts of different wood species. Holzforschung 50: (4), 303-311.
Available at	ITAM AS CR
Keywords	Drill resistance, wood
Recording author	Jiří Bláha, CET

Images

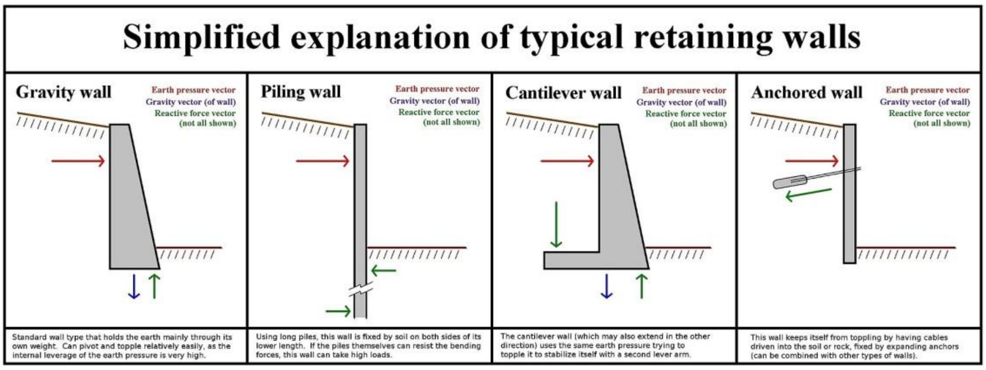


Source of images	Michal Kloiber, ITAM

Examples of application

Site Specification	Church of St. John the Baptist in Dešná
Localization	Dešná, Jindřichův Hradec District, South Bohemia Region, Czech Republic
Owner and management	Catholic church
Affected part	Roof timber frame
Intervention reasons	Evaluation of technical condition of bearing structures. Detailed description of hidden decay in order to estimate the extent of the necessary exchanges before starting of restoration works.
Intervention extent	Semi-destructive (minimally invasive)
Date of intervention	2006
Time consumption	4 hours
Results	Resistograph instrument was used successfully for mapping the extent of hidden damages.
Evaluation	It helped to determine the real extent of hidden damage of the construction elements within the roof frame.
References	

Images	
Source of images	Michal Kloiber, ITAM, 2006

Method	Retaining walls
Kind	Remedial
Basic description	A structure designed and constructed to resist the lateral pressure of soil, when there is a desired change in ground elevation that exceeds the angle of repose of the soil.
Specification	A typical use of retaining walls is where: - the path or road traverses the slope - occasionally running surface water needs to be directed to the intake areas - the inclined or unstable wall needs extra dead load at its outer base - area endangered by falling stones must be separated from publically accessible grounds
Range of use	In all locations threatened by potential slope movements or rock falling. Tracing of communications and drainage of rain water.
Intervention rate	Invasive but mostly intervene only the areas without built structures and potential archeological situations.
Main advantages	When designing the most suitable technical solutions, it is possible to use forms and materials compatible with the environment of historical ruins.
Negatives or risks	According to the local situation. Back drainage must be kept in order to prevent submerging and eventual collapse.
References	
Available at	Individual design
Keywords	Ground, gravity wall, slope, anchored wall
Recording author	Jiří Bláha, ITAM
Images	
Source of images	Wikipedia

Examples of application

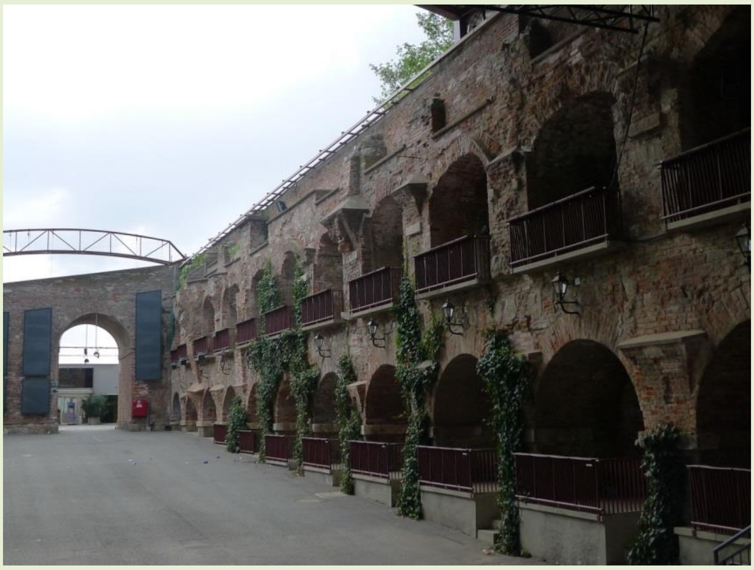
Site Specification	Hrad Točník (Tocnik Castle)
Localization	Točník Nr. 10, Beroun District, Middle Bohemia Region, Czech Republic
Owner and management	Národní památkový ústav (National Heritage Institute)
Affected part	The second castle courtyard. A pathway joining different levels of terrain within the castle ruin.
Intervention reasons	Securing the stability of a steep slope before water erosion in the event of torrential rains.
Intervention extent	Minor changes in path tracing. Reuse of stones spontaneously released from ruined parts in the past.
Date of intervention	About 2005
Time consumption	Not known
Results	The retaining construction combines dry laid stones picked in the ruin grounds with local oak tree trunks.
Evaluation	A combination of local stone and wood looks naturally and very well fulfills its purpose.
References	

Images	 
Source of images	Jiří Bláha, 2009 (1) Patrick Hoffsummer, 2006 (2 and 3)

Method	Retractable (movable) roof
Kind	Modern facilities
Basic description	Movable roofs usually have two or more modes of use according to actual needs. Extended roof providing shelter in case of bad weather and retracted state minimizing the negative effect on the preserved heritage site.
Specification	A canvas retractable roof was used already in the Ancient Rome Colosseum. Nowadays the movable roof constructions are mainly designed as sliding on rails (similar to garden swimming pools) or as suspended membrane roofs.
Range of use	Ruined objects seasonally used like summer stages or auditoriums. Could be also used as a temporary construction during repair works or excavations.
Intervention rate	Invasive because such a roof must be firmly anchored to walls or at least to the ground.
Main advantages	Offers a compromise between a need to cover the ruin or part of it and the aim to mitigate visual impact of new built structure.
Negatives or risks	Expensive when designed and constructed, because it requires an individual approach. More demanding to maintenance needs than permanent roofing.
References	http://www.kugel-architekten.com/content.php?n=1&d=28
Available at	Individual design
Keywords	Folding roofs, sliding roofs, membrane roofs
Recording author	Jiří Bláha, ITAM
Images	
Source of images	THE UBIX temporary roofing system from Combisafe International

Examples of application, no. 1

Site Specification	Schlossbergbühne Kasematten (Open-air theatre)
Localization	Graz – Innere Stadt, Steiermark Region, Austria
Owner and management	Municipality of Graz
Affected part	Former storehouse of the Graz citadel ruined by French troops in 1809 was approved and listed as historic monument in 1914 even though the vaults covering internal space has not been preserved.
Intervention reasons	Alteration leading to provide more comfortable auditorium protected from weather effects.
Intervention extent	Retractable roof designed by architects Gilly and Jörg Maier is normally reduced to one quarter of its volume. The segment shaped roof moves along the rails laid on the variously high wall-tops of a partially ruined object.
Date of intervention	1987, renovated 2009
Time consumption	Not known
Results	Open-air theatre was opened in Castle Hill in 1937. 50 years later it got a new foldable roof divided in four sections. Three sliding components can be pushed together to reduce the visual impact of the roof. In 2009 the theatrical stage with its equipment was moved to the east end and outside the ruined object.
Evaluation	In a folded state of the roof the remaining walls and vaulting bays are still dominant in the overall look of the monument.
References	https://austria-forum.org/af/AEIOU/Graz_Kasematten

Images	  
Source of images	Jiří Bláha, ITAM, 2018. Peter Palme, Graz.

Examples of application, no. 2

Site Specification	Bad Hersfeld Stiftsruine (Abbey Church)
Localization	Bad Hersfeld, Hersfeld-Rotenburg, Kassel District, Hessen Region, Germany 50° 51' 59.57" N 9° 42' 8.90" E
Owner and management	Verwaltung der Staatlichen Schlösser und Gärten Hessen (Administration of the State Palaces and Gardens of Hessen)
Affected part	Former main nave of the mediaeval basilica. One of the largest Romanesque church ruins of Europe.
Intervention reasons	Alterations leading to provide more comfortable auditorium for summer festivals.
Intervention extent	The central mast and fastening spots for 21 anchoring cables. Designed by German architect Otto Frei.
Date of intervention	1968, durability of the roofing sheet is 25 years.
Time consumption	Not known
Results	Cable-suspended membrane structure protects open-air theatre auditorium from rain. With the help of 21 engines, the tent roof can be opened and closed within two and a half minutes.
Evaluation	In a folded state it is comparable to a larger illumination mast. When opened the roof can resists wind loads up to the level of ten grades.
References	BENESCH, R. – TIBKEN, C. 1969: Zusammenraffbare Überdachung für die Stiftsruine in Bad Hersfeld. In: *Stahlbau*, v. 38, n. 10 (October 1969), pp. 306-309. www.stiftsruine.de

Images

Source of images

http://ihrueberflieger.de
Bad Hersfelder Festspiele

Method	Scale modelling
Kind	Visualisation
Basic description	The scale modelling process consists in a physical representation of an object, which maintains accurate relationships between all important aspects of the model, although absolute values of the original properties need not be preserved.
Specification	This enables it to demonstrate some behavior or property of the original object without examining the original object itself. The most familiar scale models represent the physical appearance of an object in miniature, but there are many other kinds.
Range of use	Scale models are used in many fields including engineering, architecture, film making, archaeology, military command, salesmanship, and hobby model building.
Intervention rate	Non-destructive (less invasive)
Main advantages	It's possible reply a complex object in a few hours with high resolution and accuracy.
Negatives or risks	The price and the time needed is higher than for the traditional reproduction methodologies.
References	RICKERT J. 2015: *Printing the Past: 3D Imaging Technologies and Archaeology*. Thesis to University Of Waterloo in fulfillment for the degree of Master of Arts In Public Issues Anthropology.
Available at	https://uwspace.uwaterloo.ca/bitstream/handle/10012/10137/Rickert_Jennifer.pdf?sequence=1
Keywords	Scale modelling, 3D printer
Recording author	Silvia Soldano, SITI

Images	
Source of images	http://www.dailymail.co.uk/news/article-2050919/Henry-VIIIs-lost-Nonsuch-Palace-recreated-300-years-destroyed.html

Examples of application

Site Specification	The arch of Augustus in Susa
Localization	Impero Romano street, Susa, Aosta, Piemonte Region, Italy
Owner and management	Geomatic Laboratory for the Cultural Heritage of Politecnico di Turin
Affected part	The arch of Augustus, the ancient part of the *Praetorium,* the wall of fortification build during III Century and the Castle of Maria Adelaide.
Intervention reasons	Survey record of the damage and testing integrate techniques in order to analyze the ancient part of the city.
Intervention extent	3 different blocks with different complexity.
Date of intervention	2013-11
Time consumption	To print: 1 hour in high resolution
Results	Build a scale model with a 3D printer in order to understand the complexity of the building.
Evaluation	The virtual model has the potentiality to building scale modeling by a 3D printer because they allow to convert numeric information in architectonic model.
References	CHIABRANDO Filiberto – DONADIO, Elisabetta – FERNÁNDEZ-PALACIOS, Belén Jimenez – REMONDINO, Fabio – SPANO', Antonia 2015: L'arco di Augusto a Susa: un nuovo modello digitale per rinnovate indagini, In: *SEGUSIUM - Arco di Augusto - Susa* - Anno LII - pp. 217-232.
Images	
Source of images	Geomatic Laboratory for the Cultural Heritage of Politecnico di Turin

Method	Scanning electron microscopy (SEM)
Kind	Diagnostic
Basic description	The SEM scan a sample with a focused electron beam and deliver images with information about the samples' topography and composition. Magnification in a SEM can be controlled over a range of about 6 orders of magnitude from about 10 to 500,000 times.
Specification	A high-energy electron beam scans across the surface of a specimen, usually coated with a thin film of carbon or metal to improve contrast and the signal-to-noise ratio. As the focused beam scans across the sample's surface, interactions between the sample and the electron beam result in different types of electron signals emitted at or near the specimen surface. These electronic signals are collected, the beam's position is combined with the detected signal to produce an image of the specimen's surface topography that appears three dimensional.
Range of use	The SEM is used in materials science for research, quality control, failure analysis, to generate high-resolution images of shapes of objects and to show spatial variations in chemical compositions. The SEM is also widely used to identify phases based on qualitative chemical analysis and crystalline structure. The SEM analysis enabled the visualization of the preservative deposits in the microstructural level.
Intervention rate	Sampling is required.
Main advantages	The wide-array of applications, the versatile information garnered from different detectors, the detailed three-dimensional and topographical imaging, simple and easy to operate.
Negatives and risks	The size and cost. Preparing the samples, an electron beams are deflected by molecules in the air, requiring the sample to be placed in a vacuum.
References	Goldstein, Joseph I., et al. *Scanning electron microscopy and X-ray microanalysis*. Springer, 2017.
Keywords	SEM, Scanning electron microscopy
Recording author	Dita Machová, CET
Images	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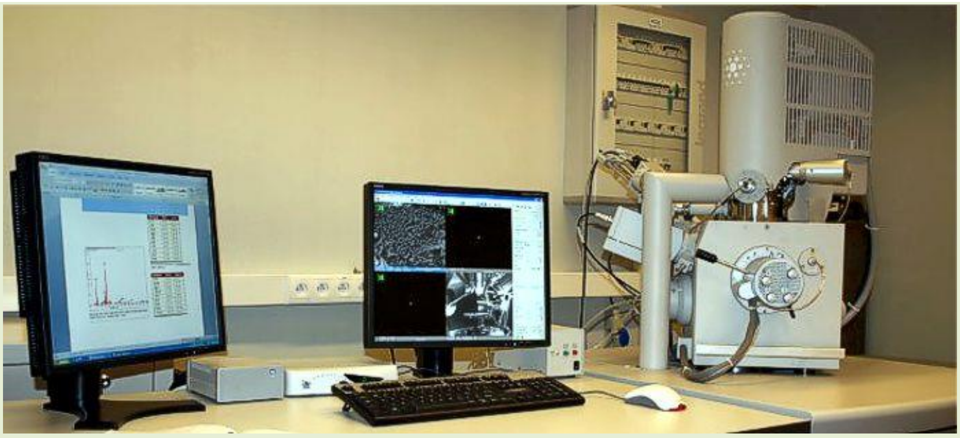
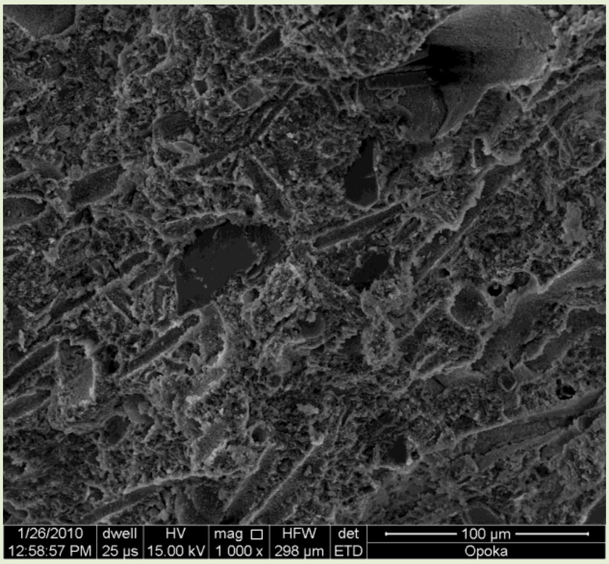
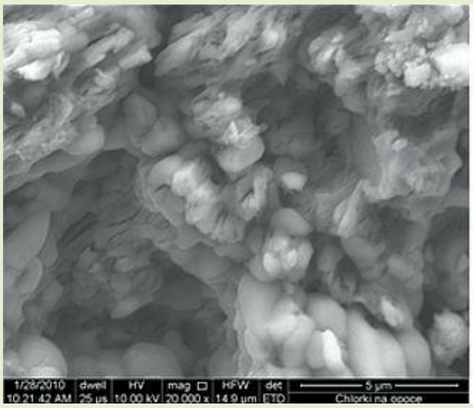
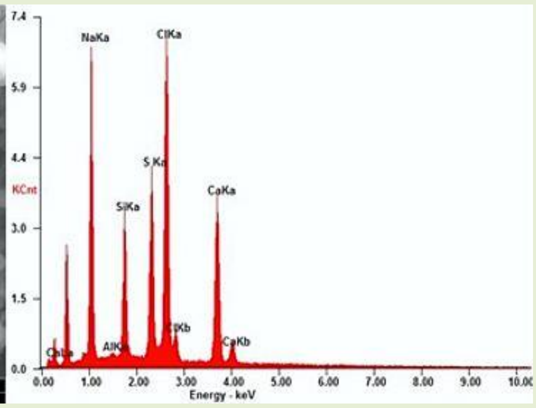








Source of images	Dita Machová, CET ITAM Archive of Construction Engineering and Architecture Department, Lublin University of Technology

Examples of application

To detect the degree of the stone de-cohesion due to the biological colonization, SEM analyses were performed.	Bartoli, F., et al. 2014: Biological colonization patterns on the ruins of Angkor temples (Cambodia) in the biodeterioration vs bioprotection debate. *International Biodeterioration & Biodegradation* 96 (2014): 157-165.
The objective of this research was to evaluate burial soil conditions and whether soils used to help conserve cultural stone heritage. Analyses on thin sections of soil samples for changes in texture and mineral composition was include scanning electron microscopy (SEM).	Zaman, Noreen – Viles, Heather 2012: Reburial of ruins: assessing the role of soil chemical and physical characteristics on stone deterioration in England and New Mexico," *12th International Congress on the Deterioration and Conservation of Stone Columbia University*, New York, 2012.

Method/Technology/Material	Scenic illumination
Kind	Modern infrastructure
Basic description	Illumination is the ephemeral partner of architecture, and lighting design has become a seamless and harmonious extension. Light, shade and gradient of light are important factors that reveal the shape and form of objects according to the direction of light.
More specification	**Lighting of cultural heritage is one of the area's most challenging and complex for lighting designers because of the multiplicity of objectives that should be pursued in the project. The lighting design recommendations related to physical appearance, surrounding areas, lighting** design techniques. Artificial lighting permits the creation of scenes that complement and lead to other readings.
Range of use	Illumination maximises the visualisation of the monument and its surroundings. The lighting reflect the modern role of the historic buildings, where night-time visitors are encouraged, and where special events can have a customized lighting system to add aesthetic appeal or highlight areas of interest.
Intervention rate	In developed countries, external lighting of objects of cultural heritage causes 5% to 20% of total light pollution. Very often, 60% to 80% of the entire light flux misses the facade and is emitted into the sky and the surroundings.
Main advantages	Only a few years ago, LED lamps became sufficiently effective for exterior lighting. The technology has been improving and will probably dominate indoor and outdoor lighting. LED ground lights have the advantage of being discreet and when located next to the building can minimise problems such as glare and being obstructive.
Negatives and risks	No lighting is nature-friendly. The colour combination in the lighting systems provides important visual and aesthetic stresses. Light pollution can reduce human health. In current practice of facade lighting for building, much of the produced light misses the target area, and facade luminance is often far larger than is necessary. This results in a dramatic waste of electrical energy.
References	Guilhot, Alain 2006: The architectural lighting: a new urban writing. Urban night space, Conference proceedings,2006 Kyba, Christopher CM, et al. 2017:A shining example of sustainable church lighting using the EcoSky LED: 96% reduction in energy consumption, and dramatic reduction of light pollution. *International Journal of Sustainable Lighting* 19.2 (2017): 132-132.
Keywords	scenic illumination*, architectural lighting, artificial illumination*
Recording author	Dita Machová, CET

Images	 Bad illuminated church, light is directed into the sky.  Suitable lighting and its regulation.
Source of images	Jan Kondziolka, (http://svetelneznecisteni.cz).

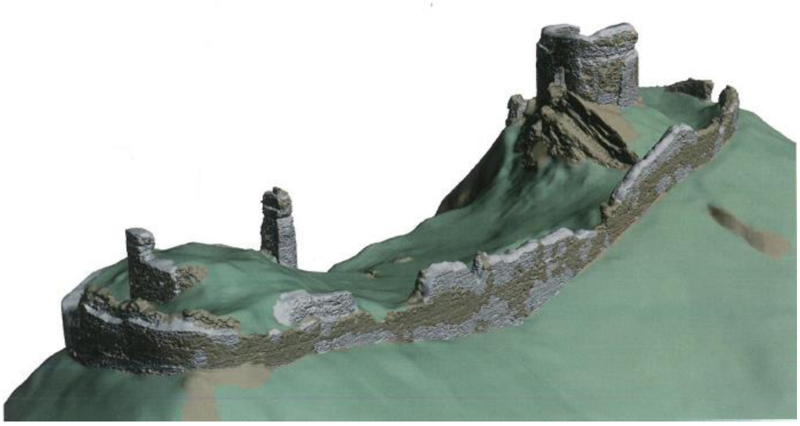
Method	Schmidt impact hammer
Kind	Diagnostic
Basic description	Determination of compressive strength of concrete by means of measuring the rebound of a spring-loaded mass impacting against the surface of the concrete sample.
Specification	Digi-Schmidt: Compressive Strength Range: 10-70 MPa; Display: 128 × 128 px; Memory: 250 measurement series of 10 values each; Battery life: app. 60 h. ND series Digi-Schmidt hammer – digital Schmidt hammer with data storage, impact angle correction and direct display of compressive strength. This, together with on board correction form factor and carbonation, allows the best possible assessment of compressive strength. It comes with a number of pre-programmed correlation curves, allowing the user to select the most suitable for the mixture under test.
Range of use	Used for assessing the condition of normal concrete in precast and monolithic concrete. Operating temperature: -10°C ÷ 60°C
Intervention rate	Semi-destructive (less invasive) method
Main advantages	Fast measurement, immediate result, non-destructive tests, suitable for on-site surveys.
Negatives or risks	Indicates only the hardness of the surface layer. Five valid impacts needed for one spot testing. The position of the instrument must be recorded to take account of the effect of gravitation.
Available at	Construction engineering Laboratory in Lublin University of Technology
Keywords	Digital hammer, impact resistance, Schmidt, sclerometer, sclerometrics
Recording author	Maciej Trochonowicz, Lublin University of Technology
Images	

Source of images	Archive of Construction Engineering and Architecture Department, Lublin University of Technology

Method	Soft (turf) capping
Kind	Remedial
Basic description	Dismantle of some upper layers on wall top, lay a new masonry using lime mortar, adjust the upper surface layer in such gradient that enable drainage of water. Planting of turf cover absorbing water (Sokol – Durdík – Štulc 1998, 17).
More specification	Repair of masonry and filling in missing mortar in masonry, if possible preserve upper turf layer, if it has suitable composition and structure, it is necessary to be maintained in order to prevent growth of trees and bushes, but in most cases is necessary to repair wall top in whole extent. It is suitable to consult situation by botanist who can advise how to remove turf and preserved it during repair, how to complete turf or where to obtain plants needed. (Žižka 2011, 27).
Range of use	For the too high and thin walls the metal plates are preferably recommended instead.
Intervention rate	Minor
Main advantages	The turf cover moderates moisture naturally, surplus moisture evaporates.
Negatives and risks	Not to keep holes on wall top, where water can stay. The adjustments for keeping turf layer cannot be superior to preservation of original substance of wall. Use of turf prepared in advance was not successful .
References	LEE, Zoe – VILES, Heather – WOOD, Chris (eds.) 2009: Soft capping historic walls. A better way of conserving ruins? English Heritage Research Project, Unpublished Report, Oxford 2009, 70pp. SCHUBERT, Alfréd 1998: Opravy hradů, městských hradeb a jiných neúplně dochovaných staveb. Požadavky památkové péče a jejich řešení. Instadsetzungen von Burgen, Stadtmauern und andren unvollständig erhaltenen Bauwerken. Anforderungen der Denkmalpflege und ihre technische Ausführung. In: Zříceniny historických staveb a jejich památková ochrana. Příloha časopisu ZPP 58, 47-57. SOKOL, Jan – DURDÍK, Tomáš – ŠTULC, Josef 1998: Ochrana, údržba a stavební úpravy zřícenin hradů, Příloha časopisu ZPP 58. Praha. ŽIŽKA, Jan 2011: K technologii a stavebním postupům při opravách torzálně dochovaných staveb. Zu der Technologie und den Bauvorgängen bei der Instandsetzung der Bauwerktorsos. PSČ 25/2, 18-36.
Keywords	Wall tops, turf, conservation
Recording author	Stanislav Vohryzek, ITAM

Examples of application

Site Specification	Hrad Valdek (Valdek Castle)
Localization	Chaloupky, Middle Bohemia, Czech Republic
Owner and management	Vojenské lesy a statky ČR, s. p.
Affected part	Entrance gate of the castle
Intervention reasons	Stabilization of the gate
Intervention extent	
Date of intervention	After 2010
Time consumption	Not known
Results	Stabilization of east side of gate
Evaluation	
References	ŽIŽKA, Jan 2011: K technologii a stavebním postupům při opravách torzálně dochovaných staveb. Zu der Technologie und den Bauvorgängen bei der Instandsetzung der Bauwerktorsos. PSČ 25/2, 18-36.
Images	
Source of images	Žižka 2011, 28.

Site Specification	Hrad Hamrštejn
Localization	Liberec XXXIII-Machnín, Liberec region, Czech Republic
Owner and management	Lesy České republiky, s. p.
Affected part	Top of walls
Intervention reasons	Conservation and preservation.
Intervention extent	Top of wall covered by clay and turf, in some parts a method of “three lost stones” is used (supplementation of the wall top with three layers of stones, which can counter to effects of weather). After removal of vegetation, debris and incoherent masonry, the coherent layers were consolidated with POROSIL ZTS, restored to their original form and covered with layers “to be sacrified”. Then the top of wall was cover with mortar and conservation solution POROSIL ZV 20 and hydrophobized with POROSIL VV 10 plus. Next day the top of wall was covered with clay covered with turf from local sources. Thin or unfavourably tops were covered with lead plates. (Kudrnovský et al. 2010, 74).
Date of intervention	2011 first phase – stabilisation of the North tower,
Time consumption	Not known
Results	Stabilization of the North tower.
Evaluation	
References	KUDRNOVSKÝ, Miloš – ŠVEJNOHA, Josef – VESELÁ, Renata 2010: Stabilizace a konzervace zříceniny hradu Hamrštejn. Stabilisierung und Konservierung der Burgruine Hamrštejn In: *Hamrštejn. Minulost, přítomnost a budoucnost zříceniny hradu*. Liberec 2010, s. 65-77, 84.
Images	
Source of images	Kudrnovský et all. 2010, 69 (castle seen from the north-west)

Site Specification	**Hrad Orlík u Humpolce**
Localization	Rozkoš, local unit of the town Humpolec, Vysočina Region, Czech Republic
Owner and management	Humpolec Town
Affected part	West curtain wall, upper castle.
Intervention reasons	Protection of the wall top, separation of the clay layer against contamination.
Intervention extent	Use of clay, geotextile, turf (Kocman 2009, 165; 2010, 19-20).
Date of intervention	2001
Time consumption	Not known.
Results	Stabilization of upper wall.
Evaluation	Unsatisfactory (see picture), after 2007 not in use on this castle.
References	KOCMAN, František 2009: Orlík nad Humpolcem. *Zpravodaj Stop*. Časopis společnosti pro technologie ochrany památek 11/2009/3, 11-22. KOCMAN, František 2010: Záchranné práce. In: *Hrad Orlík nad Humpolcem*. Humpolec, 124-176.
Images	
Source of images	Kocman 2009, 17.

Method	Soil compaction assessment
Kind	Diagnostic
Basic description	Light weight deflectometer allows measuring of surface deflection (Ev). Knowing correlations in surface deflection, it is possible to directly determine soil compaction index (Is).
Specification	Zorn ZFG 3000 GPS Dynamically loaded plate - 10/15, 10 and 15 kg track, probing range: 5-70 MN/m2 Evd and 70-105 MN/m2 Evd. The device is equipped with printer which allows for printing diagrams, charts, and analysis results. Alternatively, results can be saved onto an SD card and read in dedicated computer software. The measurements are recorded by electronic device connected to the plate with a cable.
Range of use	The device is used for determining soil compaction when laying floors, foundations, roads, etc. The plate serves the function of monitoring soil layers in embankments and by filling pits for the purposes of land exchange. The analysis is easy to conduct - a thirty-centimetre plate (in diameter) must be loaded dynamically. After three trial loads, proper surface deflection measurement is taken.
Intervention rate	Non-destructive method
Main advantages	Results are available in three minutes; could be operated by just one person. After the measurement is taken, it is immediately possible to determine whether soil compaction of the plot being analysed is sufficient.
Negatives or risks	Depth is limited to 50 cm (it is possible to dig a pit and analyse even deeper layers)
References	
Available at	Construction engineering Laboratory in Lublin University of Technology
Keywords	Dynamically loaded plate, soil compaction, soil deflection
Recording author	Maciej Trochonowicz, Lublin University of Technology

Images	 
Source of images	Archive of Construction Engineering and Architecture Department, Lublin University of Technology

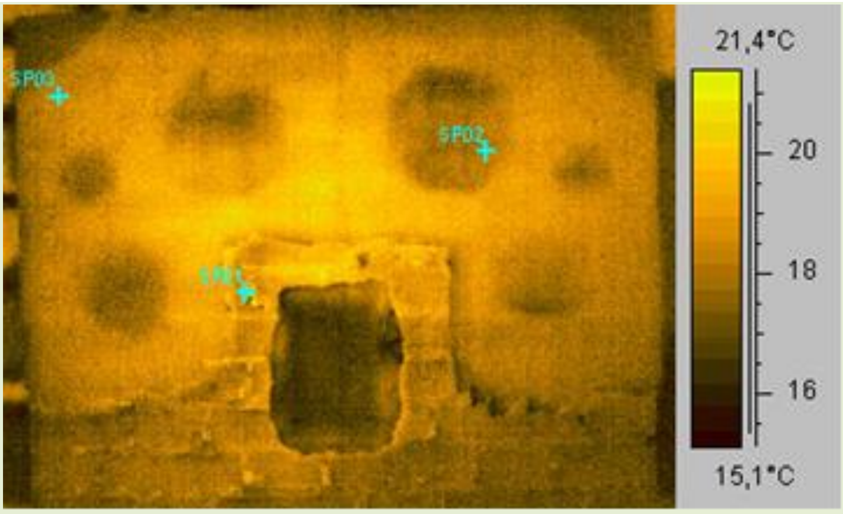
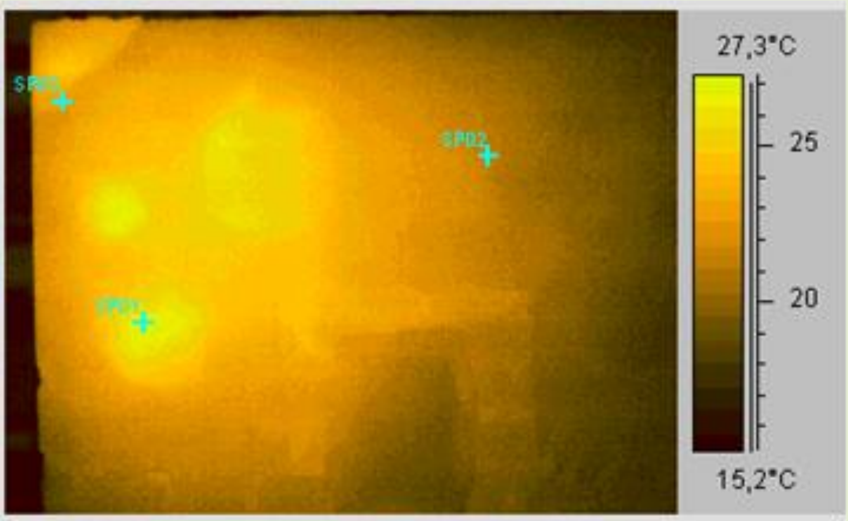
Method	Thermal analysis (TA)
Kind	Diagnostic
Basic description	The thermal analysis determines properties of materials as they change with temperature.
Specification	Group of physical chemical methods which deal with studying materials and processes under conditions of programmed changing's of the surrounding temperature. The most common methods used in soil analysis record transformations by means of the temperature either of mass, energy, or the mechanical properties of the samples.
Range of use	The thermal analysis can provide information about the composition of materials (thermal decomposition of solids and liquids, solid-solid and solid-gas chemical reactions, material specification, purity and identification, inorganic solid material adsorption, or phase transitions).
Intervention rate	Sampling is required, destructive method.
Main advantages	The rapidity of determination, small sample masses, versatility, simplicity, applicable, the minor amount of sample is required.
Negatives and risks	Relative low accuracy and precision.
References	PANSU, Marc – GAUTHEYROU, Jacques 2007: *Handbook of soil analysis: mineralogical, organic and inorganic methods*. Springer, 2007. PIRES, J. – CRUZ, A. J. 2007: Techniques of thermal analysis applied to the study of cultural heritage. *Journal of Thermal Analysis and Calorimetry* 87.2 (2007): 411-415.
Keywords	Thermal analysis, TA
Recording author	Dita Machová, ITAM

Images	
Source of images	Dita Machová, CET

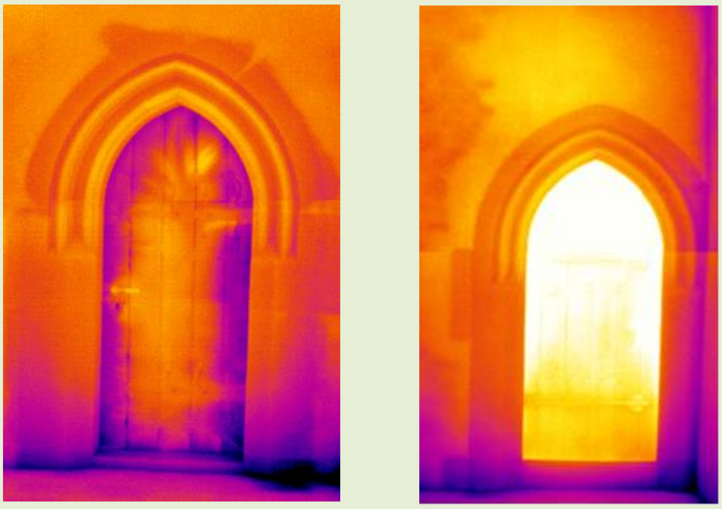
Examples of application

The study about some ancient Egyptian mortars, from Sphnix, which showed by thermal analysis that significant differences on the compositions of mortars of the same edifice can be found.	RELLER, A., et al. 1992: *Comparative studies of ancient mortars from Giza, Egypt, and Nevali Çori, Turkey*. MRS Online Proceedings Library Archive 267 (1992).
Thermal analysis, together with other analytical techniques, has been used to characterise the weathered and un-weathered stone samples.	**FRIOLO, K. H., et al. 2005: Thermal analysis of heritage stones. *Journal of thermal analysis and calorimetry* 80.3 (2005): 559-563.**

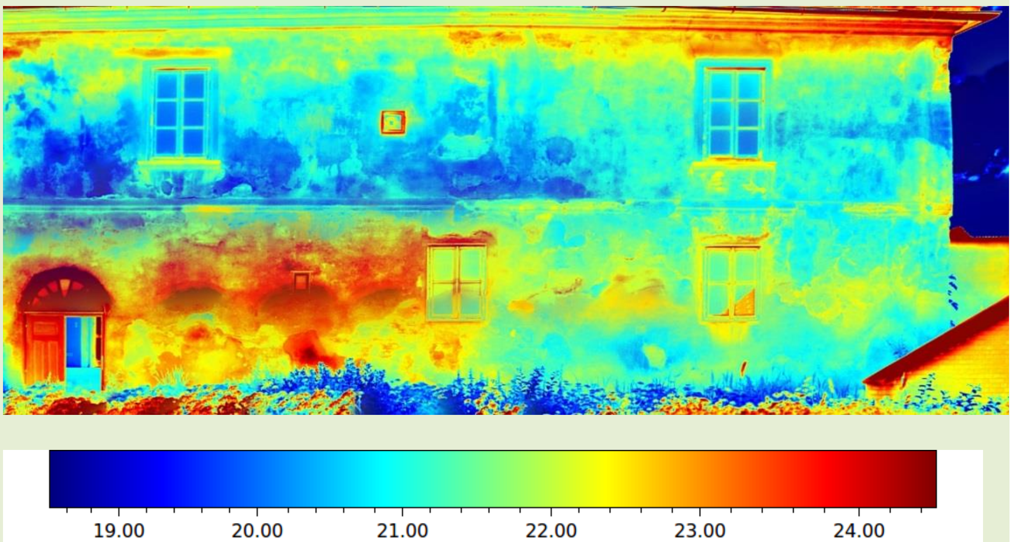
Method	Active thermography
Kind	Diagnostic
Basic description	The method detects warming and cooling processes in non-metallic bodies after or during their internal or external heating.
Specification	In civil engineering rather passive thermography indicating heat loss has been applied, nevertheless, the active variant is suitable for detection of defects (voids) inside materials of low conductivity. It takes advantage of different heat propagation in a body with subsurface defects which is manifested by different surface temperature distinguishing the integral parts from the parts possessing subsurface discontinuities. The application requires external heating or cooling of the measured region. In practice, an environmental heating/cooling variant is preferred. It exploits natural (sun) heating of a measured region during the day and natural cooling with fresh air during night, which is enough to generate measurable differences.
Range of use	The method is optimal for indication of plaster detachment. Here the detection of loosed parts is based on an idea to measure their differential cooling or heating compared to the heavy and integral parts with higher thermal inertia and different conductivity. Further, it helps to study hidden structure of masonries without removal of render or plaster. It is capable to reveal masonry interventions and changes, e. g. hidden walled up historic openings.
Intervention rate	Non-destructive
Main advantages	Very fast method, low cost operation, area measurements, direct localization of defects
Negatives and risks	Expensive thermo-camera, not known depth of defects, know how for evaluation on large surface areas, overheating when external source is applied
References	DRDÁCKÝ, M., LESÁK, J. 2006: Non-invasive survey of detachment of historic rendering. In: Fort, Alvarez de Buergo, Gomez-Heras & Vazquez-Calvo (eds.): *Proceedings “Heritage, Weathering and Conservation”*,, Taylor & Francis Group, London, 2006, 591-597. DRDÁCKÝ, M.F. – LESÁK, J. 2007: Non-destructive diagnostics of shallow subsurface defects on masonry. In: L. Binda, M. Drdácký and B. Kasal (eds.): *In-Situ Evaluation & non-destructive testing of historic wood and masonry structures* –, NSF/MŠMT/RILEM, ITAM, Praha 2007, pp. 140-147.
Keywords	Thermography, subsurface defects, hidden masonry structure
Recording author	Miloš Drdácký, CET ITAM

Images	  Temperature distribution on the plaster surface (in the central part a mortar plate was fixed along its edges with a deep gap under it). The upper picture shows a situation during external cooling of a pre-heated masonry, the lower the temperatures during external heating of the composed system. Well visible are different material layers, render detachment areas, joints between bricks and fixing mortar under the plate.
Source of images	Miloš Drdácký, Jaroslav Lesák, ITAM

Examples of application, no. 1

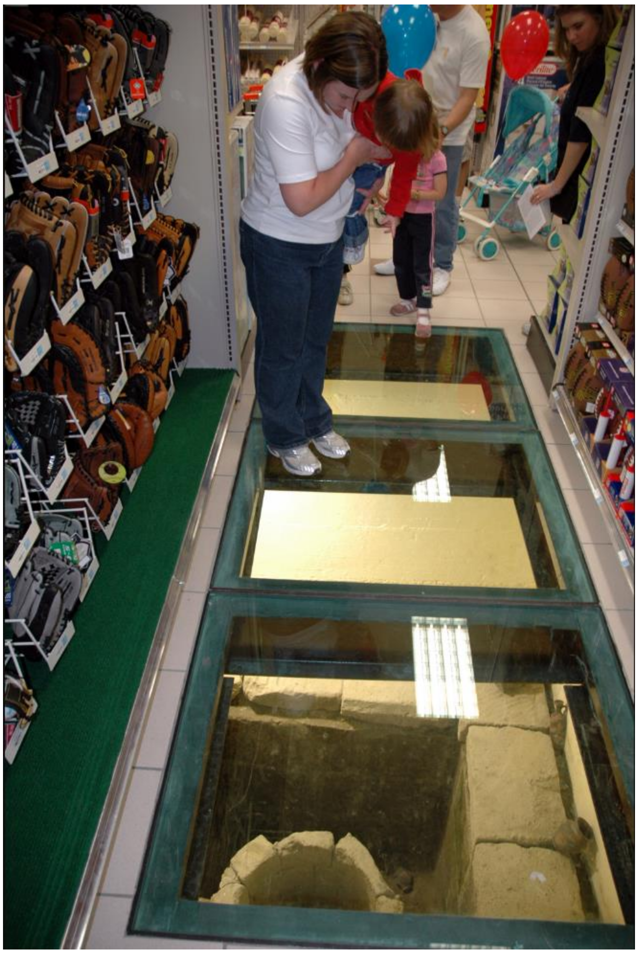
Site Specification	**Karlštejn Castle**
Localization	Karlštejn Nr. 172, Beroun District, Central Bohemia Region, Czech Republic
Owner and management	National Heritage Institute
Affected part	St. Maria Tower walls
Intervention reasons	Survey of original structural parts
Intervention extent	Untouched
Date of intervention	2003
Time consumption	About one hour
Results	Revealed shapes of door frames hidden under plastering.
Evaluation	Irregular stone parts in the masonry indicate original door frame, regular frames not integrated in the masonry are later interventions during the ruin restoration.
References	DRDÁCKÝ, Miloš – JIROVSKÝ, Ivo – LESÁK, Jaroslav 2003: *Nedestruktivní průzkum zděných a dřevěných konstrukcí Mariánské věže na hradě Karlštejně,* Zpráva ÚTAM AV ČR (grant MK ČR PK99P04OPP006, GAČR 103/03/0581 a MŠMT KONTAKT ME660), 63 str., Praha/Telč, 2003.
Images	 Original stone door frame (left) and a recent stone frame (right).
Source of images	Miloš Drdácký, Jaroslav Lesák

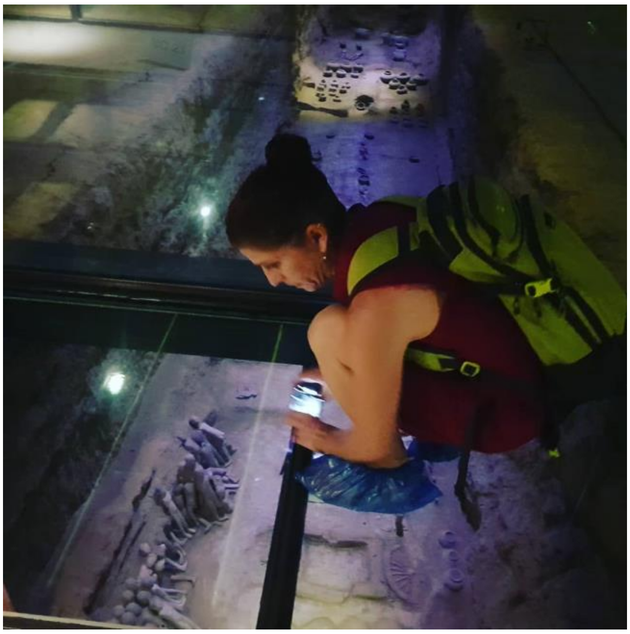
Examples of application, no. 2

Site Specification	Eisgarn Monastery
Localization	Eisgarn, Gmünd District, Lower Austria Region, Austria
Owner and management	Kollegiatstift Eisgarn
Affected part	Wall
Intervention reasons	Survey of original structural parts
Intervention extent	Untouched
Date of intervention	2015
Time consumption	About one hour
Results	Revealed shapes of door frames hidden under plastering.
Evaluation	Irregular stone parts in the masonry indicate original door frame, regular frames not integrated in the masonry are later interventions during the ruin restoration.
References	DRDÁCKÝ, Miloš – Adámek, Jiří 2016: Rukověť stavební diagnostiky / Händbuch für Baudiagnostik, kapitola v knize „*Příručka revitalizace – Sanace a zachování církevních staveb / Revitalisierungsleitfaden – Sanierung und Erhalt kirchlicher Bauten*“. St. Pölten: Diözesanarchiv St. Pölten, 2016, pp. 56-91.
Images	

	 The older interventions in the masonry (walled up windows and arches) are clearly visible
Source of images	Drdácký, Miloš; Lesák, Jaroslav

Method	Transparent floors
Kind	Modern facilities
Basic description	Transparent walkable panels built into the floor allow seeing ruins in their original context along with other archaeological artifacts.
Specification	Transparent floors are made mostly from steel and reinforced glass. They are designed for the safe movement of persons or eventually lighter vehicles.
Range of use	Presentation of archaeological excavations in intensively used buildings or in public space. Protection from weather effects and vandalism.
Intervention rate	Minimally invasive – transparent panels are usually incorporated into modern flooring.
Main advantages	Allows to combine presentation of ruins together with almost any use of the building or public space. May be designed in synergy with wall based ventilation.
Negatives or risks	In the course of time, glass surface is usually scratched and its transparency is reduced. A combination of light and higher temperature with ground humidity may lead to intense growth of algae and mosses. Transparency can be spoiled because of water condensation, so effective ventilation must be ensured.
References	NIJSSE, Robert 2003: *Glass in Structures: Elements, Concepts, Designs*. Basel, Boston – Birkhäuser Verlag, 2003.
Available at	There are a number of systems suitable for public buildings on the market.
Keywords	Walk-on glass floors, archaeological excavations, heritage presentation
Recording author	Jiří Bláha, ITAM
Images	

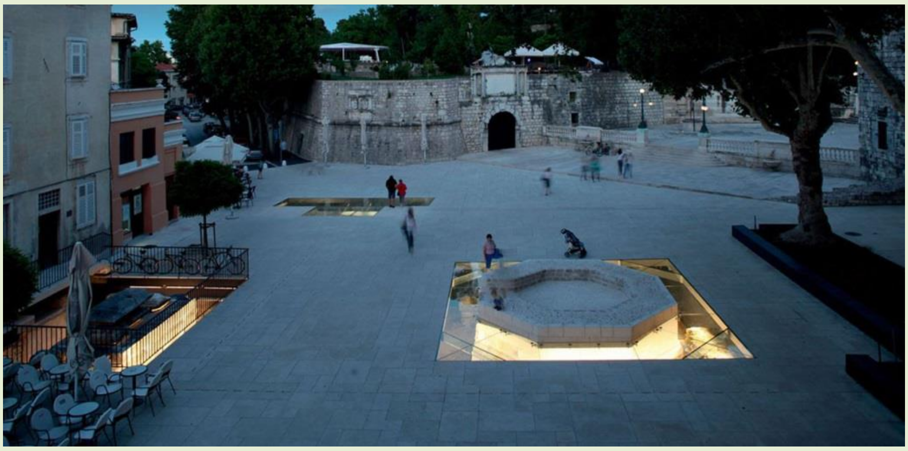
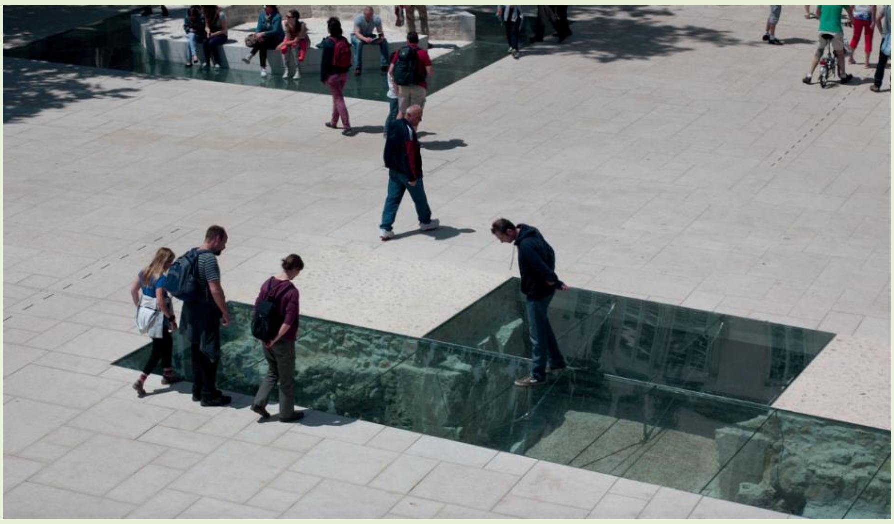


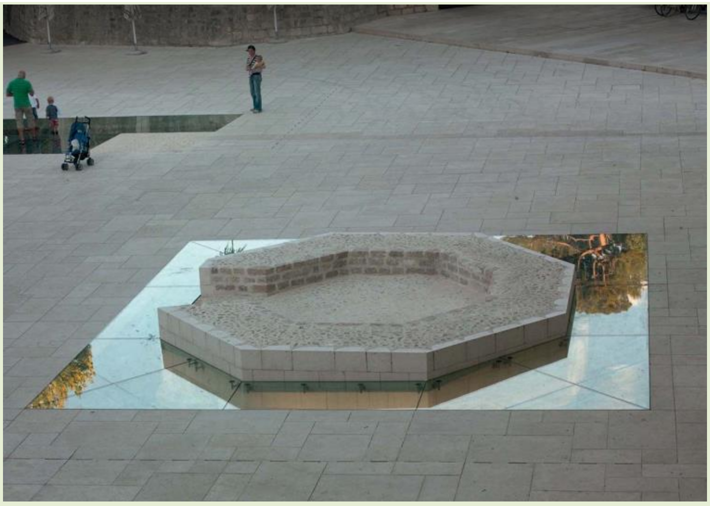


Source of images	Wikipedia

Examples of application

Site Specification	Trg Petra Zoranića (Petar Zoranic Square)
Localization	Zadar, Dalmatia Region, Croatia
Owner and management	City of Zadar
Affected part	The area of the square (2900 m2) paved with limestone slabs.
Intervention reasons	Presentation of a selected part of the foundations of the buildings exposed during the archaeological research of the square compatible with the everyday uses of the square. Making a “glass interface” between the Roman and medieval finds below and the contemporary square above.
Intervention extent	Three spots were chosen to offer a visual contact with archaeological situations. Found base of the octagonal Roman tower was completed up above the level of the terrain and modified for casual sitting.
Date of intervention	2011-2013
Time consumption	Not known
Results	The project was prepared by architects Aleksandra Krebel and Alan Kostrenčić. Three glass sections laid level with the ground are integrated into the architectural design of the square. They are offering views into the past of the city and profiting from the mirroring effect in its present life. They also manifest themselves in night illumination.
Evaluation	The square has been widely accepted as a place of social events, and is a favourite place for and casual meetings.
References	FADIĆ,Ivo – ŠTEFANAC, Berislav 2011: **Geneza grada** na Trgu Petra Zoranića u Zadru. (Genesis of the City of Zadar at Petar Zoranić Square). In: *Histria Antiqua*, 20/2011, pp. 325-332. https://www.archdaily.com/478606/petar-zoranic-square-and-sime-budinic-plaza-kostrencic-krebel

Images	  



Source of images

Damir Fabijanić
Jiří Bláha, 2017

Method	**Transparent protective roofs**
Kind	Modern facilities
Basic description	Mostly stand-alone roofs or shelters newly designed to preserve exposed archaeological sites or extra valuable parts of ruins (wall paintings, floors, etc.).
Specification	Transparent roofs can be designed as light skeletal or suspended membrane structures made mostly from steel and glass. Using of timber or polycarbonate is also possible but not so common.
Range of use	Protection of archaeological excavations from weather effects.
Intervention rate	Invasive; such roofs are normally anchored to walls outside the area with the most valuable situations.
Main advantages	Protection from weather effects, in case of complete encasement the sites are secured also against vandalism or approach of bigger animals.
Negatives or risks	New roofs usually change significantly a specific character of the place. Changing of climatic conditions may sometimes paradoxically lead to more intense damage (condensation of water, biodegradation). Vertically oriented glass causes unpleasant light reflections.
References	
Available at	Individual design
Keywords	Roofs, membrane roofs,
Recording author	Jiří Bláha, ITAM
Images	 Graz, Austria, St. Egidius Church, glass panels protect mediaeval wall paintings from weather or graffiti but unfortunately also from being seen
Source of images	Jiří Bláha, ITAM 2018

Examples of application

Site Specification	Roman Bath Ruins in Badenweiler
Localization	Breisgau-Hochschwarzwald District, Baden-Württemberg Region, Germany
Owner and management	Staatliche Schlösser und Gärten Baden-Württemberg (state heritage agency)
Affected part	The best preserved Roman spa complex situated north of the Alps. Roofed area is about 2,500 m².
Intervention reasons	The requirement was transparent structure to protect the ruins of the antique Roman bath from exposure to weather.
Intervention extent	The metal bearing structure of the roof is anchored by concrete blocks in the ground.. The total length of the roof is 67 m, max. span 40 m.
Date of intervention	2001
Time consumption	Not known
Results	Glass roof designed by Stuttgart engineers and consulting company Schlaich, Bergermann und Partner protects the most valuable parts of historical site including spa basins.
Evaluation	Glazed shell structures was intended to provide an optimum in transparency. In fact it is a distinctly dominant modern structure providing protection for exposed excavations. Shading is used to moderate climate under the roof.
References	https://www.sbp.de/en/project/protection-roof-for-roman-bath-ruins-in-badenweiler/ Çetin, F. Y. – İpekoğlu, B. 2013: Impact of transparency in the design of protective structures for conservation of archaeological remains. In: *Journal of Cultural Heritage* 14S (2013) e21–e24.
	

Images	 
Source of images	http://alamanicus.com, 2012 Jörg Holtermann 2007

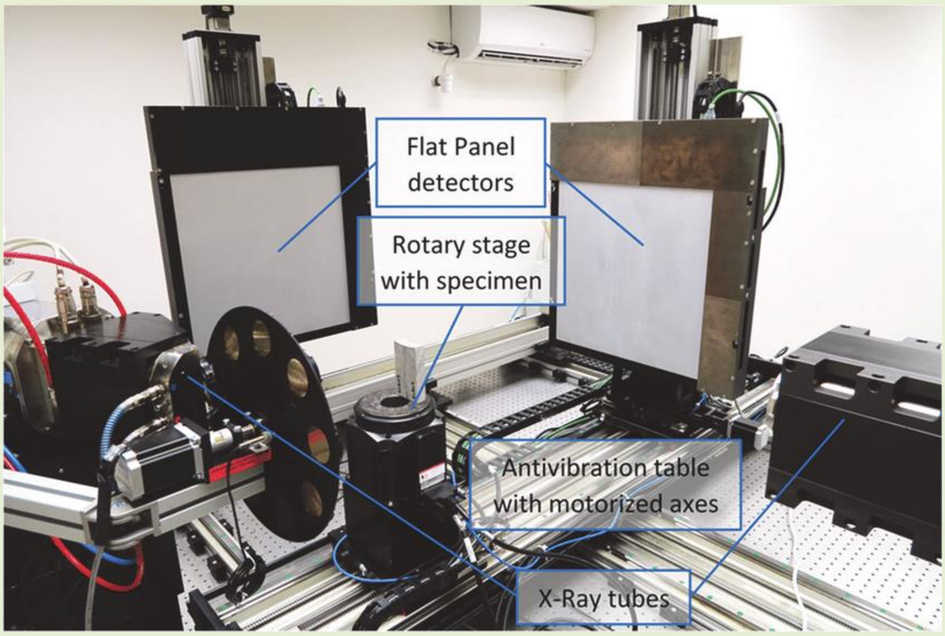
Method	Ultrasonic testing
Kind	Diagnostic
Basic description	Ultrasonic pulse-waves with certain frequencies are transmitted into homogeneous materials in terms to detect internal defects or to closer characterize materials.
Specification	Pundit Lab is an ultrasonic testing instrument designed for analysing of concrete or stone, enabling compression strength tests (correlation in computer software), integrated course, and real-time marker. The results are correlated with software database dedicated to a device. It has memory with 500 measured values, data transmission to PC via dedicated Pundit Link software, three types of power supply – battery, mains, PC (via USB charger or cable).
Range of use	Pulse velocity measurement, pulse width measurement; ultrasonic measurement of concrete elements by using direct, semi-direct, and indirect transmission; determining the depth of vertical cracks; analysing uniformity of concrete, rock, graphite, ceramics, wood, etc.; determining distance between transducers Operating temperature: -10°C ÷ 60°C.
Intervention rate	Non-destructive (non-invasive) method
Main advantages	Easy to use also in on-site inspections: compact-size, light-weight, easy to operate, large display showing immediately measured time value.
Negatives or risks	Unsuitable for layered or laminated materials. The most reliable when placing the probes in an opposing position.
References	BLITZ, Jack – SIMPSON, Geoff 1996: Ultrasonic Methods of Non-destructive Testing. London 1996, 264 p.
Available at	Construction engineering Laboratory in Lublin University of Technology
Keywords	Ultrasonic wave, pulse width, uniformity assessment, crack, decay detector
Recording author	Maciej Trochonowicz \ Lublin University of Technology

Images	 
Source of images	Archive of Construction Engineering and Architecture Department, Lublin University of Technology

Examples of application

The analysis has been carried out on a trachite stone masonry with an inside cavity. The wall wass 90 cm wide, 62 cm high and 38 cm thick, and it is made of trachite blocks sized 20×38×12 cm jointed with cement lime mortar. The block assigned to the central position of the wall was not settled, thus realizing a macrocavity with the same size of the missing block, and assumed as a known anomaly. Mortar joints have been assumed to be 1 cm thick.	CANNAS, B. – CARCANGIU, S. –CONCU, G – FANNI, A. – USAI, M. 2011: Numerical Simulations of Ultrasonic Non Destructive Techniques of Masonry Buildings. In: *Proceedings of the 2011 COMSOL Conference in Stuttgart.*

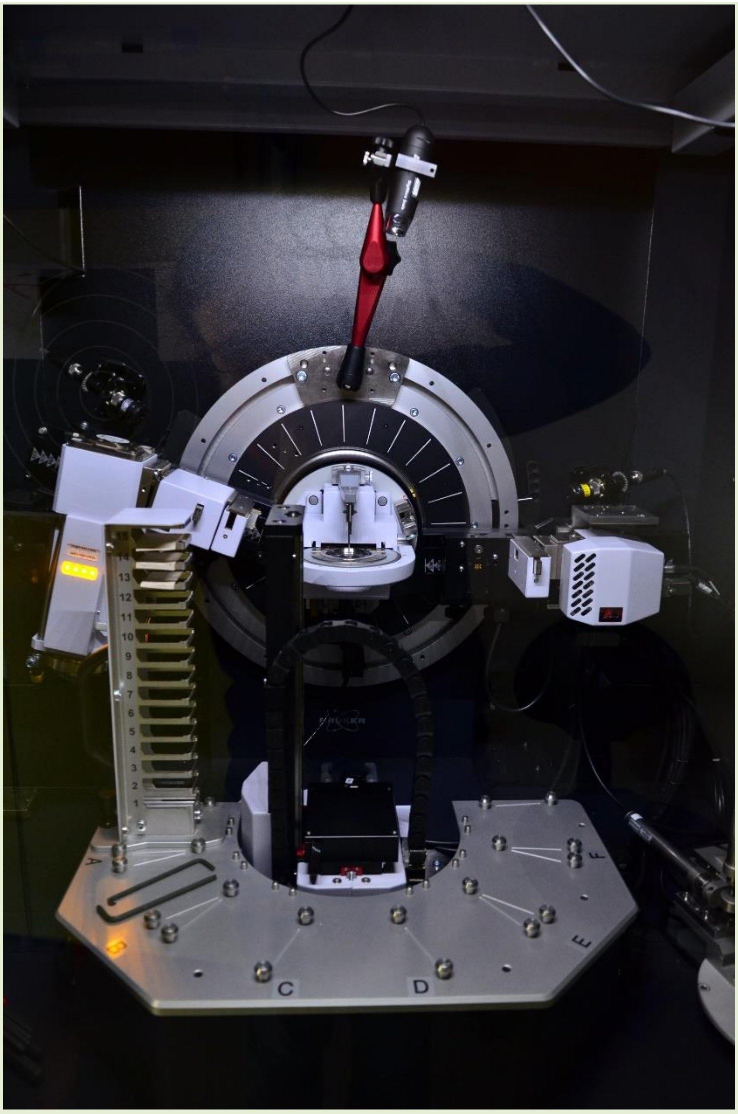
Method	X-ray computed tomography (CT)
Kind	Diagnostic method.
Basic description	*The method is able to give morphological and physical information on the inner structure of the investigated sample. The* high resolution rendering of very small objects is commonly possible, the tomography of large objects still represents a challenge.
More specification	The tomographic imaging consists of directing X-rays at an object from multiple orientations and measuring the decrease in intensity along a series of linear paths. This decrease is characterized by Beer's Law, which describes intensity reduction as a function of X-ray energy, path length, and material linear attenuation coefficient. A specialized algorithm is then used to reconstruct the distribution of X-ray attenuation in the volume being imaged. It useful for determining adequate conservation and restoration procedures and for the inspection and the classification of the object. The Centre of Excellence Telč using the world-unique patented TORATOM device (Twinned Orthogonal Adjustable Tomograph) which is a part of their equipment. This arrangement provides high modularity, large area 2D scanning as well as simultaneous dual source, it is able to operate different types of detectors and its detector holders are designed for fast and easy detector change. It is very useful and helpful method for example in archeology. First version of transportable CT systems specifically designed for Cultural Heritage analysis was developed in 2010 at University of Bologna in Italy. Actual version of mobile system operates regularly in a number of case studies per year.
Range of use	The X-ray CT can be used for the investigation of different works of art, as it preserves the integrity of the object and gives morphological and physical information on its inner structure. The X-ray CT is used to examine the capillary penetration of a consolidant, or to assess consolidant effectiveness.
Intervention rate	A non-destructive and non-invasive.
Main advantages	A little or no sample preparation required, provides images that help visualize areas of different densities inside the object without any overlay planes. The 3D rendering allows also a virtual manipulation of the reconstructed volume, therefore it is possible to enhance significant details or isolate regions of interest.
Negatives and risks	It is still difficult to see treatments and salts inside pores owing to the lack of contrast and the small amount of material scanned. It is posing a potential downside for public health. The cost.
References	Bettuzzi, Matteo, et al. "A mobile computed tomography system for on-site cultural heritage analysis." *Environment and Electrical Engineering and 2017 IEEE Industrial and Commercial Power Systems Europe (EEEIC/I&CPS Europe), 2017 IEEE International Conference on*. IEEE, 2017. Fíla, Tomas and Vavřík, Daniel "A multi-axial apparatus for carrying out x-ray measurements, particularly computed tomography." *European patent 14002662.6, granted 24.02. 2016.* (2016). Morigi, M. P., et al. 2010: Application of X-ray computed tomography to cultural

	heritage diagnostics. *Applied Physics A* 100.3 (2010): 653-661.
Keywords	X-ray, Computed tomography, CT, Radiation
Recording author	Dita Machová, CET
Images	
Source of images	Ivana Kumpová, CET

Examples of application

To collect information on saline uptake and salt precipitation was used X-Ray tomography.	*Derluyn, Hannelore, et al. 2013: Characterizing saline uptake and salt distributions in porous limestone with neutron radiography and X-ray micro-tomography. Journal of building physics 36.4 (2013): 353-374.*
The ability of water repellents and consolidants to penetrate inside natural building stones was determinated by X-Ray tomography (to determine depth of water repellents and consolidant).	*Cnudde, Veerle, et al. 2004: X-ray micro-CT used for the localization of water repellents and consolidants inside natural building stones. Materials characterization 53.2-4 (2004): 259-271.*

Method	X-ray diffraction (XRD)
Kind	Diagnostic
Basic description	***The XRD (***X-ray diffraction)***, or X-ray* Powder Diffraction**, is used for determining the atomic and molecular structure of a crystal, it can provide information on unit cell dimensions. The XRD is based on constructive interference of monochromatic X-rays and a crystalline sample.
More specification	The solid sample is irradiated by a collimated beam of monochromatic X-rays of known wavelength. A proportion of these are diffracted at angles which depend on crystal structure of the specimen. Lattice constants of a crystalline phase can be calculated easily from powder diffraction data when its crystal structure is known.
Range of use	XRD is used for the identification of unknown crystalline materials (e.g. minerals, inorganic compounds), it is an important tool in studying stone or mortars in recognizing their composition, the degradation or conservation state and, in some cases, their provenance. A portable X-ray diffraction (XRD) system, based on energy dispersive detection in reflection geometry, has been developed for the non-invasive study of cultural heritage materials.
Intervention rate	Sampling is required (grinding, milling, or polishing).
Main advantages	Powerful and rapid technique for identification unknown mineral, data interpretation is relatively straight forward.
Negatives and risks	There is no "standard" way to prepare a specimen for powder diffraction, and the most important consideration is the objective of the experiment. Technique is much more accurate for measuring large crystalline structures rather than small ones. Small structures that are present only in trace amounts will often go undetected by XRD readings, which can result in skewed results.
References	JENKINS, Ron – SNYDER, Robert L. 2012: *Diffraction theory*. John Wiley & Sons, Inc., 2012.
Keywords	XRD, X-ray, powder diffraction
Recording author	Dita Machová, ITAM
Images	



Source of images	Petra Mácová, ITAM

Examples of application

The use of lime (Ca(OH)2), in building industry as in Cultural Heritage conservation, is based on the well-known carbonation reaction and on the characteristics of calcium carbonate (CaCO3) obtained. To correlate the nanolime produced to its properties, morphological and microstructural characterisations are performed by X-ray diffraction. XRD measurements allow, as a matter of fact, to determine the crystalline phases (data from JCPDS), to estimate crystallites dimension (D) (Scherrer equation), and to understand the completeness of the carbonatation reaction.	*DANIELE, Valeria –TAGLIERI, Giuliana – QUARESIMA Raimondo 2008: The nanolimes in Cultural Heritage conservation: Characterisation and analysis of the carbonatation process. In: Journal of cultural heritage 9.3 (2008): 294-301.*
The salt content and pH evolution in solutions produced by the water-soluble extraction of accumulated pigeon droppings are a plausible source of salts commonly found on buildings. A noticeable deterioration in limestone due to acid attack was observed, including surface etching of rock forming minerals. The mixture of salts were analysed using an X-ray powder diffractometer.	*GÓMEZ-HERAS, Miguel, et al.2004: Soluble salt minerals from pigeon droppings as potential contributors to the decay of stone based Cultural Heritage. European Journal of Mineralogy 16.3 (2004): 505-509.*
The effectiveness of four polymeric water repellent coatings used for the protection of two monumental limestones, commonly used as building materials. The crystallographic structure of the stone samples was studied by X-ray diffraction.	*SIMIONESCU, Bogdana – OLARU, Mihaela 2009: Assessment of siloxane-based polymeric matrices as water repellent coatings for stone monuments. European Journal of Science and Theology 5.1 (2009): 59-67.*

Method	XRF (X-ray fluorescence) spectroscopy
Kind	Diagnostic
Basic description	The XRF is defined as the emission of characteristic “secondary” (or fluorescent) X-rays from a material that has been excited by bombarding with high energy X-rays or gamma rays. An element is identified by its characteristic X-ray emission wavelength or energy. The amount of an element present is quantified by measuring the intensity of its characteristic emission.
Specification	*The XRF is a process whereby electrons are displaced from their atomic orbital positions, releasing a burst of energy that is characteristic of a specific element. This release of energy is then registered by the detector in then XRF instrument, which in turn categorizes the energies by element.* The elements are identified by the wavelengths (qualitative) of the emitted X-rays while the concentrations of the elements present in the sample are determined by the intensity of those X-rays (quantitative). *Thereby, there are two main types of XRF spectroscopy. Energy Dispersive XRF (EDXRF) and Wavelength Dispersive XRF (WDXRF), which differ primarily in the way the fluorescent X-rays are detected and analyzed. Therefore, WDXRF spectrometers have better resolution than energy dispersive, but they are slower and more expensive.* *The widely used method in the study of cultural heritage materials of nondestructive elemental analysis is completely **portable EDXRF spectrometers.***
Range of use	The XRF is used for elemental analysis and chemical analysis, particularly in the investigation of metals, glass, ceramics and building materials. Portable EDXRF equipment is especially useful when the object to be analyzed cannot be transferred to the laboratory.
Intervention rate	*Portable EDXRF* is non-destructive and non-invasive.
Main advantages	The portable instrument which could be used on-site. The sample can be a solid, powder, liquid, thin film or coating, elements with concentrations ranging from approximately parts per million to percentage levels can be determined simultaneously with little or no sample preparation. The method is rapid, cheap, sensitive.
Negatives and risks	Possible problems can arise from overlapping peaks derived from the elements of interest.
References	RIDOLFI, Stefano 2009: Portable Systems for Energy-Dispersive X-Ray Fluorescence Analysis. *Encyclopedia of Analytical Chemistry* (2009).
Keywords	XRF, X-Ray, *EDXRF*, fluorescence, spectroscopy, spectrometry
Recording author	Dita Machová, ITAM
Images	

	 Experimental arrangement of XRF analyzer.  Handheld X-ray fluorescence analyzer.
Source of images	Vít Vlnas, National Gallery in Prague*, Dita Machová, ITAM*

Examples of application

The XRF have been utilized for studying chemical and structural features of stone artefacts as well as for investigating corrosion products and protectiveness of conservation materials.	ANGELINI, E., et al. 2006: Potentialities of XRF and EIS portable instruments for the characterisation of ancient artefacts." *Applied Physics A 83.4 (2006): 643-649.*
The system for EDXRD is suitable to identify minerals in stone objects and pigments, and inert materials in pictorial and underground layers of paintings.	MENDOZA CUEVAS, Ariadna, et al. 2015: Energy dispersive X-ray diffraction and fluorescence portable system for cultural heritage applications. *X-Ray Spectrometry* 44.3 (2015): 105-115.
A novel methodology based on the use of ED-XRF spectrometry after thin film deposition on special sample retainers and a subsequent evaporation was developed to quantify light elements (Z≤20) in aqueous extracts and heavy elements (Z>20) in acid extracts, coming from materials and degradation products belonging to the built heritage.	GARCÍA-FLORENTINO, Cristina, et al. 2017: Development of X-ray Fluorescence Quantitative Methodologies To Analyze Aqueous and Acid Extracts from Building Materials Belonging to Cultural Heritage. *Analytical chemistry* 89.7 (2017): 4246-4254.