INFLUENCE OF PRE-SATURATION REGIME ON THE SCALING RESISTANCE OF ALKALI-ACTIVATED SLAG CONCRETE

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HIGHLIGHTS

- The scaling resistance of alkali-activated concrete was tested according to EN 12390-9 “slab test” procedure.
- Three pre-saturation regimes were tested: pre-saturation in de-ionized water for 3 days, and pre-saturation in 3% NaCl solution for 3 and 7 days.
- The scaling resistance was improved by introducing the pre-saturation with 3% NaCl and by increasing the pre-saturation period.

Key words: scaling, freeze-thaw resistance, alkali-activated concrete

INTRODUCTION

Alkali-activated materials (AAMs) have been extensively researched in recent decades as a possible sustainable alternative to ordinary Portland cement (OPC) concrete. However, literature reports on the freeze-thaw resistance of AAMs are often inconsistent [1]. Freeze-thaw resistance with and without de-icing salts is of great importance for the durability of concretes in cold regions. While the parameters that are critical for freeze-thaw resistance, such as water to binder ratio, pore size and pore connectivity, and degree of saturation, are generally known [2,3], there is still a need for a better understanding of the mechanisms of freeze-thaw degradation of AAMs and the influencing factors.
Treatment of the concrete surface with de-icing salts causes scaling - peeling of the upper concrete layers [4]. The exact degradation mechanism is still under discussion, but it is known to be closely related to hydraulic pressure and osmotic pressure gradients [2].
The influence of pre-saturation on salt scaling resistance has been studied for the OPC concrete and OPC concrete with the supplementary cementitious materials [4,5], and for AAMs [1], according to different methods such as RILEM CDF test [1], ASTM C 672 or BNQ standard [4,5]. The longer pre-saturation period with freezing medium was found to be beneficial, when tested [4,5].
This paper presents the evaluation of the scaling resistance of alkali-activated slag concrete mix according to the EN 12390-9 "slab test" procedure [6] and the comparison with alternative pre-saturation regimes.

MATERIALS AND METHODS

For this experimental research, ground granulated blast furnace slag (GGBFS) provided by Ecocem, Benelux was used as a precursor. GGBFS was activated with sodium hydroxide (SH) pellets dissolved in water and commercially available sodium silicate (SS) solution Geosil 34417, produced by Woellner. Crushed dolomite aggregate with the maximum grain size of 16 mm was used, with the ratio of fine to coarse aggregate of 1:1.5. No air entrainers were used.
The mix design is presented in Table 1. Water to binder ratio (w/b) was calculated as the ratio of the sum of water in activator solutions and water added to attain satisfactory workability (add. water) and the sum of GGBFS and solids in the activator solutions. The alkali content (Na2O) was calculated as weight percent of GGBFS, while the silica modulus of the mix (Ms) represents the ratio of silica and alkali content ($n(SiO_2)/n(Na_2O)$).

Table 1. Mix design of alkali-activated slag concrete

GGBFS [kg/m³]	w/b	m(SH) - solid [kg/m]	m(SS) – solution [kg/m³]	Na_2O [%]	Ms	Add. water [kg/m³]	Aggregate (0-4mm) [kg/m³]	Aggregate (4-8mm) [kg/m³]	Aggregate (8-16mm) [kg/m³]
375	0.42	15.0	10.09	4.1	0.42	140.3	706.0	358.0	694.0

The scaling resistance of the mix was tested on three sets of four samples. The tests were conducted in accordance with the "slab test" procedure described in EN 12390-9 [6], except for the initial curing. Instead of curing in water for the first 7 days, the samples were cured sealed, due to their sensitivity to water curing [7]. While the set designated as S2 was pre-saturated in accordance with the EN 12390-9, the other two sets (S2/A and S2/B) were tested under alternative pre-saturation regimes. The test regimes for all sample sets are described in Table 2. At 28 days of age, the samples were subjected to the pre-saturation, followed by a freeze-thaw cycling (1 cycle=24h). Scaled material was collected and weighed after 7, 14, 28, 42 and 56 freeze-thaw cycles.

Table 2. Curing conditions and pre-saturation regimes - five sets of AA slag concrete samples

Sample set	Curing	Pre-saturation period	Pre-saturation medium
S2	7 days sealed / 21 days in humidity chamber*	3 days	de-ionized water
S2/A	7 days sealed / 21 days in humidity chamber*	3 days	3% NaCl
S2/B	7 days sealed / 21 days in humidity chamber*	7 days	3% NaCl

*20±2°C and 65±5%, according to EN 12390-9

RESULTS & DISCUSSION

The results of the scaling resistance test are shown in Figure 1. The sample set S2, which was pre-saturated according to EN 12390-9, showed a steep increase in scaling material in the first 7 cycles and a moderation thereafter. A similar trend was reported in the RILEM TC 247-DTA report [1], with the explanation that the low scaling resistance at the beginning of the tests could be caused by the carbonation of the upper concrete layer. However, the other two pre-saturation regimes presented in this study resulted in a drastic reduction of the cumulative scaled material in the first 7 cycles, suggesting that the reason for the initial high scaling of the set S2 should be explained by degradation mechanisms other than carbonation.

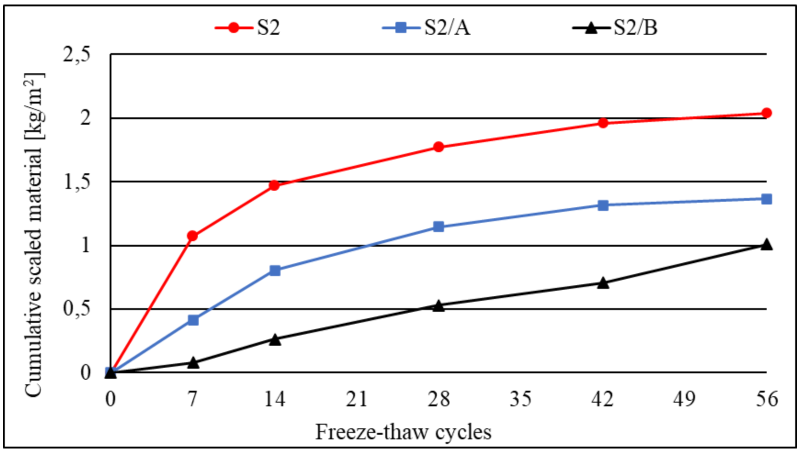

Figure 1. Cumulative scaled material of AA slag concrete mixes with different pre-saturation regimes

The improvement of scaling resistance can be analyzed from two aspects: the influence of the pre-saturation period and the type of pre saturation medium on the scaling resistance. The pre-saturation of the samples with a NaCl solution instead of de-ionized water, as prescribed in EN 12390-9, resulted in significantly higher scaling resistance of the S2/A set. Extending the pre-saturation period with NaCl solution from 3 to 7 days increased the scaling resistance of the S2/B set even more (Figure 1). This set of samples almost met the durability requirements for exposure class XF2, which is defined in the Croatian National Annex as <0.5 kg/m3 of scaled material. The use of NaCl solution as a pre-saturation medium and the extension of the pre-saturation period could be explained by balancing the ions between the salt solution on top surface and the pores in the surface layers of the concrete, reducing the osmotic pressure gradients that cause scaling [2,4].

CONCLUSION

This research presents the results of the scaling resistance of alkali-activated slag concrete, tested according to EN 12390-9 and alternative pre-saturation regimes. The results show that both the pre-saturation period, and the type of the pre-saturation medium, have significant impact on the overall scaling resistance and its progression. The comparison of the pre-saturation period showed that for the 7-day sealed curing, the 7-day pre-saturation with 3% NaCl exhibited the highest increase in scaling resistance. Further research will focus on this phenomenon and understanding the prevalence of the different freeze-thaw deterioration mechanisms.

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