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Freezing-thawing action in the deterioration of the stones of Chambord Castle

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Limestone is very common in architecture (monuments and cultural heritage buildings) and used in the sculptures. The soft and porous limestone soaks up water and show weathering patterns and forms: alveolar weathering, granular disintegration, efflorescences.
Freezing-thawing actions can be considered as one of the processes that contribute in the deterioration of stones located in the "cold regions" characterized with air temperatures below freezing point temperature. The amount of water within the pore space of the stones is a crucial factor of the decay.
The experimental work presented in this paper is a part of a research program that aims to study the mechanisms that lead to the degradation of stone building materials due to the variation of climatic conditions. The analysis of the meteorological data of the field around the castle of Chambord shows the magnitude of temperature variations and the frequency of freezing-thawing cycles.
The critical degrees of saturation at which the stone start to deteriorate after treatment with freezing-thawing cycles were examined in the tests conducted. The study concerns two porous limestone used in the construction and conservation of Chambord castle; highly porous Tuffeau stone having a total porosity of about 48 %, and medium porous Richemont stone with a total porosity of 27 %. Richemont stone has been used as a substitute stone of the degraded Tuffeau stone on the castle.
The main physical properties, total porosity, apparent dry density and skeleton density and sound velocity for mechanical properties were measured for the stone samples before and during freezing-thawing cycles. ASTM (D5312-04) procedure was applied in the freezing-thawing tests. Tuffeau and Richmond samples were prepared at nine different degrees of saturations; 0, 20, 40, 70, 80, 85, 90, 95 and 100%, and properties were measured after different freezing-thawing cycles conditions; 2, 4, 8, 12, 16, 20, 30 and 50 cycles.
The results of these tests show that when the degree of saturation exceeds 80-85%, freeze-thaw damage is inevitable even for a very few freeze-thaw cycles.
Moreover, results indicate that the two studied stones have similar critical degree of saturation of about 85 %. This can be attributed to the similar percentage of macro-pores in the two tested stones. Finally, the critical degree of saturation was not changed after increasing the number of freezing-thawing cycles, thus the critical degree of saturation can be considered as a stone property.