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Microtextural and microstructural influence on the changes of physical and mechanical proprieties related to salts crystallization weathering in natural building stones. The example of Sabucina stone (Sicily)

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HIGHLIGHTS

- A complete characterization of a calcarenite from Sabucina (Sicily) has been provided.
- Changes in microtextural and microstructural due to salt weathering have been studied.
- Variations of physical-mechanical parameters due to salt weathering have been studied.
- Correlation between degradation mechanism and engineering parameters has been obtained.
- The obtained results are useful in planning conservative action on buildings.

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ABSTRACT

The main aim of this research is to highlight the effects of salts crystallization on physical and mechanical proprieties of natural building stones in consideration of petrographic and porosimetric features. In order to achieve the goals of this work, numerous standard tests have been performed on both fresh and weathered samples of a Sicilian calcarenite named Sabucina stone, widely used as building and replace stones in local Cultural Heritages. The obtained results allow to establish interesting correlation between the intensity of degradation processes and the studied parameters; in fact, a modification of the mechanical behavior has been observed in concomitance with a change in the degradation mechanism occurred in the pore network, highlighting the influence of microtextural and microstructural modifications due to the salt crystallization in the engineering properties of the studied rock.

1. Introduction

Even if a large bibliography exists about durability esteem procedures for building stones [1–7], really a few examples of integrate study on both microtextural, microstructural and physical-mechanical proprieties changes due to weathering are available [8–9].

As it is well known, physical and mechanical proprieties of rocks represent fundamental knowledge in engineering applications and are strong influenced by petrographic features such as texture and structure [10–13]. For aforementioned, the knowledge of the relationship among these features allow to better understand the behavior of the stones, especially in the framework of restoration works. In particular, during restoration the choice of a replace stone is strictly related to proprieties as availability, aesthetical compatibility, mechanical resistance and durability.

The Sabucina stone is a yellowish coarse grained calcarenite quarried since ancient times in the area of Caltanissetta (Sicily) and employed in several important Sicilian monuments and sculptures [14] (Fig. 1). Furthermore, due to its excellent durability and aesthetic features, it is widely used as a replacement stone, especially in Baroque monuments of the Noto Valley (belonging to the UNESCO Heritage List). An example of this application is represented by the restoration works carried out on the S. Nicolò Cathedral in Noto (Sicily) (UNESCO World Heritage Site), in which the Sabucina Stone has been used in several architectural elements, especially in dome and other covering parts [15]. In view of the widely application of this stone in Cultural Heritages (both as building and replace material) is of relevant interest the understanding of the changes on its physical-mechanical proprieties due

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Fig. 1. The use of Sabucina Stone in some representative monuments of southern Italy. (a) S. Spirito church; Caltanissetta (1151); (b) Capodarso bridge (1556); (c) Noto Cathedral (1703-2007); (d) Caltanissetta Cathedral.

to salts damages, also considering the results obtained in a previously research [16] in which the application of innovative and non-destructive methodology for studying the porous network of the stone before and after accelerating aging test allow to highlight how salts are responsible of a strongly modifications of its pore structure.

For aforementioned, a multidisciplinary approach has been applied with the aim at outline the relation between physical and mechanic characteristics considering the stone degradation degree. Therefore, comparative measurements of water absorption, mechanical resistance, density, porosity and ultrasonic speed velocity have been carried out before and after accelerated weathering tests. In detail, samples have been subjected to weathering due to salts crystallization, as this process is considered the most destructive for porous building stones [17].

2. Geological setting

The study area is located 4 kilometers away from the urban center of Caltanissetta, in central Sicily, at the foot of the Sabucina Mountain (Fig. 2). This sector of Sicily holds several syntectonic sedimentary basins, formed since Upper Tortonian [18]. The analyzed calcarenite belong to the Piacenzian Enna Formation which is formed by marls and marly clays in the lower part and sands-calcarenites in the upper part. This Formation lies unconformably on the lower Pliocene deposits and it is covered by the marly clays of the Geracello Formation [19].

3. Material and methods

For this study a total of 50 samples have been obtained from a unique freshly quarried block sampled at the North-Western slope of the quarry placed in Sabucina Mountain (Caltanissetta, Sicily). Dimension and shape of the samples are related to the recommendation of the applied standard tests.

3.1. Minero-petrographic and chemical analysis

Petrographic analysis have been carried out on thin sections by using a Zeiss optical polarized microscope. Textural and structural features have been determined following Folk [20] and Dunham [21] classifications.

The semi-quantitative mineralogical composition have been determined by using a Siemens D-5000 Diffractometer on randomly oriented powders and on insoluble residue of bulk rock after acid attack with a solution of chloride acid 0.1 N in concentration. Spectra have been acquired using the range 2–65°2θ, step-size of 0.02°θ and step-time of 2 s/step. The presence of swelling clay minerals in the fine fraction of insoluble residue has been determined on oriented slides by treating samples with ethylene glycol at 60 °C for 12 h.

Chemical analysis have been performed by using Tescan Vega LMU scanning electron microscope (SEM), equipped with an EDAX NeptuneXM4-60 micro-analyzer, characterized by an ultra-thin Be window. Data have been collected by using micro-map and spot mode analyses on polished thin section with 20 kV accelerating voltage and 0.2 mA beam current.

3.2. Physical test

Physical features have been studied by applying a routine based on NORMAL and UNI EN tests. Information on real and apparent density and porosity have been obtained following UNI EN 1936 standard [22] and by performing Mercury Intrusion Porosimetry (MIP) analyses. In detail, the distribution of pore size has been determined by using a Thermoquest Pascal 240 macropore unit in order to explore a porosity range ~0.0074 μm < r < ~15 μm (r