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Original Research Paper

Extent of Fly Ash Blended Cement Concrete Deterioration Under Sulphate Attack

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ABSTRACT

Fly ash, which was once an environmental pollutant, has now found a good place in the construction industry, mainly in production of blended cement. Blended cement has replaced ordinary Portland cement (OPC) to a major extent, in lieu of its increased durability and lesser cost. In addition there is reduction in green house gases in the manufacturing of cement, thereby reducing pollution. The main aim of this work is to study the effect of sulphate attack in OPC and blended cement made by replacement of OPC with fly ash by 10%, 20% and 30%. When the analysis of concrete reveals a high sulphate content this does not necessarily indicate any deterioration although conversely, loss of strength or visible deterioration accompanied by high sulphate content would be evidence of sulphate attack. The properties were monitored periodically to examine durability. Here, an attempt is made to know the effect of sulphate attack on blended cement by monitoring the properties like density variation, compressive strength and water absorption. The test results discussed above conclude the effect of sulphate attack on OPC specimens and OPC specimens replaced with fly ash. The deterioration starts significantly after 60 days of curing in all cases. The concrete is good in sulphate resistant when fly ash is added. The fly ash added specimens performed better than OPC specimens. The result of the study indicated that the replacement of cement with 20% fly ash improved the durability of concrete to a larger extent. The final strength reduction for the specimens attacked by magnesium sulphate solution were higher than that those attacked by sodium sulphate solution.

INTRODUCTION

Sulphate attack is defined as deleterious action involving sulphate ions. If sulphates interact with cement and cause damage to it, but the action is physical and a similar action can occur with salts other than sulphates then the damage is considered to be physical attack or physical sulphate attack (Maltais et al. 2002). Calcium sulphate reacts with C_3A to form ettringite and reacts also with sodium and potassium hydroxides (Neville 2004). Magnesium sulphate reacts with all products of hydration of cement; the important resulting compounds are calcium sulphate and magnesia. Calcium sulphate can proceed to react with C_3A (Neville 2004). Concrete subjected to sulphate attack can undergo a progressive and profound reorganization of its internal microstructure (Maltais 2002). Concrete exposed to negligible sulphate concentrations (i.e., soils containing less than 0.1% of water soluble sulphate or solutions for which the SO_4 concentration is less than 150ppm are relatively vague (Maltais 2002).

Deterioration of concrete by sulphate attack is commonly observed in structures exposed to soils and groundwater containing a high concentration of sulphate ions (Hanifi & Orhan 2005). Sulphate resistance of blended cements was significantly higher both against sodium sulphate and magnesium sulphate attacks than ordinary Portland cements (Hanifi & Orhan 2005). Generally, the compressive strength at 3, 7, 28, 90 and 180 days and sulphate resistance of blended cements are investigated. Compressive strength of mortars decreases, showing the significance of sulphate attack (Hanifi & Orhan 2005).

When a homogeneous porous material has a constant hydraulic potential at wet front, liquid can mount to considerable heights due to the capillary absorption. If evaporation takes place, equilibrium between capillary absorption and evaporation is reached at certain height. This is the measure of water sorptivity. Water sorptivity is a measure of permeability, which in turn is the measure of durability. The sorptivity coefficient of concrete decreases when the compressive strength of concrete increases (Canan 2003). Sorptivity coefficient of concrete is very sensitive to the curing condition. The effect of curing condition on the sorptivity coefficient of concrete seems to be higher in low strength concretes. Curing environment has a significant influence on sorptivity development. In general, water-cured concrete gives lower sorptivity than equivalent concrete that has been air cured (Bai & Sabir 2002).

MATERIALS AND METHODS

Material properties: Ordinary Portland cement was used for the experiment. The specific gravity of the cement was 3.13. Fly ash was taken from Tuticorin power plant. The fly ash obtained was in the category Class F. The specific gravity of the fly ash was 2.12. The sand was sieved to remove all pebbles. Sand passing through the sieve of size 2.36 mm was used. Specific gravity of fine aggregate was 2.64, and bulk density 1720 kg/m^3. Specific gravity of coarse aggregate (10mm) was 2.78, and bulk density 1463 kg/m^3. Ordinary potable water was used for casting of specimens. Table 1 shows the mix design for concrete made with OPC, OPC + 10% fly ash, OPC + 20% fly ash and OPC + 30% fly ash, based on IS method.

Test methods: The specimens were cast using cubes of size 70.7 mm × 70.7 mm × 70.7 mm. All specimens were cast with the designed mix proportion. Three sets of cubes were cast with no fly ash, 10%, 20% and 30% replacement of fly ash, for which the compressive strengths were found after 28, 60, 90, 120, 300 and 450 days. The above sets are cubes cast with a total super set of 3 numbers, to be kept in ordinary water, magnesium sulphate solution and sodium sulphate solution as shown in Fig. 10. The mould was stripped after 24 hours. All the specimens were cured in the corresponding solutions for the days specified.

The tests conducted were compressive strength, density variation and water sorptivity. The compressive strength and density variation have been found from the cubes. Sorptivity test was done

Table 1: Mix design-M20.

Material/m^3	Water (kg)	Cement (kg)	Fly ash (kg)	FA (kg)	CA (kg)
OPC	196	392	-	823.68	950.95
	0.5	1	-	2.10	2.43
OPC + 10% FA	196	352.8	39.2	810.48	950.95
	0.55	1	0.11	2.3	2.69
OPC + 20% FA	196	313.6	78.4	790.42	950.95
	0.675	1	0.25	2.52	3.03
OPC + 30% FA	196	274.4	117.6	778.8	950.95
	0.714	1	0.428	2.83	3.46

using the cubes. To achieve unidirectional flow for the sorptivity, epoxy paints have been coated in all the faces of the cubes except on the bottom face.

RESULTS AND DISCUSSION

Based on the observed results, study has been done for compressive strength, density, water sorptivity variations for 5% of magnesium sulphate and sodium sulphate solutions for the concrete cubes with the replacement of cement by fly ash by 10%, 20% and 30%. The results show variations in compressive strength for 28 days, 60 days, 90 days, 120 days, 300 days and 450 days of testing. As for density variation and water sorptivity, the variation was studied up to 120 days. Figures have been drawn for varying percentage of fly ash replacement and based upon them the following results were found.

Compressive strength vs. duration of immersion: Fig. 1 gives the compressive strength variation of (OPC, OPC + 10% fly ash, OPC + 20% fly ash, OPC + 30% fly ash) specimens immersed in water for 60 days, 90 days, 120 days, 300 days and 450 days of curing. In 60 days, the specimens showed no variation in the increase in strength as expected.

Fig. 2 shows the comparison of compressive strength of (OPC, OPC + 10% fly ash, OPC + 20% fly ash, OPC + 30% fly ash) specimens immersed in 5% of sodium sulphate solution for 60 days, 90 days, 120 days, 300 days and 450 days. The immersed specimens in the solutions showed gradual increase in the compressive strength up to 60 days. The increase is of 3.8%, 0.6%, 1% and 0.3% for the specimens OPC, OPC + 10% fly ash, OPC + 20% fly ash and OPC + 30% fly ash when compared to control specimens. After 60 days gradual decreasing in compressive strength was noticed. The decrease was of 1.5%, 1.1%, 0.8% and 1.2% for OPC, OPC + 10% fly ash, OPC + 20% fly ash and OPC + 30% fly ash specimens respectively when compared to control specimens. This clearly shows the start of deterioration of the specimens. The decrease in compressive strength at 120 days is very high as compared to 90 days. There is decrease in compressive strength by 6.7%, 1.3%, 1.1% and 2.3% for the specimens OPC, OPC + 10% fly ash, OPC + 20% fly ash and OPC + 30% fly ash at 120 days when compared to control specimens, which continues till 450 days. For OPC specimens there is very steep decrease in compressive strength as compared to the specimens replaced with fly ash, which is expected to continue as the duration increases.

Fig. 3 shows the comparison of compressive strength of specimens immersed in 5% of magnesium sulphate solution. Here, also the strength increases up to 60 days for the specimens in sodium sulphate solution. After 60 days there was notifying decrease in the compressive strength. The decrease in compressive strength for OPC specimens at 90 days was of 1.8% when compared to the control specimens. For the specimens, OPC + 10% fly ash, OPC + 20% fly ash and OPC + 30% fly ash the corresponding decrease in compressive strength was by 1%, 1% and 1.6% at 90 days when compared to the control specimens. By the end of 120 days, the decrease in compressive strength for OPC specimens was 5.8%, which shows very high decrease in compressive strength when compared to the specimens replaced with fly ash. The decreasing trend continues in the same interval till 450 days. The decrease in compressive strength of blended cement concrete cubes is lesser than OPC cubes, with a difference of about 3% to 3.8%. It shows that OPC cubes deteriorate faster than blended cement concrete cubes, owing to its pozzolanic property.

Density variation vs. duration of immersion: Figs. 4 to 6, drawn between density variation and duration of immersion, show the density variation of OPC, OPC + 10% fly ash, OPC + 20% fly ash and OPC + 30% fly ash specimens in water, sodium sulphate solution and magnesium sulphate solution respectively. The specimens immersed in magnesium sulphate solution and in sodium sulphate

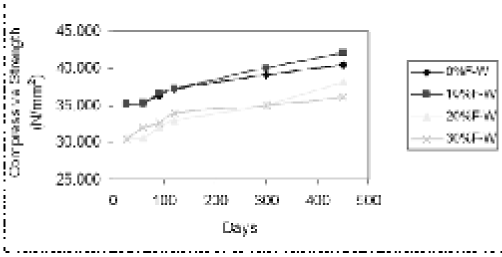

Fig. 1: Comparison of compressive strength of cubes in water.

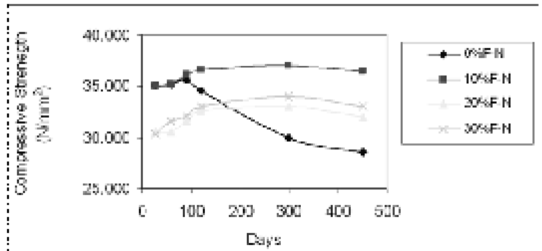

Fig. 2: Comparison of compressive strength of cubes in sodium sulphate solution.

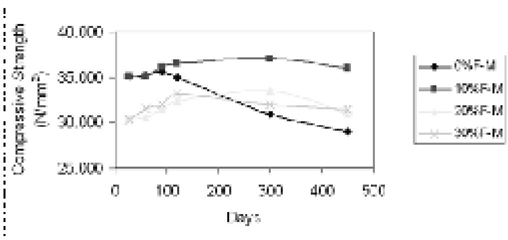

Fig. 3: Comparison of compressive strength of cubes in magnesium sulphate solution.

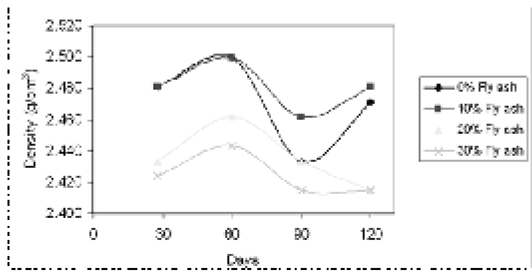

Fig. 4: Density variation in water.

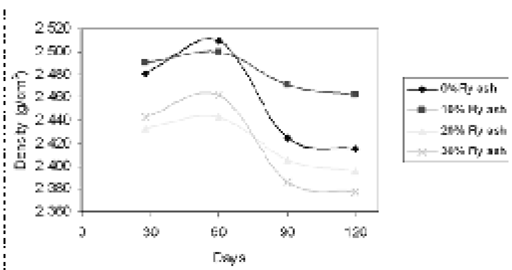

Fig. 5: Density variation in sodium sulphate solution.

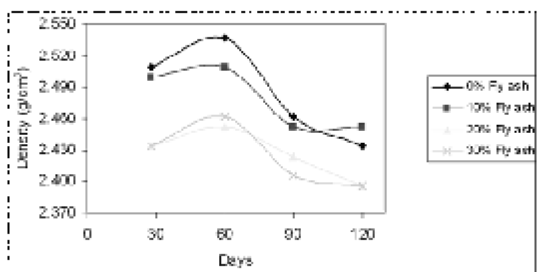

Fig. 6: Density variation in magnesium sulphate solution.

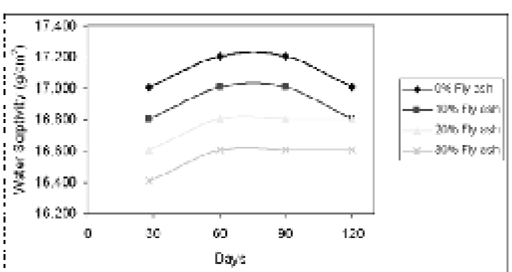

Fig. 7. Water sorptivity variation in water.

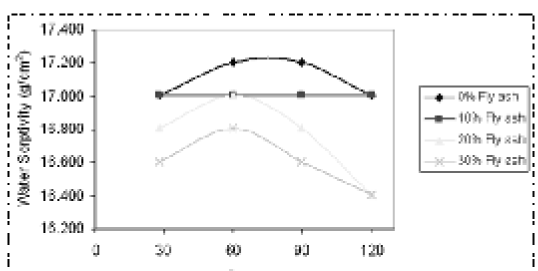

Fig. 8: Water sorptivity variation in sodium sulphate solution.

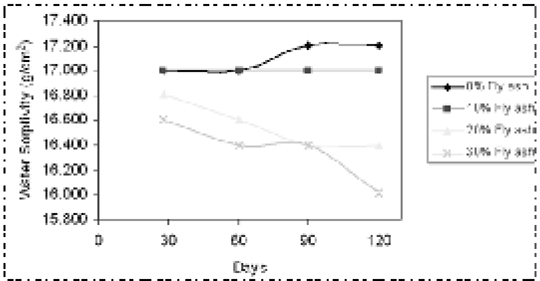

Fig. 9: Water sorptivity variation in magnesium sulphate solution.

Fig. 10: Curing of specimens in water, magnesium sulphate and sodium sulphate solutions.

solution show increase in density of 1.2% and 1.0% respectively on an average at 60 days. This might also be due to the water absorption of specimens.

At 90 days of testing, the density of OPC, OPC + 10% fly ash, OPC + 20% fly ash and OPC + 30% fly ash specimens immersed in sodium sulphate solution gets decreased by 2.3%, 1%, 0.8% and 2.3%, showing the beginning of deterioration of the specimens. The decrease in density for the specimens OPC, OPC + 10% fly ash, OPC + 20% fly ash and OPC + 30% fly ash at 120 days is 2.5%, 1.2%, 1.5%, and 2.5%. The decrease in density for OPC specimens and OPC + 30% fly ash specimens is higher when compared to OPC + 10% fly ash specimens and OPC + 20% fly ash specimens.

Fig. 6 was drawn between density variation and duration of immersion of the specimens in 5% magnesium sulphate solution. The density of the OPC cubes decreases by 3% at 120 days, while the density of the OPC + 10% fly ash, OPC + 20% fly ash and OPC + 30% fly ash specimens decreased by 1.9%, 1.5% and 1.5% respectively. This shows that the deterioration of OPC specimens is very high at 120 days. There is steep decrease in density, which is expected to continue as the duration increases. The OPC + 10% fly ash and OPC + 20% fly ash specimens show good resistance to deterioration.

Water sorptivity vs. duration of immersion: Permeability has been tested by the water sorptivity test, i.e. the unidirectional movement of water through the specimens. The curves were plotted for 28, 60, 90 and 120 days sorptivity results (Fig. 7). Based on the curves obtained, it can be seen that there is negligible or no change in the water sorptivity from 60 to 90 days. Fig. 8 shows the sorptivity of specimens kept in 5% of sodium sulphate solution. The figure shows the reduction in water sorptivity of 1.2% to 2.3% for all the specimens immersed in sodium sulphate solution at 120 days, which denotes the reduction in permeability of water as time goes on. Fig. 9 shows the water sorptivity of specimens kept in 5% magnesium sulphate solution. It indicates reduction in water sorptivity of 1% to 2% for all the specimens immersed in magnesium sulphate solution at 120 days, which denotes the reduction in permeability of water as time goes on. Due to deterioration of the cement matrix, there is saturation of water inside the specimens which reduces the water sorptivity.

CONCLUSION

The test results discussed above conclude the effect of sulphate attack on OPC specimens and OPC specimens replaced with fly ash. The deterioration of specimens in sulphate solutions starts significantly after 60 days of curing in all cases, and continues with time. The concrete is good in sulphate resistance when fly ash is added. The fly ash added specimens performed better than OPC specimens. The results of the study indicated that the replacement of cement up to 20% fly ash improved the durability of concrete. The final strength reduction for the specimens attacked by magnesium sulphate solution were higher than that those attacked by sodium sulphate solution. Since there is variation in the results at 450 days, the various other tests such as the phase analysis by x-ray diffraction and microstructural analysis by SEM and MIP can also be done to study the micropore structure of deteriorated concrete.

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