FINAL REPORT

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Assessing the deicer salt scaling resistance of concrete containing supplementary cementing materials

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PROJECT CARD

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Project title: Assessing the deicer salt scaling resistance of concrete containing supplementary cementing material

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1. DESCRIPTION OF THE OBJECTIVES OF THE RESEARCH PROJECT

Fly ash and ground granulated blast-furnace slag are now commonly used in the production of concrete mixtures for residential, commercial and industrial applications. In addition to reducing the amount of Portland cement added to concrete (which often decreases the cost of production), the addition of fly ash and slag also contributes to improve numerous physical and durability-related properties of the material and offers significant benefits from an environmental standpoint.

Despite their numerous advantages, the use of SCM for the production of concrete structures likely to be exposed to cold climates is often impeded by the fact that laboratory investigations invariably indicate that partial replacement of Portland cement with fly ash or slag markedly reduces the frost resistance of concrete in presence of de-icing chemicals. The conclusions of these numerous laboratory studies are apparently, however, not corroborated by field experience. The discrepancy between the two series of observations has led numerous researchers to question the reliability of the accelerated test procedure used in the laboratory to assess the de-icer salt scaling resistance of concrete.

The main objective of this research is to understand the detrimental influence of fly ash and slag on the de-icer salt scaling behavior of concrete as evaluated by laboratory procedures. Various ways to improve the scaling durability of concrete mixtures containing SCM will be explored. A great deal of effort will also be spent on the enhancement of the reliability of existing test procedures to assess the de-icer salt scaling performance of concrete.

The first efforts consisted in an investigation of the influence of various test parameters. Indeed, as previously emphasized, the ASTM C 672 has been extensively criticized for the relatively high variability of its test results This first task of the project is therefore entirely devoted to the investigation of the influence of the temperature cycle characteristics on the de-icer salt scaling performance of concrete (rate of freezing, minimal freezing temperature and length of freezing period).

The second task is focused on the systematic study of the effects of various curing regimes on the de-icer salt scaling resistance of concrete mixtures incorporating SCM. For each of the seven mixtures selected, the influence of three different curing regimes currently used in practice will be tested. Also a fourth series of samples will be cast in molds in which a synthetic membrane is placed at the bottom. This approach is the one suggested by the "Bureau de normalisation du Québec" (standard NQ-2621-900-1) after it was reported that this procedure significantly reduced bleeding. A sorptivity test should help to better understand the effect of bleeding, mixture design, and curing conditions on the pores network and on the transport properties of the paste located just beneath the exposed top surface (0 to 10 mm) of the sample.

The influence of fly ash and ground granulated blast furnace slag on the specific microstructure of paste located near concrete surface (0-5 mm) and the ice formation will also be investigated. This part of the study will be divided into two steps. Study of the microstructure of concrete skin containing supplementary cementitious materials was performed on samples cored from concrete sidewalks in Montreal.

2. SIGNIFICANCE OF THE RESULTS

A lot of the findings indicate that the deicer salt scaling test is very sensitive to temperature profiles, type of surface and level of SCM replacement. The effect of the curing method on the scaling resistance varies with the composition of the mixture, i.e. the type and the amount of SCM. In particular, the use of a curing compound at the end of the bleeding improves the scaling resistance of SCM concrete while the opposite effect occurs with the reference concrete that contains silica fume.

The huge increase of chloride concentration in the thin surface layer during the 56 freeze-thaw cycles under salt solution suggests that chlorides may react with the aluminates phases. Further microanalysis of damaged slab and scaled off particles is needed to support this hypothesis. The effect of the curing regime of the de-icer salt scaling specimens proved to be one of the most significant factors of all. Indeed, an extended curing regime and a pre-saturation period prior to the start of the freezing cycles generated results that correlate very well with site observations.

The observations on the concrete samples cored in Montreal sidewalks clearly showed that all fly ash concretes have a deeper carbonation depth (5-10 mm) compared to all other types of concrete (0-5 mm). Near the exposed surface, a very high proportion of fly ash particles was still unhydrated and therefore had not participated in the densification of the cement paste’s microstructure.

Based on available results, the correlation between the sorptivity and the salt scaling resistance of concrete was not clear. An explanation is the contribution of several mechanisms to the weakening of the concrete surface layer. This superposition can hide the effect of the porous characteristics. A large characterization of the concrete surface layer before and during the de-icing scaling test could permit to evaluate the importance of each parameter on the damage.

3. OUTCOME AND FUTURE WORK

The study in well-controlled conditions of the freezer pointed out the most important parameters of temperature cycle that influenced the de-icing scaling damage. These observations are being used to improve requirements on the use of the freezer in the accelerated scaling test methods. In addition, these observations can help to qualify the exposure conditions in field in relation with the standard test conditions.

This new understanding of the damage mechanisms are also used to determine technical recommendations for mix design and curing methods that can ensure adequate salt-scaling resistance of SCM concretes. Recommendations on the choice and design of accelerated scaling test methods to better forecast the in-situ salt scaling durability of concretes containing SCM were brought forward to different ASTM/CSA forums.

4. Dissemination of Research Results and Technology Transfer

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Dimitre Vassilev MASc Thesis Sept. 2012, "Development of an Improved De-icer Scaling Test", University of Toronto.

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Replacement Method for ASTM C 672 – Standard Test Method for Scaling Resistance of Concrete Surfaces Exposed to Deicing Chemnicals - Working Group 9367 *DRAFT*