THE NEW RILEM TC 271-ASC RECOMMENDATION FOR THE DURABILITY ASSESSMENT OF POROUS BUILDING MATERIALS AGAINST SALT CRYSTALLIZATION

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KEYWORDS

Salt weathering, accelerated aging, sodium sulfate, sodium chloride, damage assessment

EXTENDED ABSTRACT

Salt crystallization is among the most harmful deterioration mechanisms impacting the preservation of porous building materials worldwide. Therefore, predicting the materials' response to salt damage is crucial in the conservation practice and building sector to guarantee adequate performance and durability. These, in turn, are instrumental to achieving sustainable interventions. Numerical models have been developed to describe salt decay susceptibility quantitatively, but the most diffused approach still relies on performing accelerated weathering tests in laboratory conditions.

So far, the main limitations associated with most of the available experimental and standard accelerated weathering tests arise from the generally long time they require, the lack of consensus on the methods for assessing the damage progression and extent, and the use of testing scenarios hardly representative of real-world conditions. These include simulating unrealistic accumulation and salt transport processes, which in turn significantly affect the resulting deterioration patterns and the final damage extent, and the use of remarkably high salt solution concentrations.

The RILEM Technical Committee (TC) 271-ASC, active between 2016 and 2022, has pursued an innovative direction to simulate more realistic salt crystallization pathways to test single porous materials (stone and clay brick units). The TC aimed

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to develop a reliable accelerated aging procedure for laboratories in the architectural heritage conservation and construction sectors. The requirements for the new procedure focused on achieving realistic results in a relatively limited time, without significantly altering the deterioration process and allowing for a simple damage assessment based on readily available and non-sophisticated techniques. The test simulates the deterioration effects induced by capillary transport of sodium sulfate and sodium chloride aqueous solutions, considered as single salts, toward the evaporative surface of cylindrical specimens.

Building on the experience of reinforced concrete durability research, the TC has explored the feasibility of a two-stage approach (Fig. 1) to trigger damage development and progression, only after a certain degree of pore filling – as a result of salt accumulation – is reached.

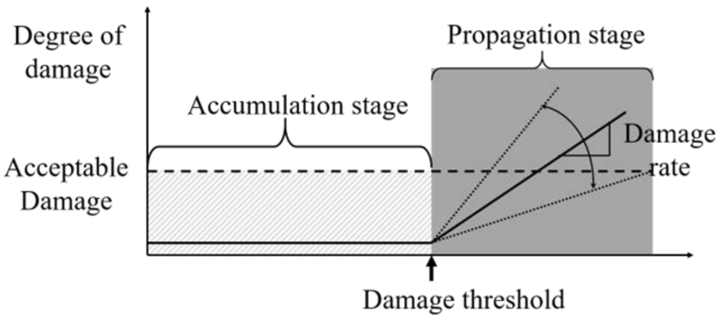

Figure 1: Two-step damage development of stone/brick substrates due to salt crystallization (from [1])

The new procedure translates this theoretical assumption into two distinct testing phases: a preliminary salt accumulation phase, during which the porous substrate is contaminated with salt solution with fixed concentration, and capillary transport promotes its accumulation close to the evaporation surface without causing visible damage, followed by a propagation phase (Fig. 2).

Figure 2: Photographic documentation of stone specimens (Tuffeau limestone) during the accumulation phase (left), after two propagation cycles (middle), and at the end of the accelerated aging procedure (right).

The propagation phase activates the damage development due to repeated crystallization and dissolution cycles.

The testing conditions for the accumulation phase are the same for both salts. Specimens are subjected to capillary absorption of 5% and 10% concentrations of sodium sulfate and sodium chloride solutions and then dried until the evaporation of at least 80% of the absorbed water.

Then the propagation phase starts, based on four 3-week cycles. Differently from the accumulation phase, the set conditions of such cycles differ (i.e., T and RH values, duration, and use of rewetting stages) depending on the type of salt employed. In brief, each single 3-week cycle of the propagation phase of NaCl employs a series of high relative humidity adsorption sub-cycles alternated with drying stages, followed by a rewetting step and a final drying (Fig. 3, above). Each Na_2SO_4 propagation phase starts with a cooling and rewetting sub-cycle at room conditions, followed by drying (Fig. 3, below).

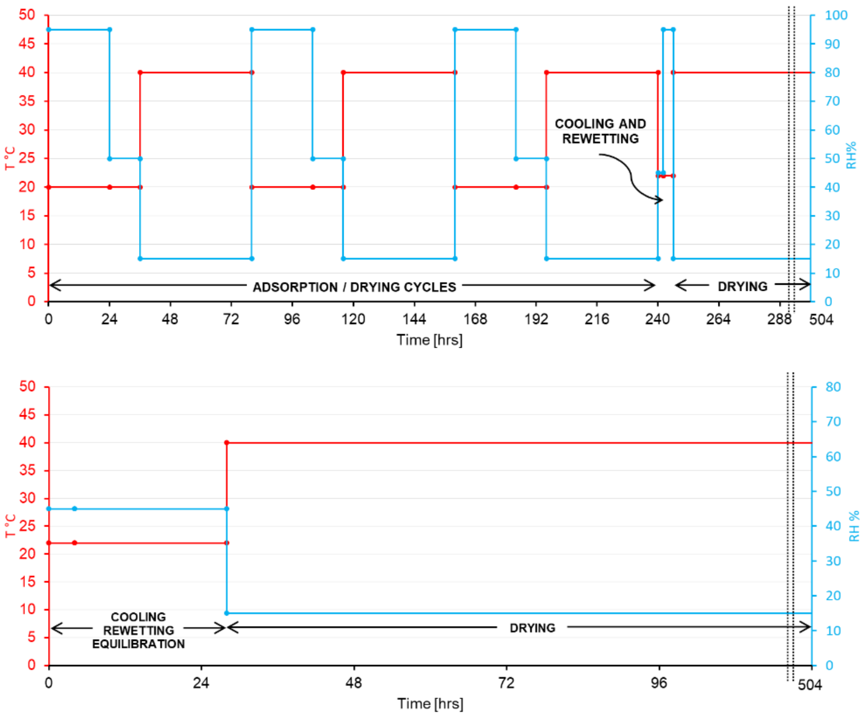

Figure 3: Testing conditions (propagation phase) characterizing each 3-week cycle of the NaCl (above) and Na_2SO_4 (below) testing procedure.

Two round-robin testing programs have been conducted to validate the accelerated weathering procedure, involving ten research laboratories across Europe and the US [2]. The substrates tested during the validation phase include five stones (Lecce, Massangis and Migné limestone, Tuffeau, and Mšené "Prague" sandstone) and two fired-clay bricks. The physical characteristics of such substrates cover an open porosity range between 13% and 50% (vol %) and a capillary water absorption interval between 50 and 1070 $g/m^2s^{0.5}$.

The new accelerated aging procedure has been recently published as a RILEM recommendation [3]. The document details the two procedures for testing single porous materials and includes a simplified methodology based on visual observations, photographic documentation, and mass loss recording to guide the evaluation of the salt crystallization results. A damage glossary for identifying the deterioration patterns is also provided, derived from selected terms of the ICOMOS-ISCS Stone Deterioration Glossary [4] and the MDCS Damage Atlas [5].

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