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Effect of Internal Hydrophobization on the Properties of Porous, Cementitious Materials

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1 Introduction

There are very limited number of regular studies or they are insufficient in determining the effectiveness of internal hydrophobization of cement-based building materials with organosilicon compounds. In this paper we investigate the influence of two different silicon-based admixtures on fundamental properties of cement mortar/paste. The addition of hydrophobic admixtures to the batch water was intended to create a hydrophobic material in its whole volume.

2 Hydrophobizing Agents: Triethoxy(octyl)silane and Poly(dimethylsiloxane)

Silanes are monomeric molecules (have one atom of silicon) with low molecular weight of 178. They are a silicon analogue of methane. Silane derivatives of the general formula: R_nSiX_{4-n} have the most important practical significance (R can be a hydrogen atom, an alkyl or aryl group, X can be a halogen atom or an alkoxy group). Initially silanes undergo hydrolysis and polycondensation reactions. Subsequently they cross-link under elimination of alcohol and as a result of which polymers, with polysiloxane chain, are formed (Ciabach, 2001). Triethoxy(octyl)silane is an alkyl alkoxy silane with three ethoxy groups and one octyl group in its structure.

Siloxanes are oligomeric molecules with a molecular weight about 400-600. The basic structure of siloxanes is a polysiloxane chain (O-Si-O-Si-O). Despite of the polar character of siloxane bonds (Si-O bonds have ionic character in 50%) organosilicon compounds show similarity to paraffins in terms of low critical surface tension. Siloxanes have very low surface energy and exceptional hydrophobicity. PDMS chains are arranged in helixes and present of the methyl groups ($-CH_3$) give hydrophobic character of modified materials (Chruściel *et al.*, 2008; Cypryk *et al.*,2007; Grabowska *et al.,* 2019).

3 Materials

Two different type of water-repellent agents were used for the internal hydrophobization. The first of them is an aqueous emulsion of silane: triethoxy(octyl)silane (OTES). The second admixture is also an aqueous emulsion but the matrix is poly(dimethylsiloxane) (PDMS). The

amount of the hydrophobic admixture in cement mortar or paste was 0%, 1%, 2% or 3% (refer to cement mass). They were added to the batched water. Both admixtures are recommended for volume hydrophobization.

4 Results

The addition of admixture based on PDMS successfully reduces capillary water absorption. For reference sample capillary water absorption coefficient was 0.21 kg/(m^2*$min^{0.5}$) and 0.098 kg/(m^2*$min^{0.5}$) for cement mortar containing 3% of PDMS admixture. Absorbability of hydrophobized cement mortar decrease to 3.7% from 7.6%. In case of poly(dimethylsiloxane) the heat of hydration of Portland cement decrease from 217,25 J/g to 182,05 J/g. Even better hydrophobic results in reducing capillary water absorption and absorbability were obtained for the second admixture based on triethoxy(octyl)silane. This water repellent agent decreases capillary water absorption by almost 90% (from 0.21 kg/(m^2*$min^{0.5}$) to 0.02 kg/(m^2*$min^{0.5}$)) and reduce absorbability by 70% (from 7.6% to 2.2%) at the maximum amount of admixture. Also, in case of silane admixtures heat of hydration was reduced. The lowest value was obtained for 3% of OTES (149.12 J/g). Unfortunately, both admixtures decrease compressive strength of cement mortar. The largest decreases in compressive strength were observed for the dosage of 3% of silicon-based admixtures. PDMS admixture reduce mechanical strength of cement mortar by an average of 50% and OTES one only by 15%. The present of non-polar such as methyl groups (-CH_3) and octyl groups (-C_8H_{17}) attached to the silicon atom provide desirable effect of internal hydrophobization of cement mortar. For the same reason the compressive strength of cement mortar might have been decreased. Changes in the heat release, during hydration process**,** indicate that the admixtures can bind to the cement phases (alite, belite or tricalcium aluminate) making water-cement reaction more difficult. This may cause incomplete hydration of the cement and thus a subsequent decrease in strength.

5 Conclusions

As a conclusion, it can be said that triethoxy(octyl)silane is an efficient water-repellent agent for cementitious materials. However, the first results are very promising this admixture still requires more studies especially when it comes to mechanical properties.

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