



## **Petrophysical characterization and durability assessment of the archeological site of Tipaza, Algeria**

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The archeological site of Tipaza, which is located 61 km away from Algiers is believed to have been founded by the Roman Empire but the origin of the site is rather confusing, it seems that Phoenician established a commercial trading post at this site before the Roman Empire. It represents two historical periods linked to Phoenicians and Romans. Four varieties of stone have been described; two types of ornamental stones a white marble and a diorite and two other lithologies a yellowish limestone and porous sandstone that were used as ashlar and bulk stone elements. The field observations show an alarming degree of weathering, the extent of degradability is very variable depending on the type of stone used. The main points of this study are: i) the general characterization of stones, ii) the characterization of the original stone source by means of petrographic, physical and mechanical analyses, and iii) the durability assessment of the stones by accelerated weathering test.

The in-situ tests (ultrasound pulse velocity test and Schmidt hammer hardness) were conducted in order to assess the grade of decay. The polarizing microscopy and X-ray diffraction (XRD) were used to characterize the stones. The physical and hydric tests were carried out on six cubes of  $5 \times 5 \times 5$  cm for each stone type. Apparent density and open porosity data were obtained. For mechanical characterization, both destructive (uniaxial compression and flexural strength) and non-destructive (ultrasound pulse velocity and Schmidt hammer hardness) tests were carried out. Average values and standard deviations were calculated. Salt crystallization test were carried out by cycles of immersion – drying in pure water and in a saline solution. Similar cubic samples were immersed in sodium sulfate solution ( $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$ , 14%) during 4 hours and dried at room temperature during 20 hours, 100 cycles were realized. The laboratory tests results allowed finding relationships between the petrographical and physico-mechanical properties of studied rocks of Tipaza. The use of the in situ tests allows us to determine four level of deterioration; slightly weathered, moderately weathered; weathered and very weathered. The stone's weathering in the archeological site of Tipaza is quantified and discussed according to the results found in the laboratory by visual evaluation and by weight measurements before and after each cycle. 100 cycles were realized, several decay forms are observed in the building stones mainly differential erosion and alveolization. The visual observation of the stones after the salt crystallization test showed that the damage was important in the porous sandstone and in the limestone in the form of material loss which was especially intense at the edges of cubic stone specimens. Cavities of some millimeters in length and depth were also observed linked to the dissolution of calcite or removal/expansion of clay minerals. It indicates that porosity is not the only parameter responsible for stone deterioration.