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# Improving the resistance of mortar to NaCl damage by the use of crystallization inhibitors

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**Abstract.** The use of crystallization inhibitors for mitigation of salt decay in building materials was proposed for the first time about 20 years ago. Since then, research has been carried out to explore possible applications of crystallization inhibitors. This work discusses the potentials and limitations of mortars with mixed-in sodium-ferrocyanide, an inhibitor of sodium chloride crystallization, and provides an outlook for further developments.

Over the past 20 years, the potential of sodium ferrocyanide (NaFeC), an inhibitor of sodium chloride (NaCl) crystallization, to improve the resistance of mortars to salt decay was investigated. At first, the inhibitor was introduced in mortar under capillary action, dissolved in the NaCl solution. The mortar was then subjected to RH changes leading to crystallization and dissolution of NaCl. The experiments showed that NaFeC was able to inhibit crystallization-induced expansion and damage to the mortar [1]. Subsequently, a pilot study was carried out in which NaFeC was added to a lime-cement mortar during mixing. The mortar was then subjected to an accelerated crystallization test; the results confirmed the effectiveness of NaFeC to reduce salt decay [2]. Encouraged by these positive results, research was set up to thoroughly investigate the effect of NaFeC when mixed in air lime-based mortars. Such mortars are commonly used in the conservation of cultural heritage and are susceptible to salt decay. The laboratory study showed that NaFeC significantly improves the salt resistance of air-lime based mortar, without negatively affecting its properties at the fresh (water content, workability) and hardened (mechanical strength, moisture transport behaviour) state [3, 4]. Next to the laboratory research, on-site tests were carried out. The mortar with NaFeC was applied on a wall affected by NaCl damage, next to a reference mortar without NaFeC. After 4 years, the reference showed significant loss of cohesion (sanding), while the mortar with NaFeC did not suffer any material loss. However, a blue discoloration was visible on the mortar with NaFeC, due to formation of Prussian blue [5].

In order to broaden the application field of mortars with mixed-in NaFeC to renovation and new constructions, the effect of NaFeC on the properties and salt resistance of hydraulic mortars was investigated. Also in this case, the mixed-in inhibitor was able to improve the salt resistance of the hydraulic mortars without negatively affecting its properties [6, 7].

The above reported experiments made it clear that NaFeC reduces salt decay in mortar, but pointed out that NaFeC, being water soluble, can leach out of the mortar [4]. To understand the relevance of this problem, an experimental study was carried out to quantify the diffusion and advection-driven leaching of ferrocyanide ions $[Fe(CN)_6]^{4-}$in mortar. The results confirmed that the transport of $[Fe(CN)_6]^{4-}$ is fast, and only slightly slower than that of chloride ions. Thus, in the presence of water, the inhibitor is easily transported to the

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surface of the mortar, and quickly depleted [8]. To slow-down the release of NaFeC, encapsulation of the inhibitor was attempted. Two bio-polymers were chosen for preparing the capsules: calcium alginate (CA) and chitosan (Cs). CA swells at high pH, increasing the capsule permeability and favouring the release of NaFeC; Cs has an opposite behaviour. The release of NaFeC can thus be tuned by the changing the Cs to CA ratio [9]. Calcium alginate capsules with different percentages of chitosan (CsCA) were prepared and the release of NaFeC was tested, both in pore solution and in mortar [9]. The results show that CsCA capsules (Cs:CA=0.25) are able to slow down the leaching of the NaFeC, both in diffusion and advection experiments, in comparison to mixing NaFeC directly in mortar. The effect of CsCA capsules on properties and durability to salt decay of NHL-based mortar were investigated. The capsules, added in an amount of 3.78% of binder wt, (equivalent to 1% of NaFeC as wt of binder), were shown to have no negative effect on the properties of the fresh and hardened mortar. Optical and scanning electron microscopy observations were carried out too (figure 1). The durability to salt decay of the NHL mortar with encapsulated NaFeC was assessed by a crystallization test, and compared to that of mortars with NaFeC directly mixed in the mass and without NaFeC. The test showed that NaFeC (both in mixed-in and encapsulated form) is able to significantly reduce salt damage, in comparison to the reference mortar. Moreover, specimens with CsCA capsules leached lower NaFeC than specimens with mixed-in NaFeC [7].

In future, for further exploitation of these results, some fundamental questions (effect of NaFeC on crystallization pressure, interaction of NaFeC with salt mixtures) and practical issues (prevention of Prussian blue, optimization of capsules composition) need to be tackled.

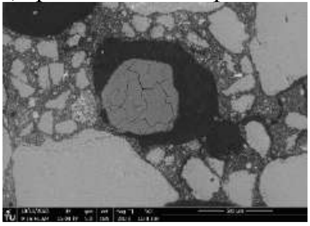

**Fig. 1.** SEM image of a capsule embedded in mortar matrix.

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