Influence of micro climatic conditions on salt weathering

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This study evaluated the influence of micro-climatic conditions on rock weathering in the Yoshimi hyaku-ana cave. Air temperature and relative humidity (RH) were measured at hourly intervals. Samples of weathering debris, which had fallen from the cave wall, were collected on a monthly basis and analysed by X-ray Powder Diffraction (XRD) to identify the mineralogy of the salts within the debris. The results showed that, within the range of temperature and relative humidity investigated here, there were significant decreases in air temperature with increasing distance from the cave entrance, but no significant differences in relative humidity between the sites. The amount of salts and debris near the cave entrances was greater than from inner cave wall surfaces, which may be linked to the micro climatic conditions. Gypsum (CaSO4.2H2O) was the only secondary mineral identified in the fallen debris which may be related to the higher humidity within the cave. Gypsum (CaSO4.2H2O) also has a very low solubility and is therefore liable to crystallize under a wide range of environmental conditions. The highest rates of salt weathering were observed under the more humid conditions during spring and summer, with lower rates of salt weathering in the drier conditions during autumn and winter.

キーワード：塩類風化、環境モニタリング、石膏
Keywords: salt weathering, environmental monitoring, gypsum

Processes of structural deterioration of an abandoned old concrete bridge in Kozushima Island, facing the Pacific Ocean

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Many concrete structures face serious structural deterioration several decades after construction necessitating countermeasures. This study focuses on the impacts of weathering on the structural deterioration of concrete, by investigating a concrete bridge constructed around 1942. The bridge was used for transporting building stone in Kozushima-Island. The current physical and mechanical properties were investigated by non-destructive methods and chemical properties were analysed from small samples. The results shows that the central part of the bridge now has low strength as a result of sea-salt weathering under tidal conditions.

キーワード：劣化、風化、コンクリート、神津島
Keywords: deterioration, weathering, Concrete, Kozushima Island

A formative process of raised rims along joints on shore platforms made of andesite at Oh Island coast, Okinawa, Japan

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Raised rims are well developed along polygonal joints on andesite layers forming intertidal shore platforms at Oh Island coast, Okinawa, Japan. The landform is called "tatami ishi" and has been declared a national natural treasure. The rims have widths of 5-10 cm and have relative heights of 1-5 cm from the bottom of adjacent depressions (called pools). To explore the process of rim formation, measurements of the hardness and moisture contents of the andesite surface were conducted at the rims and pools. A schmidt hammer and a moisture meter were used for the former and latter measurements, respectively. The schmidt hammer testing showed that the rims and pools have no significant difference in hardness . This result does not support the existing explanation that the elevated rims are formed due to case hardening, i.e., cementation by concentration of calcium, silica and/or iron. Temporal changes in the measured moisture content during ebb tide showed that the value at the pools decreased drastically in low tide due to strong drying caused by direct insolation, while rims maintained higher moisture contents by capillarity in narrow joints. These results suggest that (1) the higher moisture content prevents drying and thus salt weathering on the surface of andesite along the joints, which results in little deterioration of the surface strength, and (2) the surface lowering occurs as a result of strength reduction due to salt weathering prevailing on the place apart from the joints, i.e., on the pools. This leads to the conclusion that the rims and pools are landforms controlled by the difference in fluctuation of moisture contents.

キーワード：リム、波食棚、含水比、岩石強度、風化、安山岩
Keywords: Raised rims, Shore platform, Moisture contents , Hardness, Weathering, Andesite

Quantification of color change of building limestone due to humidity variations

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Colorimetry is a Non Destructive Technique (NDT) commonly used in cultural heritage. It allows quantifying the subjective nature of color in order to characterize, identify or distinguish materials or to control their weathering stage. Indeed, whether it is by biocolonisation, salt crystallization or pollutant accumulations, the weathering processes often lead to a color change. This technique is then often used directly on the field on buildings, or in the laboratory. But climatic conditions (temperature, relative humidity and even rain) can be quite different from the field and the laboratory, and in the field, from one day to another. It is well known that color is highly dependent on humidity. A wet stone has often a different color than a dry stone. So, when using this technique to compare color data from one day to another, for example during monitoring campaigns, it is hard to have the same climatic conditions and to know if the color variations are significant. Color change of materials due to humidity is mainly related to mineralogy, porosity, pore distribution and specific area. All materials will not have the same behavior.

In order to quantify color change due to humidity, 4 building stones were sampling, characterized and submitted to different humidity conditions before color measurements.
Materials were building stones used in monuments of North-Eastern Paris (France): one building limestone (Bj) from the Bajocian layer of the Paris Basin (France) and one reconstituted stone made with debris this limestone (Rs) and that was used as substitution stone during restoration works; one limestone from de Lutetian layer of the Paris basin (Cv) and one limestone from the Portlandian layer usually used to replace the Lutetian (Sv). All of them have light color with yellowish tendency.
Each material were characterized by microscopy, water and mercury porosity and adsorption-desorption kinetics were measured. Results showed similar characteristics of the four materials, especially between the pairs.

Color was measured on 6 samples (5x5x1 cm^3) of each stone at different states: dry, after adsorption at 33%, 75% and 97%, wet and during drying. The colorimetry was set up with a Minolta CR400 chromameter.
Results showed that the parameter that changed the most with humidity was the Luminance (L*).
Maximum adsorption of stone was around 1% in weight except for the reconstituted stone that was around 2.5%. Even the maximum of weight increase at 97% of RH was for the RS, only the Bajocian limestone showed a color variation ΔE up to 3, meaning that the color change was visible to the naked eye.
Color change (ΔE) after immersion showed that the wet restoration stones (Rs and Sv) had a higher change of color ($\Delta E > 15$) than the original stones (Bj and Cv).
During drying, the value of luminance was directly correlated to the saturation. ΔE was significant (>3) until the saturation reached 15% for Bj, Rs and Cv and 5% for Sv.

This study showed that stones with close petrophysical properties could have different color change behavior enough to distinguish them on a building. It also showed that stones were highly sensitive to humidity, but that this change was related to how this humidity is located in the porous network (adsorption-desorption or absorption-drying). Further experiments would test color variation with humidity of stone contaminated with salts.

Keywords: colorimetry, relative humidity, limestones

Use of strain gages in the control of frost action

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Frost action is one of the major weathering factors of building stones. Freezing of water inside the porous network causes dilation due to the volume change of water (9%) and the movements of liquid water due to cryosuction. On a monument, the particularity is that frost enters the stone only through the exposed façade. The surrounding blocks and the milder indoor conditions protects the other faces. To assess the effect of freeze-thaw on stones, standard tests are commonly used or adapted in terms of temperature or time of freezing. All these tests, even the adapted ones, consist in freezing the samples after prior immersion in water and thawing them in room temperature water. All the stone faces are exposed to damage, though this does not reproduce the real monument conditions.
These standardized tests assess the decay produced by the ice by means of loss of material (visible or by weight measurements) and tensile strength decrease. In both cases, if the test itself is not destructive enough to produce material detachment, these evaluation methods are irrelevant. In addition, this kind of tests cannot be performed out of the laboratory and in real monuments with immovable materials.

In this study we tested an alternative solution to these constraints with a non destructive setting that allowed to produce freezing on only one face of the stone and the use of strain gages attached along the stone to assess microscopical structural damages. This setting was tested on a common building Lutetian limestone.
Two kinds of water saturation were tested: i) partial saturation obtained by continuous capillary water supply, and ii) partial saturation obtained by a previous total immersion during 48 hours. In the first one, the capillary fringe reached 6cm height of the sample and a differential damage produced between the bottom and the top of the sample was expected. In the second one a homogeneous damage along the sample was expected.
To produce the freezing, a cooling plate was placed vertically in contact to one vertical face of the prismatic sample. The rest of the faces were sealed with a thermal insulator to avoid evaporation and cooling.
To assess frost action strain gauges were set up at different heights of the sample with different orientations from the direction of freezing penetration. To control the freezing penetration inside the sample, thermocouples were placed at different depths within the stone specimen. Even this was a partially destructive method, it was necessary to control if freezing was produced within the stone and at which moment, and then to establish the best experimental protocol. Previous tests showed that the cooling plate had to be set up at -15˚C in order to reach temperature below 0˚C inside the sample.
Five cycles of continuous freezing were applied. Cycles were divided in 12 hours of freezing at -15˚C and 12 hours of thawing at +10˚C. During the whole time of the two tests, the sample was water supplied by capillary absorption from a bottom water tank.

For both tests, the sample could be divided in three parts according to its dilation behavior: the capillary zone (up to 6 cm), the fringe zone (6 cm) and the upper zone not soaked.
Results showed the deformation perpendicular to the freezing direction was negligible except for the fringe zone where it could reach 6.10^{-4}. The deformation parallel to the freezing direction showed an expansion during freezing and a contraction during thawing whose intensity was correlated to saturation.

Only at 6 cm this deformation was close to zero. A small residual deformation was recorded only with the total saturation.
The use of gauges small enough (2mm) to produce the less damage possible even when removed after the test, could be applied in real stone monuments. In addition, they measured the damage produced on the surface not only by ice but also by temperature changes or liquid water movements. The gauges allowed measuring the immediate damage before it reached the inside of the stone and before a visual degradation. This original test also showed the importance of the capillary fringe in the frost action on building stones.

Keywords: frost weathering, unidirectional freezing, strain gages, limestone

