Microscopic investigation of salt induced damage at repair mortar-masonry interfaces

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INTRODUCTION

Salt crystallization is a widely studied damage phenomenon in the field of historic conservation. Detachment of paint and mortars from the substrates is a very common problem [1-4].

Sodium chloride crystallization is very likely one of the main degradation mechanism acting in Havana, Malecon, specifically the detachment of the renders. The salt is coming primarily from sea spray, and is found to be saturated within the substrate materials. Most damage is occurring from salt precipitating at the interface of the repair material and the substrate.

The most representative damage pattern associated to salt crystallization that can be observed in Havana is granular disintegration on the surfaces of stone, bricks and mortars. Alveolar formation on stone, renders and bricks is also observed extensively. Characterization of original and modern repair materials in reference buildings, as well as monitoring of temperature and relative humidity in the atmosphere and in the surface of the materials were carried out. [5]

The aim of the present work is to observe the salt crystallization at the interface between brick and mortar samples prepared in the laboratory and to evaluate its influence on the adhesion properties.

EXPERIMENTAL

The real situation in Malecon consists of the presence of historical buildings with salt saturated substrates and also modern buildings that can be considered as clean or

slightly salt loaded. Therefore, in the lab, two sets of 50 mm cylindrical brick samples (in diameter and height) were prepared. The first set is clean, with no salts. The second set of bricks were sealed radially, placed in a container containing a solution of NaCl. The amount of the NaCl was 1% of the total weight of the sample in dry state and was dissolved in the amount of water needed for the total saturation of the sample. The salt loading took place in a room at 20 °C and RH 50%. When the salt solution was totally uptaked by capillarity, the samples were sealed on the bottom, placed in an oven at 40 °C and dried until constant weight.

A 2 cm layer of mortar was applied in the top of the brick cylinders. Three types of mortars were used for this experiment. The first two mortar formulations (Mix 2 and Mix 3) were prepare according to the most commonly used recipes that have been and still being used in Havana Malecon, first to repair the original renders and then for the successive interventions [6]. They consist of a mix of calcium hydroxide (Ottesbein HYDRADUR) and white cement (AALBORG) in different proportions. A third mortar (Mix 1) consists of a mix of calcium hydroxide (Ottesbein HYDRADUR) and limestone calcined clay cement (LC^3), which is locally available and recently produced in Cuba. Quartz and carbonated sandstone was used as aggregate. (Table 1). The components were mixed in dry state for two minutes and water was added to reach good workability, as normally happens onsite. The w/c ratio was higher than 0.6 in all cases.

Brick/mortar composite samples were cured for 28 days at 95% RH. Six samples of each brick/mortar composite were produced. After this period, pull-off strength was measured with a universal testing machine. A tensile load was applied until failure. The interfaces were observed by SEM and the salt composition was checked by EDX analysis.

Table 1: Mortar proportions for the three mixes.

	$Ca(OH)_2$	White	LC^3	sand
Mix 1	1	-	1	3
Mix 2	1	0.1	-	3
Mix 3	2	1	-	3

RESULTS AND DISCUSSION

In Figure 1, it can be observed that calcined clay based mortar has the highest pull-off strength on clean substrates. On salt loaded substrates the calcined clay based mortar behavior remains the same, but the results are more variable.

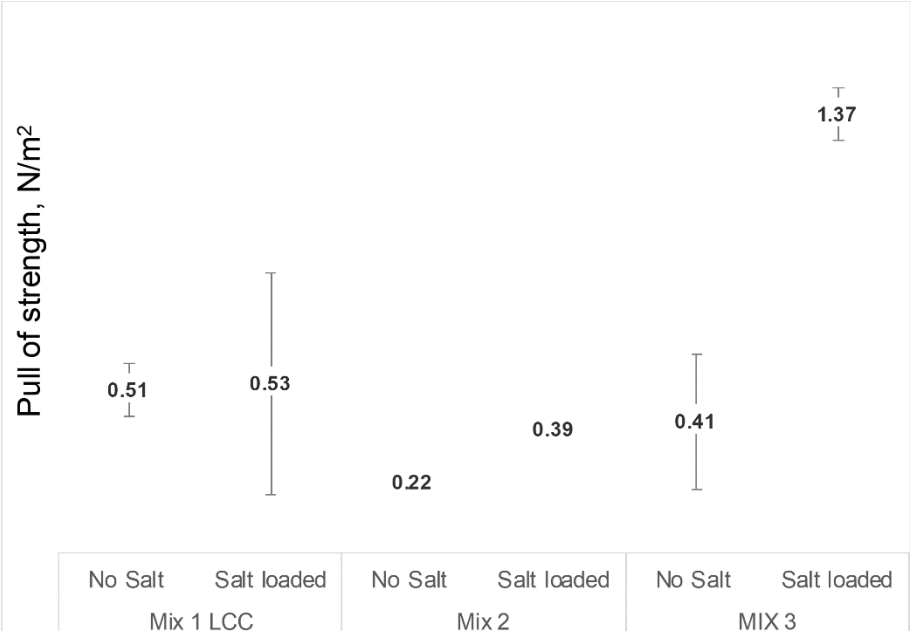

Figure 1: Pull-off strength of mortar from brick substrates. Substrates are either salt free or salt loaded.

We observed a significant increase of the pull-off strength of Mix 3 on salt loaded substrate, which is the mix containing more white Portland cement. There are a few possible explanations for the high pull off strength: the first explanation could be that the NaCl enhances water retention on the interface, which can support hydration. However, degree of hydration on areas near and far from the interface were studied by means of SEM microscopy and the difference was not noticeable.

Another explanation could be that the NaCl can enhance mechanical cohesion at the interface through interlocking and pore filling. In the SEM images of Mix 1 and Mix 2 in Figure 2, one can observe that sodium chloride crystals are mostly cubic and some of them are partially dissolved.

If observing the interface of Mix 3, the one which higher content of white cement and where the highest pull-off strength was found, a NaCl whisker morphology, is developed in most of the interface, and that could connect the interfacial porosity. Whiskers can grow under certain conditions, specifically they grow from a substrate covered by an non-continuous solution film [7]. It seems that the interfacial conditions of Mix 3 tend to favor whisker formation. There is also the possibility that the whiskers on the interface enhances roughness which can lead on a increasing of the pull-off strength.

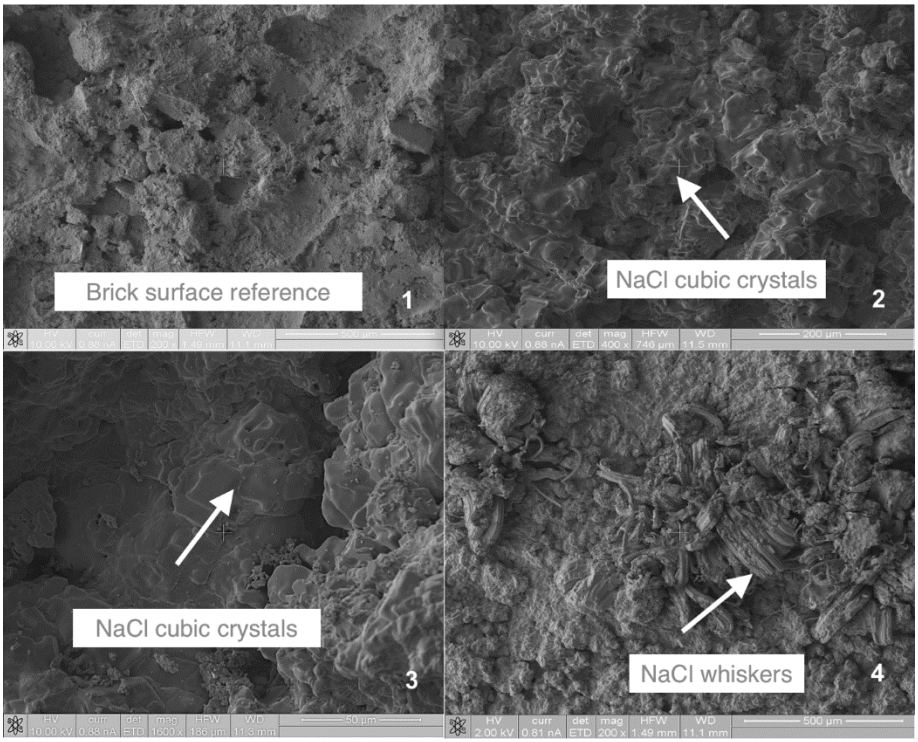

Figure 2: SEM of salt-loaded brick interfaces. 1. Reference brick surface 2. MIX 1 Cubic crystals of NaCl 3. MIX 2 Cubic crystals of NaCl 4. MIX 3 NaCl whiskers.

CONCLUSIONS

In this study, the adhesive strength of the one mortar containing higher amount of white Portland cement was enhanced in salt loaded substrates. NaCl whisker morphology was the only observable difference seen in microscopic investigation, indicating possible enhancement via mechanical interlocking.

The performance of LC^3 based mortar is not compromised in salt loaded substrates.

Current work is being focused, first, on the improvement of the sample preparation set up to get more reliable pull off strength results and to better highlight the effect of the salts. This can be accomplished by brick surface preparation and controlled application energy of the mortar onto the brick, among other methods.

Ultimately, RH cycling of salt loaded substrate and mortar composites will be carried out to assess true durability performance, and additionally to confirm if the mechanical interlocking is a reason for the enhanced adhesion.

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