EFFECT OF WET-DRY CYCLES IN SULFATE SOLUTION ON THE PHYSICAL AND MECHANICAL PROPERTIES OF CONCRETE

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I- INTRODUCTION:

Sulfate attack on concrete is the most intensively studied type of concrete corrosion because it is most frequently encountered during the service life of concrete structures [(1-3)]. Intrusion of sulfates into concrete takes place through the pores of the cement paste and hence, the severity of the sulfate attack depends, to great extent, on the permeation properties of concrete [(2)]. The incorporated materials in the concrete mix, the manufacturing process along with the concentration and cations associated with sulfates are the most important factors affecting the severity of the attack. Service conditions, namely, temperature and cycles of wet-dry exposure to sulfates are believed to magnify the deleterious effects of exposure to sulfates solution.

II- OBJECTIVES:

The current research work has been conducted to achieve the following objectives:

1. Evaluate the effect of wet-dry cycles in 1.5% sulfates solution on the physical and mechanical properties of different concrete mixes.
2. Investigate the effect of exposure temperature on the severity of sulfate attack.
3. Compare the concrete behavior in wet-dry fresh water cycles to its behavior in wet-dry 1.5% sulfate solution cycles.

III- EXPERIMENTAL PROGRAM

Study Parameters:

The parameters of interest are; w/c ratio, Aggregate/c (A/c) ratio, presence of Silica Fume, Cyclic exposure to Magnesium Sulfate solution, and Temperature of Exposure. Four values of w/c were considered: 0.30, 0.35, 0.40, 0.45 to cover the allowable range by the Egyptian code of concrete design and construction [(4)] and other international codes. Four values of A/c were considered: 4.5/1, 5/1, 5.5/1, 6/1 to cover the high and low cement contents. The full combinations of the w/c values and A/c values gave 16 concrete mixes. Four additional concrete mixes with w/c ratio = 0.4 and containing 10% of cement weight silica fume made the total number of concrete mixes equal 20 mixes. The exposure medium is 1.5% magnesium sulfate.

Incorporated Materials:

The concrete mixes have been prepared using sand with 2.2 modulus of fineness; gravel with 20mm nominal maximum size; ordinary portland cement and tap water. Superplasticizer has been used to control the workability. Silica fume has been added to the last four mixes as pointed out earlier.

Testing Plan:

Six 10x20cm cylinders for every mix have been cast and cured under water for 28 days. After curing, the cylinders were divided into three groups. The first group was subject to immersion in fresh water at ambient temperature for six days and then furnace-drying at 50 ºC for one day. The second and third groups were subject to similar cycles but in 1.5% magnesium sulfate solution. The second group was at ambient temperature while the third group was at 50 ºC.

The samples were subjected to 30 of the abovementioned cycles. At the end of every cycle, the surface scaling (if any) of the concrete samples and the absorption capacity were measured. Any cracks or deposits were monitored.

At the end of the 30 cycles, the splitting tensile strength of all samples were determined and compared. The depth of carbonation was measured, and representative small concrete pieces were extracted from the different samples and examined using XRD.

IV- RESULTS AND DISCUSSIONS:

Due to the space limitations, carbonation and X-ray analysis results are not included.

Surface Deterioration:

Figure (1) shows four specimens after exposure to 30 dry-wet cycles. The specimens subjected to fresh water did not show any scaling or salt depositing whereas the samples subjected to sulfates at ambient temperature showed patches of salt deposition. The samples subjected to sulfates at 50°C showed severe scaling and salt deposition. There was no observed difference between samples with different cement content or those with different w/c ratios. After exposure to sulfate solution at 50°C, samples containing silica fume showed a minor degree of scaling (less than 20% of the surface).

Permeation Changes:

Figure (2) shows the initial values of water absorption of the different tested mixes. It is evident that the initial water absorption, which is a measure of the permeation characteristics of the specimens, increases with the increase in w/c and A/c. The initial absorption of mixes containing silica fume is very low (less than 1%). The water absorption of the different mixes was monitored for the thirty exposure cycles. Figure (3) shows the trends of Absorption-exposure cycles for mixes having w/c = 0.4. The test results show that; the absorption of the different mixes is reduced considerably after a few cycles due to the deposition of non-soluble reaction products. In mixes with originally high absorption percentage, carbonation is also a possible cause of the reduction of the absorption capacity. Specimens exposed to sulfates at 50°C show greater and faster reduction in their water absorption capacity due to the acceleration in the reaction. Absorption values of concrete in sulfates at 50°C are 50%-60% lower than those for concrete in sulfates at ambient temperature. With the presence of silica fume, absorption is affected slightly by A/c ratio in all exposure conditions.

Keywords: Concrete Durability, Sulfate Resistance, Wet-Dry Cycles, Splitting Tensile Strength, Concrete Deterioration
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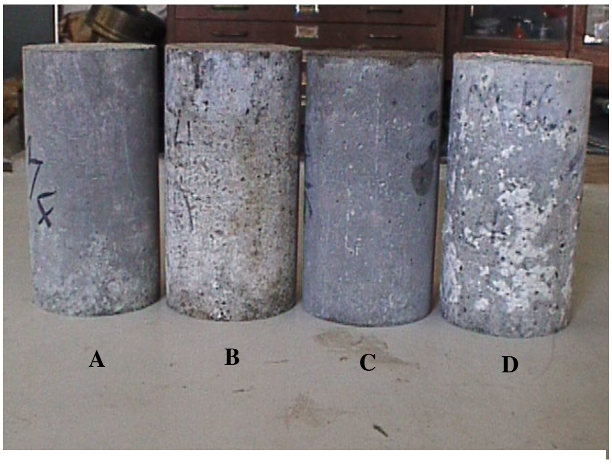

Fig. 1. Surface deterioration of Concrete samples After Exposure to Wet-Dry Cycles

A: A/c = 6.0, w/c = 0.40, in fresh water
B: A/c = 6.0, w/c = 0.40, in 1.5% sulfate at 50 °C
C: A/c = 4.5, w/c = 0.40, in Fresh water
D: A/c = 4.5, w/c = 0.40, in 1.5% sulfate at 50 °C

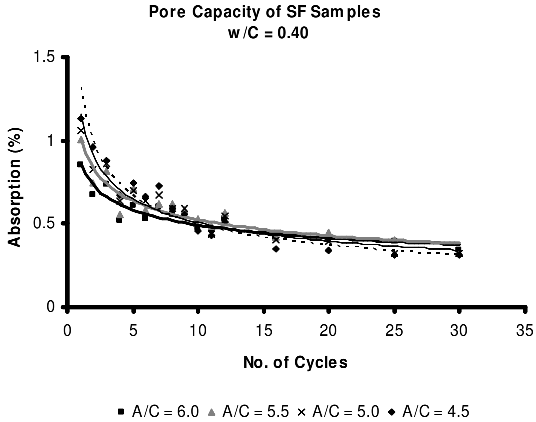

Fig. 3. Reduction in Water Absorption
(Cycles in Sulfates at 50 °C)

Silica fume reduces the permeation capacity of concrete and hence retards the effects of the sulfates attack.

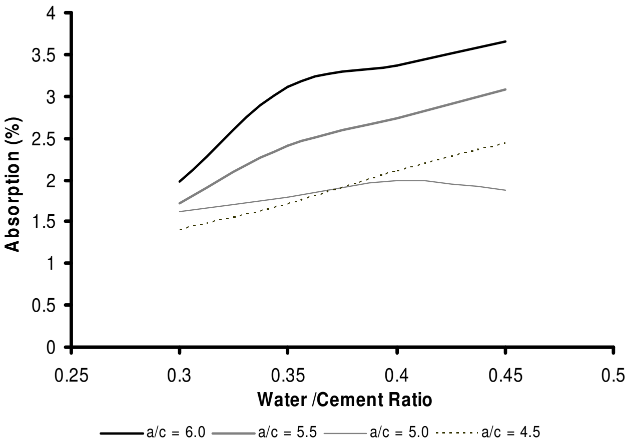

Fig. 2. Initial Absorption of Different Concrete Mixes

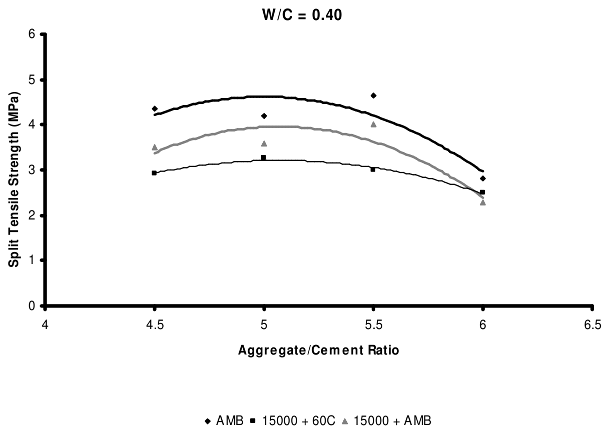

Fig. 4. Splitting Tensile Strength After 30 Dry-Wet Cycles

Splitting Tensile Strength:

Residual splitting tensile strength is used in this research to indicate the durability of concrete against sulfates attack. Figure (4) shows the splitting tensile strength of concrete samples containing w/c = 0.4 after exposure to 30 wet-dry cycles. The exposure to sulfates reduces the tensile strength. The reduction may reach 30% for the case of samples containing A/c = 4.5/1 and exposed to 30 wet-dry cycles in sulfates at 50°C. Presence of silica fume enhances the concrete durability drastically. A reduction of only 10% in splitting tensile strength is observed when comparing specimens exposed to dry-wet cycles in fresh water to those exposed to the same cycles in sulfate solution at 50°C.

V- CONCLUSIONS:

The present research work shows that: exposure to sulfates in wet-dry cycles when accompanied with an ambient temperature of 50 °C has great effect on concrete. Only 30 of these cycles cause severe scaling and 30% reduction in splitting tensile strength. Replacement of cement with 10% silica fume enhances the durability of concrete drastically.

VI- REFERENCES:

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