Chemical and mineralogical properties of backfilling soils of Yokosuka Dry Dock, Kanagawa, Japan

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Three dry docks of Yokosuka Arsenal opened during 1871-1884. The first one was constructed according to the guidance of French engineer, Francois Leonce Verny (1837–1902). These dry dock areas have been occupied by the USA navy after the World War II, and still been in service even today. Surface covering stones of the docks are volcanic rocks or tuff collected from Izu or Manadzuru peninsula (Shizuoka and Kanagawa prefectures). They are cut in the size of around 60×40×30 cm and placed on the surface of cut bedrock, Pleistocene mudstone or silt, reinforced by “Beton” which is improved soil composed by gravel, lime and volcanic ash. In order to investigate the properties of beton, boring core samples were taken from a few points and mineralogical and chemical analyses were carried out using powder XRD and SEM-EDS, respectively. The dominant minerals are quartz and K-feldspar in the bedrock reflecting original sediments, whereas quartz and calcite in the beton. Chemical analysis results shows that the higher contents of SiO2 and K2O indicating the existence of K-feldspar, and that the higher contents of CaO, Al2O3 and FeO+Fe2O3 but low content of SiO2 reflecting beton. To consider these differences, the CaO/SiO2, MgO/SiO_2 , $(FeO+Fe_2O_3)/SiO_2$ ratios are fairly useful to compare the influences of lime or cement. From these investigation, it is concluded that the beton had similar characteristics as a dawn cement in civilization in Japan, and that some points were affected by seawater leak.

キーワード：横須賀ドック、ベトン、改良土
Keywords: Yokosuka Dry Dock, beton, improved soils

Quantitative relationships between salt-weathering of tuff and microclimatic environments, in the Yoshimi Hyaku-Ana historic site, Japan

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This study monitored the temperature and relative humidity near the cave wall of the Yoshimi Hyaku-Ana, a historic site. The purpose of the study was to investigate the relationships between salt-weathering denudation of the cave wall (which is composed of tuff) and the local weathering environment. Five measuring points were established inside the cave, with differing degrees of tuff denudation. Monthly observations and measurements were made over 1 year. Small ‘button-type’ sensors (with data loggers) were attached to the cave wall to record temperature and humidity at hourly intervals. After collecting these data, the relationships between environmental condition (temperature and humidity) and the degree of denudation due to salt weathering were evaluated. The degree of denudation were larger in dry measureing point near the entrance of the cave, compared with the inner areas of the cave. This suggests that humidity is one of the major climatic conditions for salt weathering.

キーワード：削剥、相対湿度、塩類風化、凝灰岩、吉見百穴、史跡
Keywords: Denudation, Relative humidity, Salt weathering, Tuff, Yoshimi Hyaku-Ana, Historic site

An experimental study for evaluating weathering susceptibility of cave sediments with relief structure on the wall

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Weathering is a universal phenomenon which is observed not only in natural landscapes but also many historic buildings. Salt weathering is often reported, however, there are very few studies of slaking at these historical sites. The Taya cave in Kanagawa Prefecture is now suffering from exfoliation, which has been attributed to damage by slaking (wetting and drying weathering). To explore these phenomena, simple slaking tests were carried out. Physical properties of the rocks were also measured. The results indicate that that the rocks of the Taya cave system are susceptible to slaking.

キーワード：スレーキング、乾湿繰り返し実験、膨潤性粘土
Keywords: slaking, wetting and drying experiment, swelling clay

Interdisciplinary investigation of stone heritage sites for conservation purposes; a case study of the Székesfehérvár Ruin Garden in Hungary.

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Székesfehérvár is a historic town in Hungary, Central Europe, located 65 km southwest of Budapest, the current capital. The Ruin Garden of Székesfehérvár is a unique monument, which served as the coronation and burial church for the Kings of the Hungarian Christian Kingdom. The site is considered a "National Monument" due its importance in the Middle Ages, therefore its protection is deemed necessary. Several expansions and/or reconstructions took place between the 11th and 15th centuries. The Basilica and other associated buildings were severely damaged by the Turks (16th to 17th century). Further deterioration was followed; the site was used for storage and many of its building and decorative stones were removed and reused in new constructions in the area. The first archaeological excavations began in the 19th century.

Several lithotypes could be found among the remaining stones on site. The interdisciplinary characterisation of the identified materials was crucial not only for the conservation of the Székesfehérvár Ruin Garden but also for other historic structures in Central Europe. The different lithologies were described and depicted on coloured maps, which were also used for the different construction phases of the monument and the weathering phenomena observed on the materials. Moreover, non- or micro-destructive tests were implemented for the in-situ characterisation of the studied building materials (e.g. Schmidt Hammer, moisture content measurement, micro-drilling). Further testing and analysis took place under laboratory conditions, using analogous stones obtained from active quarries and it included petrographic analysis, X-Ray Diffractometry, determination of real density by means of helium pycnometer and bulk density by means of mercury pycnometer, pore size distribution by mercury intrusion porosimetry and by nitrogen adsorption, water absorption, determination of open porosity, micro-drilling, frost resistance, ultrasonic pulse velocity test, uniaxial compressive strength test and dynamic modulus of elasticity.

The most common lithotypes were limestones (>80%). Porous Miocene limestone prevailed, while cemented Mesozoic limestone and travertine were less common. Rhyolite, siliceous sandstone and white marble were sparse. The stones showed moderate to high grade of weathering. The main identified weathering form was black crust on the porous limestones. White crusts, scaling and flaking were also common. Biological growth was also identified on several parts of the ruin.

The laboratory results showed that strength was not necessarily a clear indicator of the stone durability. Bedding and other lithological heterogeneities could influence the strength and durability of the specimens. In addition, long-term behaviour was influenced by the exposure conditions, the fabric and the pore size distribution of each sample. Porosimetry showed high porosities for the oolitic limestones, with their main pore volumes found in the range of larger pores. On the contrary, cemented Mesozoic limestone showed very low porosities. Wide ranges in water absorption and strength values were recorded suggesting significant physical differences among the lithotypes. The interdisciplinary study confirmed that the monumental stones suffered from deterioration in terms of mineralogy, fabric and physical properties, when compared to the freshly quarried stones. Compatibility between the freshly quarried and historical stones was proven, which would be crucial in case of future interventions demanding new materials of similar properties and composition. The strong correlation observed between the micro-destructive techniques and the laboratory test indicated the possibility of minimizing sampling from

cultural heritage sites. The interdisciplinary investigation of the stone material properties and long-term behavior can contribute to the preservation of the site and allow the selection of appropriate interventions and conservation measures.

Keywords: building, stone, interdisciplinary, characterization, conservation, Székesfehérvár

Changes in weathering environment due to clearance of trees in the Angkor temples, Cambodia

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Angkor temples severely damaged were covered by dense vegetation when those were discovered in the mid-19th century. Then trees on building materials have been cleared with the progress of conservation and protection projects for the temples. Tree cutting, however, is possible to generate new weathering environment related to temperature and moisture of the building materials. In order to find such environment, this study carried out the analysis of thermal condition at some sandstone-built temples such as Angkor Wat, Ta Prohm and Banteay Kdei that have different vegetation cover. The sandstone blocks of temples are mainly subjected to weathering processes of wet-dry repetition and salt efflorescence. Air temperatures were measured using about forty data loggers on March and September 2014 under the cooperation of APSARA National authority and with field research workers. In addition, surface temperatures of sandstone block was frequently measured by a thermography during each observation period. As the results, it is found that there is high temperature condition at Angkor Wat temple in which trees were cut at surrounding sanctuary. The surface temperatures of sandstone block reached 55˚C in the morning and a temperature difference between the sandstone block and air temperature was more than 20˚C in the temple. In the night time, air temperature of the sanctuary showed 5˚C higher than air temperature of vegetated area. Such continuous high temperature condition is able to induce desiccation of the sandstone blocks. Namely weathering impacts originating from moisture changes in the sandstone blocks may increase in new environment. Although the tree cutting has progressed since the 19th century to conserve and protect the temples, it may be reduced the function of thermal buffer owing to trees, and accelerate to sandstone weathering.
I appreciate the approval of temperature observation in the temples by the Authority for the Protection and Management of Angkor and the Region of Siem Reap (APSARA National Authority), Cambodia and cooperation of Sophia Asia Center for Research and Human Development. I also appreciate the installation and collection of loggers by Dr. T. Takemura, Dr. W. Song, Dr. A. Hada, Dr. T. Kajiyama, Y. Hiki, T. Maeda, M. Hayashi, N. Kambe, and M. Sato as field research workers.

キーワード：アンコール遺跡、熱環境、乾湿風化、砂岩
Keywords: Angkor monuments, thermal environment, wet-dry weathering, sandstone

The use of multiscale 3D digital models for non-destructive morphological measurements on sculpted bedforms: implications for erosion and weathering models in bedrock rivers in protected areas

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Rock surfaces are the most sensitive portion to weathering an erosion processes, and therefore, a detailed analysis of surface morphologies is of paramount importance. This importance increases when dealing with heritage sites, such as geosites, cultural heritage sites or any other relevant rock outcrop in protected areas, as sometimes a relatively small surface change may lead to a significant loss of aesthetic or scientific values. There are number of non-destructive techniques to characterise surface morphology to various scales. This communication describes surface morphologies at different scales on the river bed of the Manzanares, a bedrock reach located in “La Pedriza”; within the National Park of Sierra de Guadarrama (Central Spain). “La Pedriza” constitutes the largest granitic outcrop in Europe and a place of historic importance for the development of the geology both in Spain and globally. The studied portion is a place of particular geological interest where the erosion generated by the river reveals a series of microdioritic dikes intruding a coarse-grained Variscan leucogranite. This lithological combination generates dissimilar patterns in terms of weathering and erosion. Surface morphology analysis was made by means of 3D digital models obtained at different scales, from metric scale acquired with photogrammetry from a drone to micrometric scale obtained with a Innowep-TRACEiT surface roughness tester. Combining the results of these techniques relationships between roughness at different scales and erosion-weathering balance were determined as well as the main processes involved in surface weathering and erosion. The resulting features at various scales were identified and its relation to flow patterns and the response of different substrate lithologies to river flow.

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Keywords: Non-destructive testing, bedrock rivers, rock weathering, Protected areas

Characterization of lime-based mortars from historic aqueducts in Cyprus

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The use of composite materials, such as mortars, in construction dates back to prehistoric times. The systematic study of these materials can reveal the technological knowledge of past civilizations. Therefore, mortar studies can be of great importance for material scientists, engineers, historians and archaeologists. With regards to heritage conservation, the interdisciplinary research of mortars is mandatory for the design, production and application of compatible conservation materials.
This work presents results from the study of fifteen indicative mortar samples collected from nine different sites in Cyprus. All samples were collected from the remains of various aqueducts that date back to different historic periods. A thorough documentation of the specimens preceded the systematic analytical approach that was adopted for the investigation of the mortars. Macroscopic and stereoscopic observations, as well as other experimental analyses were carried out, aiming to characterize the samples in terms of their composition, properties and state of conservation. X-ray diffractometry (XRD) was used for the qualitative and quantitative identification of the main mineral crystalline phases of the specimens. X-ray fluorescence (XRF) was performed on pressed pelletized powder samples for the determination of their chemical composition. Differential thermal analysis (DTA) and thermogravimetry (TG) was also undertaken; based on the results of the structurally bound water, the mortar samples were classified according to the extent of their hydraulicity. Mercury intrusion porosimetry (MIP) took place for the determination of their pore structure and volume (i.e. open porosity, average pore size, bulk density). Last but not least, a portable drilling resistance measurement system (DRMS) was used for the micro-destructive assessment of their mechanical state.
The macroscopic and stereoscopic observations of the specimens showed differences in texture, hardness and microstructure, which could be associated with their use in practise (e.g. plaster, joint mortar). The presence of crushed ceramic fragments was also observed; this was more evident in plaster samples. Furthermore, in some plasters, different layers could be observed, indicating changes in the microstructure of the areas close to the exposed surface. The experimental analyses confirmed calcite as the main mineral in all samples. The presence of quartz was also found. Plagioclase feldspars and dolomite were among the minerals commonly found in the mortar samples, as well. Gehlenite was present in all analyzed materials; this mineral is characteristic of the presence of ceramic fragments in the composites. The latter was probably used in the absence of natural pozzolanas on the island in order to enhance the performance of the mortars, increase their mechanical strength, adhesion and hydraulicity and prolong their longevity. The purposeful use of finely crushed ceramic for the production of hydraulic mortars in Cyprus dates back to the Late Bronze Age; this has already been scientifically proven by the authors as the earliest use of artificial pozzolanic material in the history of mortars technology. The presence of clay minerals in all specimens could be related to the composition of the raw materials and/or the presence of subsequent deposits. The gypsum content in some specimens could be associated with secondary salt formation due to atmospheric pollution. The thermal analyses indicated that the mortars under study might be classified as weakly to strongly hydraulic. DRMS and MIP results showed heterogeneity in the microstructure of the mortars, which can be attributed to the different construction methods that were followed at different time periods, as well as to the occurrence of weathering phenomena.

Keywords: lime, mortars, aqueducts, characterization, conservation, Cyprus

Repair mortar –porous limestone compatibility: an overview of physical properties

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The compatibility of stone and repair mortar is a key issue in the longevity of restoration works. The mortar and stone used in heritage structures can differ in many aspects, in appearance (surface roughness, colour, texture, etc.) in physical properties (density, porosity, strength, etc.) or in composition (mineralogy, chemistry) and any of these differences can contribute to the loss of stone or historic mortar. The current research focuses on the physical properties and tries to outline and compare the properties of porous limestone with different types of repair mortars. A Miocene porous limestone and four different types of restoration mortars were tested. The Miocene limestone is an important “heritage stone” since it is found in historic buildings of Budapest and other cities throughout Hungary and in the surrounding countries of Central Europe such as Austria, Slovakia, Romania and the Czech Republic. The tested stone belongs to the one that occurs near Budapest at Sóskút quarry. It was used for the construction of bridges, fortresses and public buildings, as well as terraced houses. The tested repair mortars are commonly used in the restoration practice for repairing this porous stone. The compatibility tests focused on bulk density, porosity, ultrasonic pulse velocity and compressive strength. Cubic specimens of 3 cm in size were casted and tested 3-360 days after casting. Mortar with added limestone sand filler (50wt%) and pure repair mortars were tested. The results of the tests were compared to the ones of the porous limestone. These experiments have verified that most of the studied commercially available repair mortars have higher strength (10-20 MPa after 28 days) than that of the porous limestone (5-7 MPa). Adding 50wt% of porous limestone sand filler reduced the strength of the mortar but the required loss in strength was still not obtained for the higher strength mortars. The ultrasonic pulse velocity readings show the same trend, higher values were recorded on mortars. In terms of porosity and pore-size distribution most of the studied mortars had lower porosity (26-36%) than the porous limestone (34-38%) and the pore-size distribution was also different. 50wt% of limestone filler mostly increased the porosity of the repair mortars, but with this increase required rate of changes in pore-size distribution were not achieved. Our experiments have proved that the tested commercial repair mortars are not compatible with the highly porous carbonates and the assessment of the physical compatibility and durability require long-term monitoring of physical changes. The research was financed by Hungarian National Research, Development and Innovation Fund (K 116532).

Keywords: mortar, uniaxial compressive strenght, porous limestone, compatibility, historic monument