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Durability Of Concrete To Sulfate Attack Under Different Environments

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***Abstract*— Concrete Experts International has extensive, world-wide experience with deteriorated concrete suffering from sulfate attack caused by water containing sulfate. Diagnosing external sulfate attack is an integrated part of our petrographic analysis of concrete. This paper investigate the durability of concrete to sulfate attack under different environments**

I. INTRODUCTION

External sulfate attack is a chemical breakdown mechanism where sulfate ions from an external source attack components of the cement paste. Such attack can occur when concrete is in contact with sulfate containing water e.g. seawater, swamp water, ground water or sewage water. The often massive formation of gypsum and ettringite formed during the external sulfate attack may cause concrete to crack and scale. However, both laboratory studies and examinations of field concrete show that external sulfate attack is often manifested, not by expansion or cracking, but by loss of cohesion and strength.

There is a general agreement that concrete suffering from external sulfate attack develops a more and less pronounced mineralogical and chemical zoning which can be studied in the optical fluorescence microscope and the scanning electron microscope.

ASTM C856 recommends chemical analysis to verify that the sulfate content of the concrete has been increased over that expected from the concrete constituents in order to diagnose external sulfate attack.

Please to not hesitate to contact CXI if you have some problems regarding external sulfate attack or any other deterioration mechanisms.

Degradation of cementitious systems exposed to sulfate salts is the result of sulfate transport through the pore system, chemical reaction with the hydration product phases present, generation of stresses due to the creation of the expansive reaction products, and the mechanical response (typically spalling and cracking) of the bulk material due to these stresses. Each component of this process plays a unique role in the ultimate response of the concrete; change the material properties relevant to any one component and the concrete performance can change dramatically.

Therefore, laboratory tests of ”sulfate attack" that are based primarily on submerging the specimens in sulfate solution and then measuring some physical property, such as expansion, are effectively lumping all of these mechanisms into a single test. The result is a test that characterizes how a particular concrete performs under specific conditions. If the field conditions are different, the performance of the concrete can also be different.

Often, it is assumed that the performance of concrete regarding its resistance to external sulfate attack depends on the composition of the cement used. Therefore, most standard tests are based on measuring macroscopic properties of cement pastes or mortars, such as expansion, modulus of elasticity, or compressive strength.

Evidence of the first blended cements dates back to Roman times, when volcanic ash was used in a crude blend with slaked lime to give the user a product that developed higher early strength than the usual slaked lime as well as significant durability. Evidence of this can be seen in the Aqueducts and the Colosseum in Rome. The area in Italy where the volcanic ash was discovered is called Pozzuola, hence the term for a reactive substance being called a pozzolan. Some academics have assumed that the Roman Empire discovered the process of cement manufacturing, which was lost with the decline of this empire and rediscovered in the nineteenth century in Britain. In truth, it is more likely that the lime the Romans calcined (burnt) for the purpose of slaking approached an argillaceous lime in chemical composition and hence had to be milled rather than naturally slaked. When mixed in the normal manner with water, this product showed large early strengths and was probably the first cement made. A mixture of Portland cement and other material such as granulated blast-furnace slag, pozzolan, hydrated lime, etc., combined either during or after the finish grinding of the cement at the mill. ACI 116, Cement and Concrete Terminology1, defines blended cements as hydraulic cements "consisting essentially of an intimate and uniform 21

blend" of a number of different constituent materials. They are produced by "intergrinding portland cement clinker with the other materials or by blending Portland cement with the other materials or a combination of intergrinding and blending.”. Concrete can be produced with blended cement containing slag plus other cementitious materials (most commonly fly ash or silica fume) added at the batch plant. These are considered ternary systems. Ternary systems can be designed to attain performance characteristics that may be difficult to achieve in a binary system.

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There are a number of systems that are used to make blended cements. Some systems are capable of "on-demand" blending, while others may blend the materials in a fixed percentage into a storage silo. All of the systems meter the constituent products in the desired proportions, and then blend them to a uniform mixture. In most cases proportions can be adjusted to produce blends that optimize the desired properties in concrete.

III. EXPERIMENTAL RESULTS

P.O.42.5R OPC conforming to IS standard and similar to the 42.5 R Portland cement conforming to EN197- 1:2009, was used for preparing concrete in this research. The physical and mechanical properties of the cement are listed in Table 1. Table 2 presents the chemical composition of FA and Table 3 the performance index of SF used in this study as partial replacement of OPC. Crushed limestone aggregates were used as coarse aggregates and washed mountain sand as fine aggregates. The fineness modulus of fine aggregates was tested according to Chinese standard JGJ52-2006 (similar to ASTM C136-01) and the results are tabulated in Table 4. Tap water was used for mixing concrete. A commercially available water reducer (i.e. SM) was used to keep concrete slump between 80 and 100 mm. Sodium sulfate anhydrous with 99% purity were used for making sulfate solutions as the sulfate attack source.

Compressive strength of the concrete specimens containing FA or SF after 60 drying-immersion cycles in 5.0% by wt Na2SO4 solution is given in Fig. 2(a) and (b) which demonstrated similar varying features for both FA and SF series concretes, i.e. both series of concrete specimens actually gained strength during the 60 drying-immersion cycles in the 5.0% by wt Na2SO4 solution. In the FA and SF series, strength gains were steadily after 60 drying-immersion cycles and were 15%–18% and 7%–17% respectively relative to their strengths prior to drying-immersion test. The results were consistent with Bakharev's findings [30] on compressive strength variation subjected to sulfate attack and strength of specimens exposed to sulfate solution increased in the first month of the test, and then had a steady decline. Dulaijan [31] indicated that 20% FA and 7% SF by weight replacement level of OPC could improve the resistance of OPC concrete to sulfate attack.

Fig. 2(c) shows the results of DRCCS. The DRCCS of concretes without any admixture (C-8) were 95.5% and 102.4% after 30 and 60 drying-immersion cycles, respectively. The results suggested that FA and SF were effective to increase DRCCS and the resistance to sulfate attack in 5% Na2SO4 solution and by comparison SF performed better than FA.

Fig. 3 presents the RDEM of the series C concrete up to 175 freezing-thawing cycles in sodium sulfate solutions in which the C-3-0, C-3-5 and C-3-10 series represents concrete specimens subjected to freezing-thawing cycles in sodium sulfate solutions of the concentration of 0%, 5% and 10% by weight respectively. The average initial frequencies of C-3 series concrete prior to immersion in sodium sulfate solution were 2335, 2373 and 2385 Hz, respectively and RDEM up to 175 freezing-thawing cycles is presented in Fig. 3. According to the figure, RDEM of concrete decreased after freezing-thawing cycles in clean water (C-3-0) and the concrete had the minimum RDEM value of 92.7% up to 175 freezing-thawing cycles in clean water.

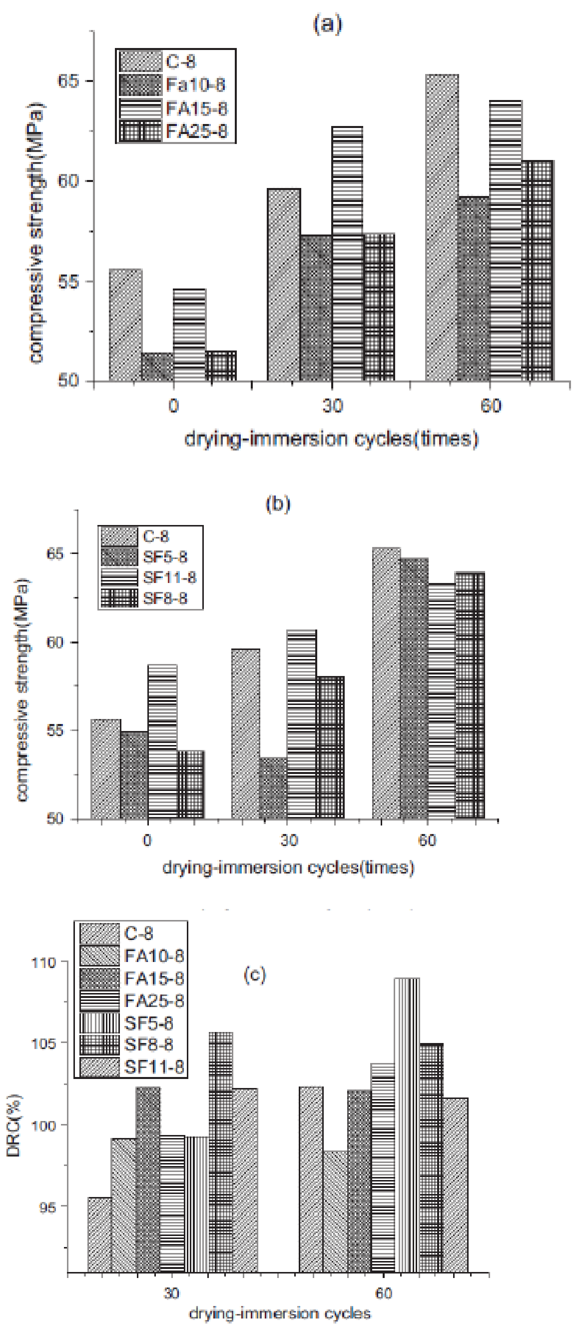

Fig. 1: compressive strength changes of concrete with FA and SF

CONCLUSIONS

Durability of concretes with w/b of 0.38 and 0.33 containing FA and/or SF against combined freezing-thawing and sulfate attack was investigated in this study. The following conclusions can be drawn based on the experimental results.

(1) Exposed to 5% sodium sulfate solutions, concrete containing FA and SF both gained compressive strength and DRCCS during the period of 60 drying-immersion cycles. Both FA and SF can improve the resistance of concrete to sulfate attack with SF performing better than FA.

(2) Sulfate solution has a combined positive and negative effect on concrete subjected to freezing-thawing cycle. As for concrete without any admixture, 5% and 10% sodium sulfate solutions could enhance concrete's resistance to freezing thawing cycle up to 125 while decrease after 125 cycles. 10% sodium sulfate solutions more obviously restricted the deterioration of concrete with 25% by weight FA replacing OPC than 5% sodium sulfate solutions up to 175 freezingt hawing cycles. As for concretes with 8% by weight SF replacing OPC, 5% and 10% sodium sulfate solution retarded concrete deterioration and the effect was similar.

(3) In general, FA and SF as the concrete admixture improved concrete's resistance against the combined freezing hawing and sulfate attack with 25% FA and 5–8% SF by weight replacement level of cementitious materials leading to significant improvement in concrete durability.

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