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STUDY ON STRENGTH AND SORPTIVITY CHARACTERISTICS OF FLY ASH CONCRETE

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ABSTRACT

When fly ash is added in concrete, the reactive silica present in fly ash reacts with calcium hydroxide liberated during cement hydration and forms calcium silicate hydrate (C-S-H) gel. Compact C-S-H gel gives higher strength and lower permeability and absorption characteristics. They are indicators of durability of concrete. Therefore, a study was carried out on influence of fly ash on sorptivity of OPC-Fly Ash concrete. The experiments were conducted using a mix proportion of cement (1) : sand (1.57) : 10 mm aggregates (1.35) : 20 mm aggregates (2.03) with four water to cementitious material (Cement + Fly Ash) ratios (w/cm) (0.55, 0.475, 0.40 and 0.340). The cement replacement by fly ash was varied between 0 to 50%. Compressive strength and water absorption tests were conducted on each of the twenty-four mixes. The sorptivity of concrete was compared with that of the control concrete. The results indicated that higher volume of cement replacement and lower w/cm ratios have lower values of cumulative water absorption and sorptivity. There was a small reduction in 28 days compressive strength of concrete with increase in fly ash content. However, it was found to be almost the same or marginally higher than that of control mix at 90 days.

Keywords: fly ash, HVFA, water absorption, sorptivity.

INTRODUCTION

The deterioration of concrete usually involves movement of aggressive gases and/or liquids from the surrounding environment into the concrete followed by physical and/or chemical reaction within its internal structure, possibly leading to irreversible damage. The pore structure and alkalinity of the cover concrete were found to be the most important properties that affected the durability of a concrete. A lower permeation property of cover zone protects the steel from corrosion for a longer period; hence enhance the durability of concrete. The measurement of sorptivity could be used as an indicator of durability [1,2,3]. Sorptivity is a property associated with capillary effects. It is defined as the gradient of the volume of water absorbed per unit area of the surface and the square root of the absorption time. The movement of water into concrete is described by the classical square-root-time relationship [4]. In this relationship, water absorption into porous materials increases as the square root of the elapsed time t. Assuming a constant supply of water at the inflow surface, the following relationship holds [5]:

$i = A + St^{0.5}$

where

i = cumulative volume absorbed per unit area of inflow surface;

S = sorptivity of the material (expressed in mm/min$^{1/2}$)

MATERIALS AND METHODS

The experiments were carried out using a concrete mix with four different w/c ratios. The cement replacement levels were varied from 0% to 50%. Cube specimens were prepared for compressive strength and absorption testing. The cube specimens were demoulded 24 hours after casting and cured in water. Compressive strength tests (After 7 days, 28 days and 90 days) were conducted after curing the specimens in water for 7 days, 28 days and 90 days respectively. Cube specimens for sorptivity measurement were cured in water for 28 days after casting.

Materials

Cement
Ordinary Portland Cement of 43 Grade confirming to IS-8112 [6] was used for the investigation.

Fine aggregate
Locally available river sand having a fineness modulus 2.90 and specific gravity of 2.62 was used as fine aggregate. The sand was conforming to Zone III of IS: 383 [7].

Coarse aggregate
Crushed quartzite stone aggregates of 20mm and 10mm nominal size having specific gravity of 2.59 were used.

Fly ash
The physical and chemical properties of the fly ash used in the investigation are given in Table-1.

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Table-1. Properties of fly ash used.

Type of properties	Description	Requirement as IS: 3812-2003	Dadri fly ash
Physical properties	Fineness-sp. surface(m^2/kg)	**> 320**	**437**
	Lime reactivity-avg. compressive strength (n/mm^2)	**> 4.0**	**5.0**
	Comp. strength at 28 days as % of cement mortar cubes	**> 80**	**86.8**
	Drying shrinkage	**< 0.15**	**0.05**
	Soundness by autoclaving expansion method	**< 0.8**	**0.04**
	Retention on 45 micron sieve (%)	**< 34**	**3-4%**
	Moisture (%)	**< 2.0**	**0.2**
Chemical properties	Loss on ignition (% by wt.)	**< 12**	**1.06**
	Silica as SiO_2 (% by wt.)	**> 35**	**67.31**
	Iron oxide as Fe_2O_3 (% by wt.)	**---**	**4.52**
	Alumina as Al_2O_3 (% by wt.)	**---**	**30.02**
	Total of SiO_2, Fe_2O_3, Al_2O_3 (% by wt.)	**> 70**	**92.45**
	Calcium oxide CaO (% by wt.)	**---**	**2.54**
	Magnesium oxide MgO (% by wt.)	**< 5.0**	**0.46**
	Sulphur as SO_3 (% by wt.)	**< 2.75**	**Traces**
	Alkalies (% by wt.) Sodium oxide Na_2O Potassium oxide K_2O	**< 1.50**	**0.08** **1.11**

Test variables

Concrete mixes having 1:1.57:1.35:2.03 (Cement: Sand: 10mm Aggregates: 20mm Aggregates.) proportions having 0.55, 0.475, 0.40 and 0.34 w/c ratios were used. The cement replacement by fly ash was kept at 0%, 10%, 20%, 30%, 40% and 50% of total cement content (by weight) for each w/cm ratio. Hence properties of twenty four concrete mixes have been studied to find the effect of fly ash on concrete properties. The control mix was prepared using 0.55 water cement ratio and 0% fly ash and for the rest of the mixes superplasticizer doses were varied to achieve a compacting factor greater than 0.85.

Test details

Concrete cubes of 100 x 100 x 100 mm were used after 28 days water curing for Sorptivity evaluation. The cubes were stored in an oven at 105^0C for 72 hours, then the samples were cooled at room temperature for 24h. Protective coating of epoxy resin was applied to the four faces of the cube to prevent water from penetrating through the sides. The specimens were weighed, and then one face was placed in contact with water. The schematic arrangement of the sorptivity test is shown in Figure-1. The specimens were immersed in tray containing water on 10mm diameter steel rods to allow free access of water to the inflow. The water level was maintained at 5mm above the base of the cube. Immediately after the immersion of the cube surface into water, the start time of the test was recorded; the gain in weight due to water absorption was measured after mopping off with a dry tissue at suitable intervals up to 48 hours. The sorptivity was calculated from the volume of water absorbed per unit cross-section, A, and the square root of time, t. Values of sorptivity were given in mm per $min^{1/2}$. The slope of the line was considered as the parameter describing the sorptivity.

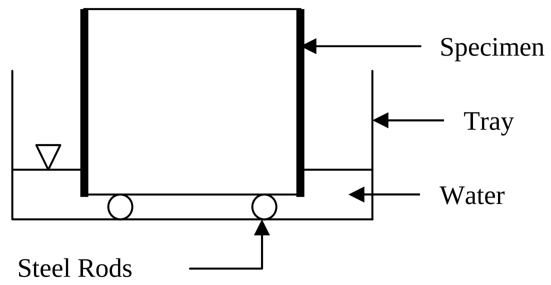

Figure-1. Schematic diagram for sorptivity test.

RESULTS AND DISCUSSION

The Compressive strength of three samples was found out after water curing at 7 days, 28 days and 90 days. The results of the tests at 7, 28 and 90 days have been plotted in Figure-2(a-c), respectively. As the fly ash content increased the compressive strength of concrete with 0.55 w/cm ratio decreased. However, compressive strength of fly ash concrete is almost equal or little less than that of the control mix even after 50% replacement of cement by fly for 0.4 and 0.475 w/c ratio concrete. The strength of 0.34 w/c ratio concrete decreased with increase in fly ash content, this may be due to high dosage of superplasticizer (3.0%) used in this case.

At 28 days and 90 days, the compressive strength was almost equal or higher for all the cases even after 50% cement replacement by fly ash except 0.34 w/cm ratio. At this low w/cm ratio the strength of found to be lower than the 0.4 w/cm ratio, which probably resulted due to very high doses of plasticizer as mentioned above. The gain in strength with ages is higher in case of fly ash concrete; such gain is more predominant in case of high volume fly ash concrete than that of low volume fly ash concrete.

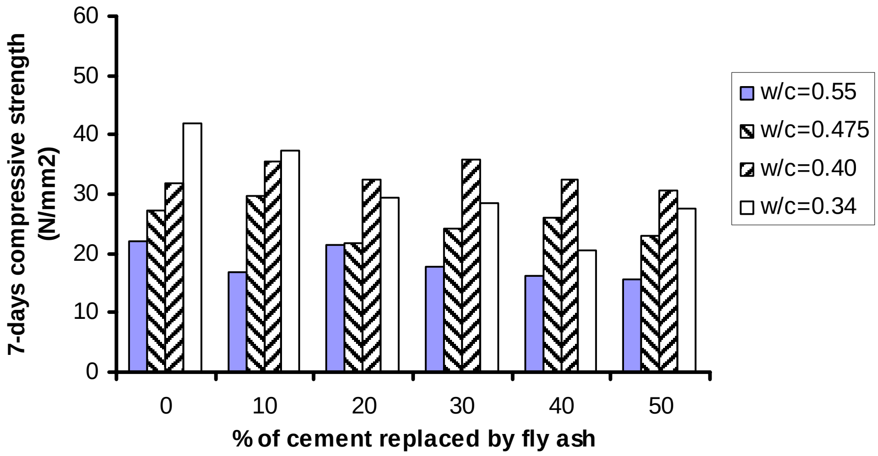

Figure-2a. Compressive strength (7 days) with change in percentage of cement replacement by fly ash.

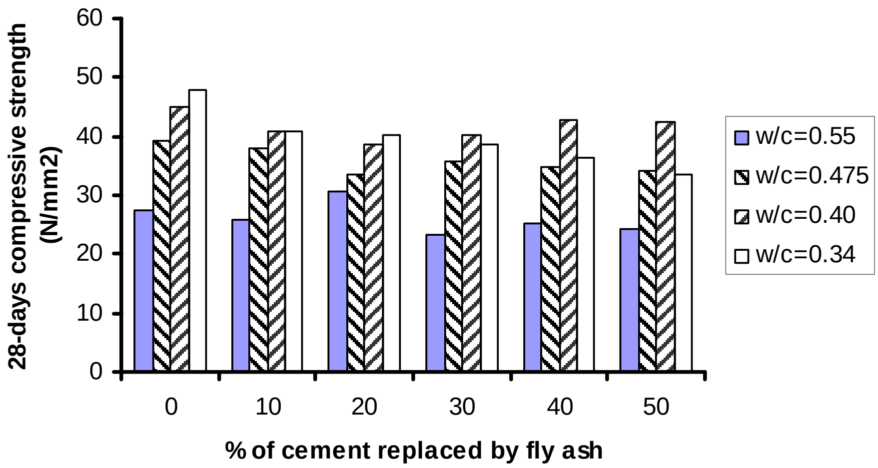

Figure-2b. Compressive strength (28 days) with change in percentage of cement replacement by fly ash.

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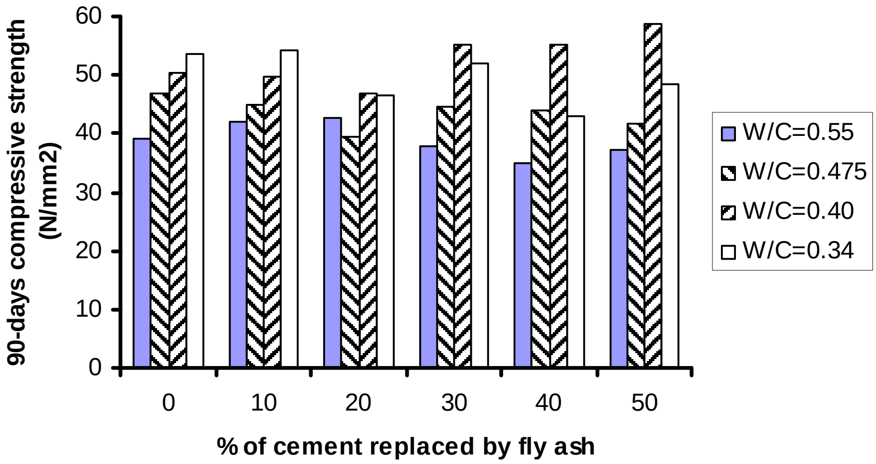

Figure-2c. Compressive strength (90 days) with change in percentage of cement replacement by fly ash.

The lower the sorptivity value, the higher the resistance of concrete towards water absorption. It mainly depends on the pore distribution and micro structural properties of concrete i.e. water could be transported through the pores by capillary action or by diffusion in both capillary and gel pores [8].

The results of the cumulative water absorption with square root of time in minutes for the observations taken for a period of 48 hours are shown in Figures 3 to 6. The slope of the line defines the sorptivity of the concrete determined by linear regression. The linear relationship if a good fit of the equation $i = A + St^{0.5}$. The values or correlation coefficient r lies in the range of 0.977 to 0.999. Figure-7 shows the relationship between sorptivity with the change in percentage of cement replacement by fly ash. The sorptivity of the mixes lies in the range of 0.017 to 0.1373 mm/min$^{1/2}$. The cumulative water absorption of concretes with cement replacement of 40 and 50% is generally less than that of control concrete for all the w/cm ratios except for concretes with w/cm = 0.475. This indicates that these concretes with high volume of cement replacement have denser structure due to the pozzolonic and the filler effect of fly ash. The porosity of the concrete is lesser with less number of interconnected pores. The cumulative water absorption of the concrete mixtures decreases with the decrease in w/cm ratio for all the concrete due to less amount of water in the mix, resulting into dense concrete. The cover zone property of the concrete improves due to high volume replacement of cement. Sorptivity has been observed to decrease as the cement replacement by fly ash increases (Figure-7).

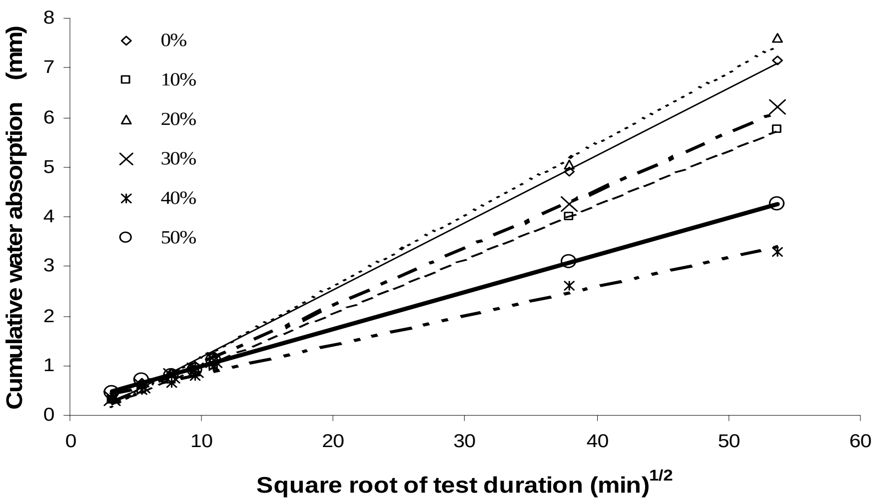

Figure-3. Relationship between cumulative water absorption and test duration for W/C = 0.55

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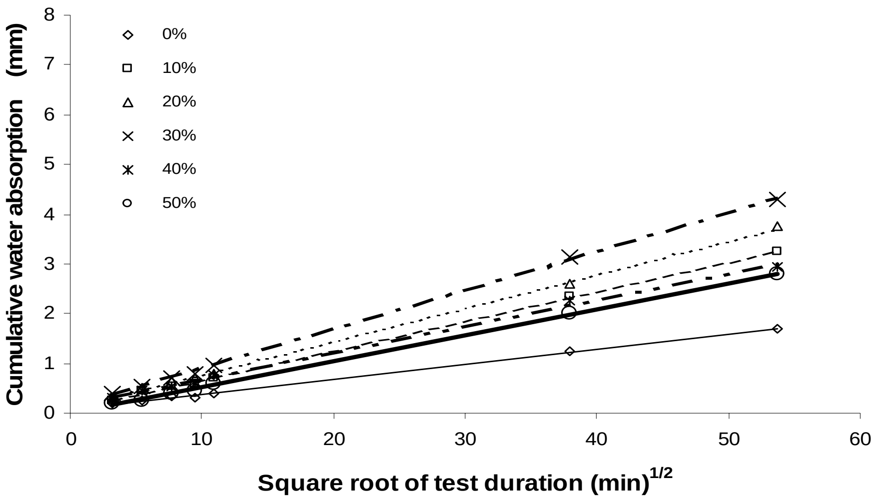

Figure-4. Relationship between cumulative water absorption and test duration for W/C = 0.475

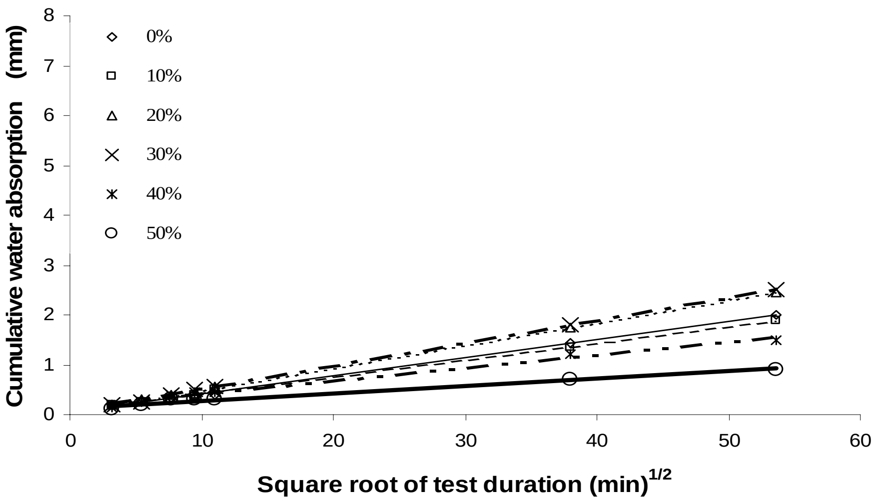

Figure-5. Relationship between cumulative water absorption and test duration for W/C = 0.40

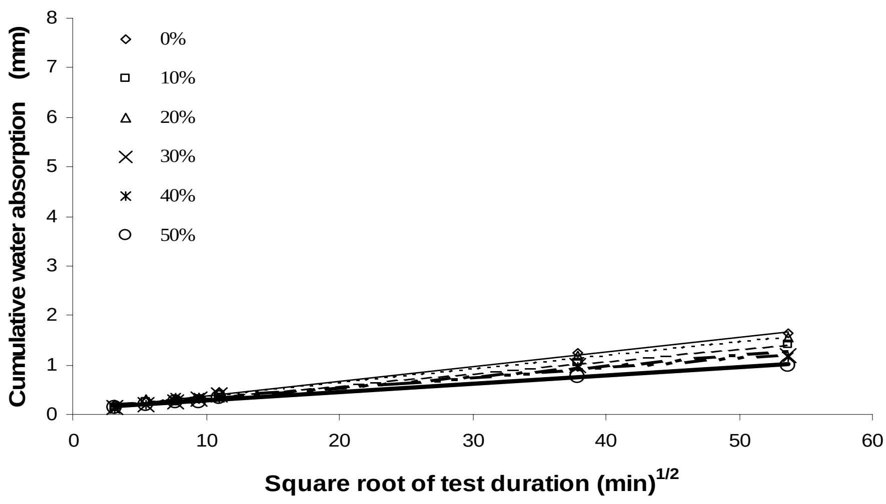

Figure-6. Relationship between cumulative water absorption and test duration for W/C = 0.34

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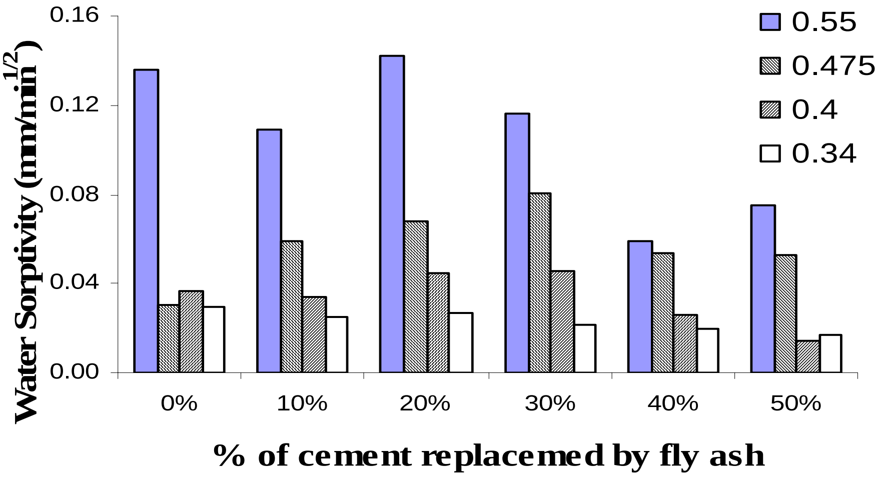

Figure-7. Sorptivity with change in % of cement replacement by fly ash.

CONCLUSIONS

Based on the study, the following conclusions can be drawn:

- Concretes having higher volume of cement replacement by fly ash showed lower values of cumulative water absorption indicating lower porosity in cover zone.
- Concretes with lower w/cm ratio have lower water absorption for all the mixtures. The sorptivity values are least due to lower amount of water in the mix, resulting in lower porosity.
- The 28 days compressive strength of concrete was in most of the cases marginally equal to or less than that of the control concrete. The 90 days compressive strength in some cases was even higher than that of control concrete. However, the strength was found to be lower in case of 0.34 w/cm ratio. This was mainly due to high dosage of superplasticizer (3.0% by weight cement), which delayed the hardening of concrete and also form removal.
- Cement replacement up to 50% by fly ash is feasible without significantly reducing the compressive strength of the concrete. The absorption characteristics are even better than that of the control mixes. The higher percentage replacement of cement will result in environmental benefits of utilizing the waste material and lower CO_2 emission.

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