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Salt and Ice Crystallization Resistance of Lime Mortars with Natural Lightweight Aggregate

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1 Introduction

Porous aggregate with pozzolanic properties can improve not only the mechanical properties of mortars, but also their ability to salt accumulation from masonry, frost resistance, and liquid water transport to the mortar surface. The use of natural lightweight aggregates is quite common in concrete, however their utilization in lime mortars is still scarce.

In this study, the comparison of lava sand, pumice, and natural zeolite as lightweight aggregate in air lime mortars, natural hydraulic lime mortars, and cement-lime mortars has been investigated with emphasis on the resistance of salt and ice crystallization. The strength characteristics, pore structure and capillary water action of natural zeolite mortars and lava sand mortars, respectively, have already been investigated (Vyšvařil *et al*., 2019, Vyšvařil *et al*., 2019) with the conclusion that both natural aggregates positively affect the mortar strength, increase their porosity by forming coarse pores and facilitate water capillarity.

2 Materials and Methodology

A commercial hydrated lime CL90-S, a natural hydraulic lime NHL 3.5, and a laboratory prepared blend of CL90-S and Portland cement CEM I 42.5 R were used as binders in prepared mortar mixes. Each mortars group consisted of reference samples made of quartz sand and 3 types of samples with natural lightweight aggregate (0/2 mm), fully replacing quartz sand, namely, natural zeolite, lava sand, and natural pumice. Mortar mixtures were made using the correct amount of water required to obtain a good workability of the mortars (160 ± 5 mm; measured by the flow table test). The composition of mortar mixtures considers constant binder:aggregate volume ratio of 1:1.15. Fresh mixtures were cast into prismatic moulds of size 40 × 40 × 160 mm and storage at 22 ± 2 °C and relative humidity of 50 ± 5%.

The total porosity of the specimens was assessed using a mercury intrusion porosimetry. Frost resistance tests required 15 freeze-thaw cycles. One cycle consisted of 6 h freezing at −20 °C and 12 h thawing in a desiccator at constant relative humidity of 98 % and temperature of 20 °C. The frost resistance coefficient was determined as the ratio of flexural strength of specimens subjected to 15 freeze-thaw cycles to the flexural strength of reference specimens. The salt crystallization resistance of mortars was determined using 10% Na_2SO_4, 3% NaCl, and 3% NH_4NO_3 solutions. The dried samples were immersed into the solutions for 7 h and then dried for 16.5 h at 60 °C. The process was performed in the number of 10 cycles or till the partial disintegration of the samples. Detailed microstructure images were taken via a scanning electron microscope equipped with EDX probe.

3 Results and Discussion

The increasing total porosity of the mortars corresponded to the decreasing loose bulk density of the lightweight aggregate, therefore the mortars with the lightest aggregate (natural pumice) showed the highest total porosity, which can be potentially beneficial for salt and ice crystallization resistance of these mortars.

All tested mixtures withstood 15 freeze-thaw cycles. The frost resistance of mortars increased with increasing porosity of the samples, except for natural zeolite mortars, where the huge water-binding capacity led to a decrease in the frost resistance; the best results were obtained using natural pumice. The mortars with natural zeolite were not resistant to crystallization of sodium chloride. All mortar samples were also broken down after several crystallization cycles of sodium sulfate, where gypsum with high molar volume were formed. The NHL and cement-lime mortars break down in the sodium sulphate solution earlier due to the presence of the aluminate phase and the formation of bulkily calcium sulfoaluminates (monosulfate and ettringite). In the case of NH_4NO_3, no products of relevant degradation reactions were observed in the microstructure of mortars, only calcite recrystallization occurred. The structure remained relatively close. The poor resistance of lime mortars with natural zeolite to NaCl crystallization is likely due to leaching of the binder from the mortar structure, since no degradation reaction products have been observed in these mortars.

4 Conclusions

- All lightweight aggregates increased the total porosity of mortars in accordance with their decreasing loose bulk density.
- Full replacement of quartz sand with natural lightweight aggregate has led to a considerable improvement in the frost resistance of mortars (except natural zeolite); the best results were obtained using natural pumice.
- Salt crystallization resistance of the mortars was improved by using lava sand and natural pumice, while the mortars with natural zeolite were not resistant to crystallization of sodium chloride. The mortars have relatively little resistance to the reacting of Na_2SO_4, where gypsum and calcium sulfoaluminates were formed.
- In terms of salt and ice crystallization resistance, natural pumice seems to be the most suitable natural lightweight aggregate for lime mortars.

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