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OPTIMIZING SELF-HEALING MECHANISM OF SLAG CEMENT CONCRETE UNDER NATURAL CARBONATION

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ABSTRACT

Dutch construction industry is well known for its wide use of mineral admixtures in concrete production. Ground granulated blast furnace slag cement (slag cement) is most commonly used in northern European countries including The Netherlands with a market share of more than 50%.Slag cement exhibits economically as well as environmentally attractive properties. Having high durability and its suitability in low heat applications makes, slag-rich concrete one of the best options to be used in aggressive environments; e.g. exposure to acid, chloride attack and sulfate attack. Apart from all the positive aspects, it is known that slag-rich concrete has poor resistance against carbonation and frost salt scaling. Therefore slag cement is rarely used in the structures prone to frost attack i.e. roads, balconies of houses and bridge decks. Recently, a new Sodium monofluorophosphate (Na-MFP) based application has been introduced in order to enable self-healing in slag-rich concrete. Successful results have been obtained with respect to healing carbonation damage in slag-rich concrete in accelerated and natural conditions. In a new PhD project, possibilities will be investigated regarding the application of Na-MFP as curing agent, surface coat and encapsulated self-healing agent on concrete specimens prepared on specifications which are currently being used by Rijkswaterstaat, the Dutch roadwork administration. A detailed chemical interaction of Na-MFP will be studied while changing the dosage and material preparation techniques, and improvement of other durability properties e.g. tensile strength, capillary water uptake, surface abrasion, porosity will be examined after healing mechanism. The objective of this study is to optimize and replicate the favorable results from the preliminary lab studies in the full-scale on site testing of slag-rich concrete under natural carbonation.

Generally, the microstructure of Portland-slag cement pastes is not very different from plain Portland cement. However, laboratory tests and independent reports show that slag-rich concrete have a poor resistance against atmospheric carbonation due to its significant lower $Ca(OH)_2$ content. The carbonation of cementitious matrix leads to shrinkage and micro cracking in the skin of BFSC concrete where the material mechanical quality and durability is reduced considerably. Reduced surface micro-quality often makes the BFSC concrete vulnerable against external influences such as frost salt scaling, which is known as the most challenging obstacle against utilizing slag-rich cements in road and pavement constructions. This posses a common problem in the Dutch construction industry since ordinary slag-rich concrete fails in the standard frost salt scaling tests, enforcing contractors to opt for ordinary Portland cement or choosing very low Water/Cement ratio which are economically and environmentally punishing.

This research proposes the techniques for optimizing the self healing of slag-cement based materials before industrial application. The initial results of a 2- year post-doc project (SHM0616) showed that Na-MFP is highly effective as a self-healing agent when triggered by atmospheric carbonation in the concrete skin. The healing mechanism of Na-MFP for an ideal self-healing action will be 1) producing concrete and impregnating its surface with healing agent 2) Surface degradation by carbonation of cementatious matrix and formation of porous silicates hydrates and carbonates 3) Initiation of self-healing action by the

reaction between the carbonated matrix and the healing agent that yields stable amorphous apatite-like formations 4) and finally obtaining durable slag-rich concrete surface that is resistant against frost salt attack.

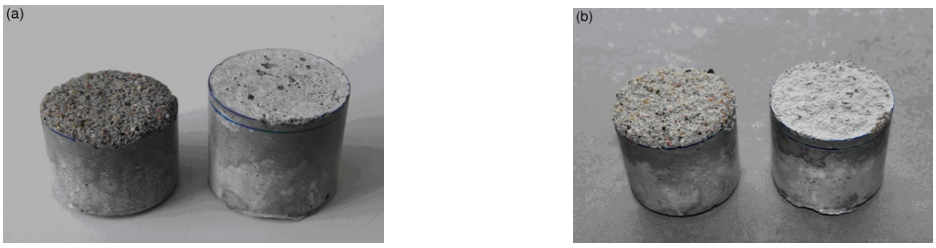

Figure 1: Conditions of mortars after 3 cycles of frost salt scaling test: (a) pre-treatment series (Left: Pre-W; Right: Pre-M), (b) post-treatment series (Left: Pos-W; Right: Pos-M).

Figure 2: Image (Left). Severely carbonated slag-rich mortar surface condition after frost salt attack. Image (Right): Identical mortar with Na-MFP healing agent near surface shows almost no signs of damage under the identical frost salt attack.

Currently CEM I and CEM II/B-V are the only options in road construction in The Netherlands, results obtained by this study will give boost to use of eco-friendly and economical blast furnace slag cement concrete. Investigation of NA-MFP under natural carbonation will be the last evaluation step before its industrial application

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REFERENCES

[1] Sisomphon, K., Çopuroğlu, O. and Fraaij, A.L.A., Microstructure and Frost Salt Scaling Durability of Carbonated Blast-Furnace Slag Mortars with Sodium Monofluorophosphate Treatment, Submitted to Cement and Concrete Research (2008).

[2] Sisomphon, K., Çopuroğlu, O. and Fraaij, A.L.A., Application of encapsulated lightweight aggregate for self-healing of blast-furnace slag mortar from carbonation and frost salt scaling problems, Submitted to Construction and Building Materials (2008).

[3] Sisomphon, K., Çopuroğlu, O. and Fraaij, A.L.A., Durability of Blast-Furnace Slag Mortars Subjected to Sodium Monofluorophosphate Solution Curing, to be published in Proc. 4th International Conference on Construction Materials: Performance, Innovations and Structural Implications, Nagoya, Japan, 2009.