

ASSESSMENT OF SORPTIVITY AND WATER ABSORPTION OF CONCRETE WITH PARTIAL REPLACEMENT OF CEMENT BY FLY ASH AND HYPO SLUDGE

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Abstract: Moistness transport in permeable means plays an important role in a wide variety of processes of ecological and technologies concern, such as the degradation of building materials like concrete. When excess water in concrete vaporises, it leaves cavities inside the concrete element creating passageways which are directly related to the concrete permeability and porousness. By proper selection of ingredients, mix proportioning and following the good construction practices almost impervious concrete can be obtained. The flow of water through concrete is similar to flow through any porous body. The pores in cement paste consist of gel pores and capillary pores. The pores in concrete as a result of incomplete compaction are voids of larger size which give a honeycomb structure leading to concrete of low strength. Due to problems associated with porosity are studied by the absorption test and permeability tests. There is a need for another type of test. This test should measure the rate of absorption of water by capillary suction, “sorptivity” of unsaturated concrete. In this paper, an attempt is made to study the properties of fly ash and hypo sludge concrete. The mix design was carried out for M25 and M40 grade concrete as per IS: 10262-2009.

Keywords: capillary suction, sorptivity, water absorption, fly ash, hypo sludge, concrete.

I. INTRODUCTION

Concrete basically has porous structure. This porous nature of concrete allows the penetration of gases and water through it. The durability of concrete depends largely on the movement of water and gas enters and moves through it. The permeability of concrete is directly related to the porosity. The permeability is an indicator of concrete’s ability to transport water more surely with both mechanism that is controlling the up-take and transport of water and gaseous substances into cementitious material. Permeability is a measure of flow of water under pressure in a saturated porous medium while Sorptivity is materials ability to absorb and transmit water through it by capillary suction.

Uptake of water by unsaturated, hardened concrete may be characterised by the sorptivity. This is a simple parameter to determine and is increasingly being used as a measure of concrete resistance to exposure in aggressive environments.

Sorptivity, or capillary suction, is the transport of liquids in porous solids due to surface tension acting in capillaries and is a function of the viscosity, density and surface tension of the liquid and also the pore structure of the porous solid. It is measured as the rate of uptake of water.

Transport mechanisms act at the level of the capillary pores and depend on the fluid and the solid characteristics. A low water/cement ratio results in concrete structures which are less permeable and characterized by small pores which are not interconnected.

II. DESIGN MIX MATERIALS

a) Supplementary cementitious material: Fly Ash and Hypo Sludge

Fly ash is composed of the non-combustible mineral portion of coal. Particles are glassy, spherical ‘ball bearings’ finer than cement particles. It is a pozzolonic material which reacts with free lime in the presence of water, converted into calcium silicate hydrate (C-S-H) which is the strongest and durable portion of the paste in concrete. The fly ash is procured from Maize Products (A division of Sayaji Industries Ltd) Power plant. This plant is located near Kathwada in Ahmedabad District, in Gujarat State.

The hypo sludge contains calcium and calcium chloride and minimum amount of silica. Hypo sludge behaves like cement because of high content of CaO and CaCl₂ and considerable presence of SiO₂ and MgO. This silica and magnesium improve the strength and setting of the concrete. The hypo sludge is procured from J.K.Papers Mill Pvt.Ltd, plant. This plant is located near Songadh in Tappi District in Gujarat State.

For comparison the chemical properties of ordinary portland cement (OPC), Fly Ash and Hypo sludge are listed in Table 1:

**TABLE 1
CHEMICAL PROPERTIES OF ORDINARY PORTLAND CEMENT (OPC), FLY ASH AND HYPO SLUDGE**

Chemical Properties	Ordinary Portland Cement (OPC) (Percent by mass)	Fly ash (Percent by mass)	Hypo sludge (Percent by mass)
Silicon Dioxide (SiO ₂)	21.77%	62.22%	5.28%
Calcium Oxide (CaO)	57.02%	5.30%	47.84%
Magnesium Oxide (MgO)	2.71%	6.09%	6.41%
Sulphur Trioxide (SO ₃)	2.41%	3.00%	0.19%
Aluminium Oxide (Al ₂ O ₃)	2.59%	7.63%	0.09%
Ferric Oxide (Fe ₂ O ₃)	0.65%	0.13%	0.73%
Loss on Ignition	2.82%	9.98%	38.26%

b) Ordinary Portland Cement

The most common cement used is an Ordinary Portland Cement (OPC). The Ordinary Portland Cement of 53 grade conforming to IS:8112-1989 is being used. Specific gravity, consistency, setting, compressive strengths, etc. tests are conducted on cement. The results are tabulated in Table 2.

**TABLE 2
PROPERTIES OF 53 GRADE ORDINARY PORTLAND CEMENT (OPC)**

Sr. No.	Physical properties of cement	Result	Requirements as per IS:8112-1989
1	Specific gravity	3.15	3.10-3.15
2	Standard consistency (%)	28%	30-35 (%)
3	Initial setting time (minutes)	35 min	30 minutes (minimum)
4	Final setting time (minutes)	178 min	600 minutes (maximum)
5	Compressive strength- 7 days	38.49 N/mm ²	43 N/mm ²
6	Compressive strength- 28 days	52.31 N/mm ²	53 N/mm ²

c) Coarse Aggregate

The fractions from 20 mm to 4.75 mm are used as coarse aggregate. The Coarse Aggregates from crushed Basalt rock, conforming to IS: 383 are to be used. The Flakiness and Elongation Indices were maintained well below 15%.

d) Fine aggregate

Those fractions from 4.75 mm to 150 micron are termed as fine aggregate. The river sand is be used in combination as fine aggregate conforming to the requirements of IS 383-

1970. The river sand is washed and screened, to eliminate deleterious materials and over size particles. Table-3 gives the properties of aggregates.

Specific gravity, water absorption and gradation of sand (FM) test were carried out as per IS 2386 (part I and Part III) - 1963. Physical test for specific gravity, water absorption, bulk density were carried out for coarse aggregate as per IS -2386 (I, II & IV) 1963.

**TABLE 3
PROPERTIES OF AGGREGATES**

Property	Fine Aggregate	Coarse Aggregate	
		20 mm down	10 mm down (Grit)
Fineness modulus	3.35	7.54	3.19
Specific Gravity	2.38	2.76	2.69
Water absorption (%)	1.20	1.83	1.35
Bulk Density (gm/cc)	1753	1741	1711

e) Water

Water is an important ingredient of concrete as it actually participates in the chemical reaction with cement. Since it helps to form the strength giving cement gel, the quantity and quality of water is required to be looked into very carefully. Water cement ratio used is 0.50 for M25 and 0.38 for M40 concretes.

III. DESIGN MIX METHODOLOGY

a) DESIGN MIX

The concrete mix of M25 and M40 grade was designed as per IS 10262:2009 and the same was used to prepare the test samples. The design mix proportion is shown in Table 4

**TABLE 4
CONCRETE DESIGN MIX PROPORTIONS**

Sr. No.	Concrete Mix	% Replacement of Cement By Fly Ash and Hypo Sludge	Concrete Design Mix Proportion (By Weight in kg)				Cement Replacement by Fly ash	Cement Replacement by Hypo Sludge
			W/ C ratio	C	F. A.	C. A.		
1	A1	0 %	0.50	372.00	558.60	1251.90	-	-
2	D1	5% + 5%	0.50	334.80	558.60	1251.90	18.60	18.60
3	D2	10% + 10%	0.50	297.60	558.60	1251.90	37.20	37.20
4	D3	15% + 15%	0.50	260.40	558.60	1251.90	55.80	55.80
5	D4	20% + 20%	0.50	223.20	558.60	1251.90	74.40	74.40
6	A2	0 %	0.38	473.68	341.91	1419.30	-	-
7	D5	5% + 5%	0.38	426.31	341.91	1419.30	23.69	23.69
8	D6	10% + 10%	0.38	378.94	341.91	1419.30	47.37	47.37
9	D7	15% + 15%	0.38	331.58	341.91	1419.30	71.05	71.05
10	D8	20% + 20%	0.38	284.21	341.91	1419.30	94.74	94.74

W/C = Water/Cement, C= Cement, F. A. = Fine Aggregate, C. A. = Coarse Aggregate

b) Water absorption test

The 100mm dia x 50 mm height cylinder after casting were immersed in water for 90 days curing. These specimens were then oven dried for 24 hours at the temperature 110°C until the mass became constant and again weighed. This weight was noted as the dry weight (W1) of the cylinder. After that the specimen was kept in hot water at 85°C for 3.5 hours. Then this weight was noted as the wet weight (W2) of the cylinder. Figure 1 and figure 2 shows the setup of oven and setup of hot water curing respectively.

$$\% \text{ water absorption} = [(W2 - W1) / W1] \times 100$$

Where,

W1 = Oven dry weight of cylinder in grams

W2 = After 3.5 hours wet weight of cylinder in grams.



Fig 1: Setup of oven



Fig 2: Setup of hot water curing

c) Sorptivity test

The sorptivity can be determined by the measurement of the capillary rise absorption rate on reasonably homogeneous material. Water was used of the test fluid. The cylinders after casting were immersed in water for 90 days curing. The specimen size 100mm dia x 50 mm height after drying in oven at temperature of $100 + 10$ °C were drowned as shown in figure 4 with water level not more than 5 mm above the base of specimen and the flow from the peripheral surface is prevented by sealing it properly with non-absorbent coating. The quantity of water absorbed in time period of 30 minutes was measured by weighting the specimen on a top pan balance weighting upto 0.1 mg. surface water on the specimen was wiped off with a dampened tissue and each weighting operation was completed within 30 seconds. Figure 3 and figure 4 shows the setup of weight and setup of sorptivity test respectively.

Sorptivity (S) is a material property which characterizes the tendency of a porous material to absorb and transmit water by capillarity. The cumulative water absorption (per unit area of the inflow surface) increases as the square root of elapsed time (t)

$$I = S \cdot t^{1/2} \text{ therefore } S = I / t^{1/2}$$

Where;

S= sorptivity in mm,

t= elapsed time in mint.

$$I = \Delta w / A d$$

Δw = change in weight = W2-W1

W1 = Oven dry weight of cylinder in grams

W2 = Weight of cylinder after 30 minutes capillary suction of water in grams.

A= surface area of the specimen through which water penetrated.

d= density of water



Fig 3: Setup of weight



Fig 4: Setup of sorptivity test

IV. EXPERIMENTAL RESULTS

Table-5 and 6 gives the water absorption and Sorptivity test results of % replacement of cement by fly ash and hypo sludge in concrete for 90 days curing. The % replacement v/s % water absorption and Sorptivity results are graphically shown in figure 5, 6, 7 and 8.

TABLE 5 AVERAGE % WATER ABSORPTION AT 90 DAYS FOR M25 AND M40

Concrete Mix	% Replacement of Cement by Fly Ash and Hypo Sludge	Dry Wt in grams (W1)	Wet Wt in grams (W2)	% Water Absorption
A1	0 %	929.67	934.67	0.54
D1	5% + 5%	931.23	942.67	1.23
D2	10% + 10%	919.42	933.17	1.50
D3	15% + 15%	932.33	955.67	2.50
D4	20% + 20%	870.33	897.17	3.10
A2	0 %	968.67	972.67	0.41
D5	5% + 5%	950.17	960.33	1.07
D6	10% + 10%	894.67	908.17	1.51
D7	15% + 15%	873.67	898.33	2.82
D8	20% + 20%	876.00	910.50	3.94

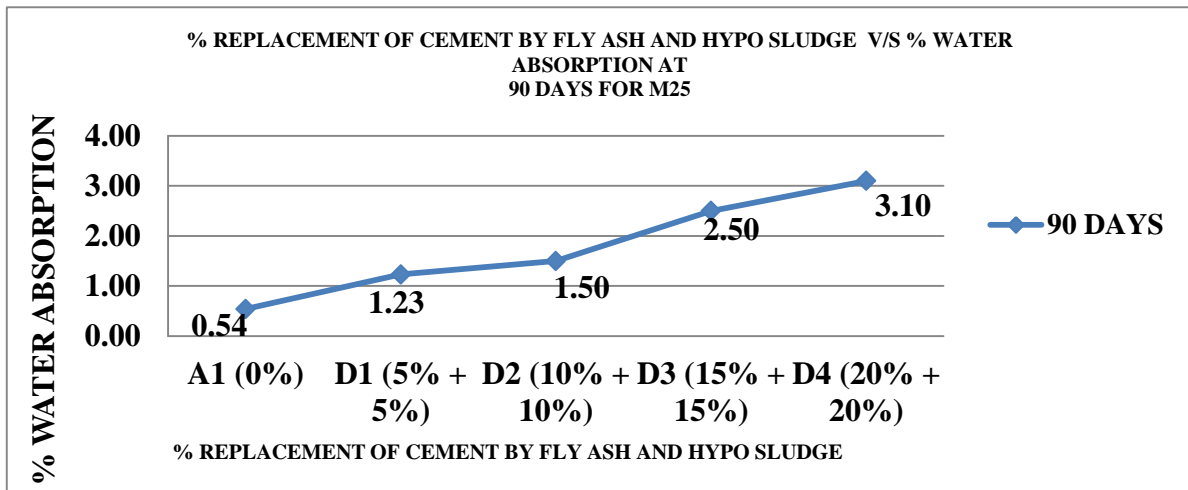


Fig. 5: % Replacement of cement by fly ash and hypo sludge versus % water absorption at 90 days for M25

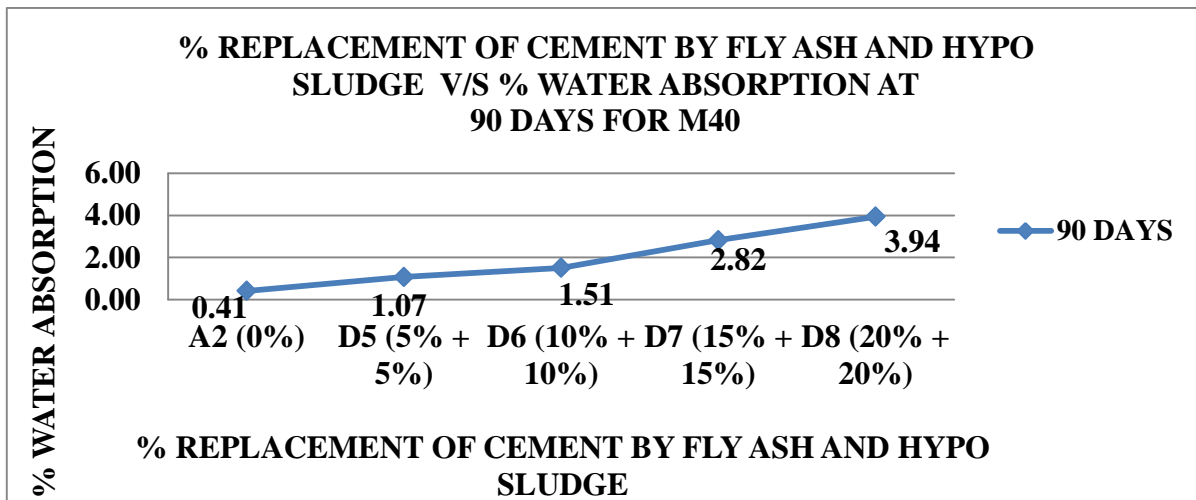


Fig. 6: % Replacement of cement by fly ash and hypo sludge versus % water absorption at 90 days for M40

TABLE 6 SORPTIVITY ($\text{mm}/\text{min}^{0.5}$) AT 90 DAYS FOR M25 & M40

Concrete Mix	% Replacement of Cement by Fly Ash and Hypo Sludge	Dry Wt in grams (W1)	Wet Wt in grams (W2)	Sorptivity value in $10^{-5} \text{ mm}/\text{min}^{0.5}$
A1	0 %	979.00	980.00	2.32
D1	5% + 5%	931.33	932.75	3.29
D2	10% + 10%	921.33	923.00	3.88
D3	15% + 15%	935.67	937.47	4.19
D4	20% + 20%	875.33	877.20	4.34
A2	0 %	979.00	979.50	1.16
D5	5% + 5%	949.00	949.83	1.94
D6	10% + 10%	885.00	885.92	2.13
D7	15% + 15%	871.50	872.75	2.91
D8	20% + 20%	880.25	881.67	3.29

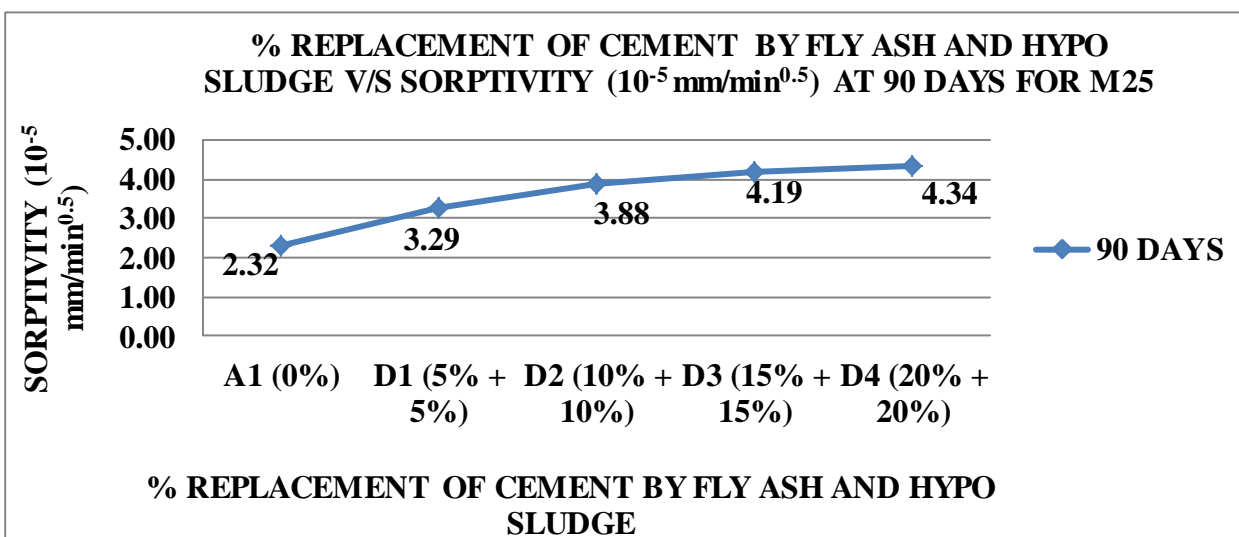


Fig. 7: % Replacement of cement by fly ash and hypo sludge versus sorptivity at 90 days for M25

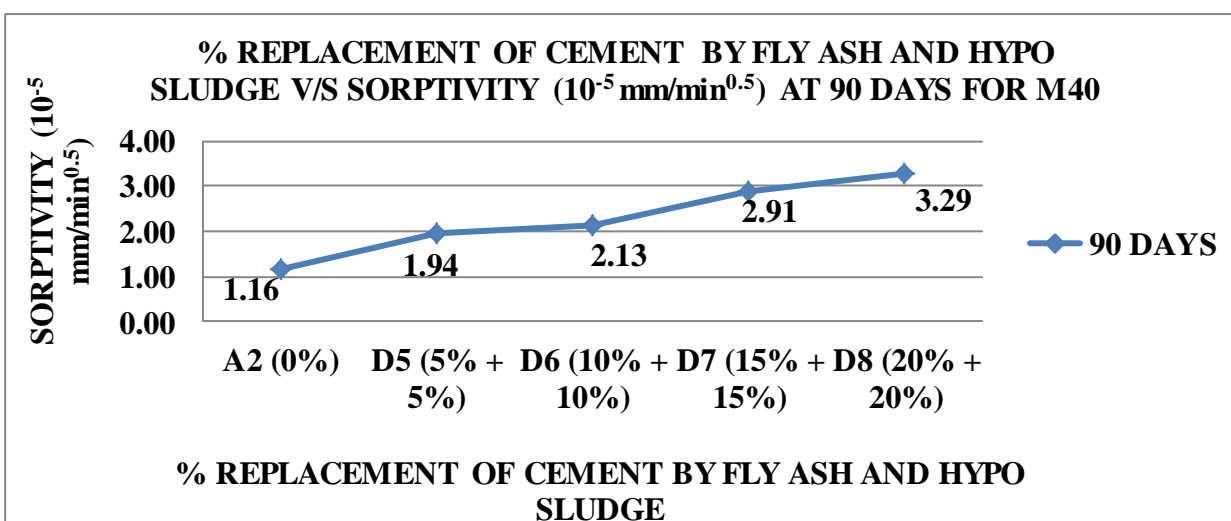


Fig. 8: % Replacement of cement by fly ash and hypo sludge versus % water absorption at 90 days for M40

V. CONCLUSION

Based on limited experimental investigation concerning the water absorption and sorptivity of concrete, the following observations are made regarding the resistance of partially replaced fly ash and hypo sludge for M25 and M40 grade concrete:

- (a) The water absorption and sorptivity of fly ash and hypo sludge concrete shows lower water absorption and sorptivity at 10% replacement with fly ash and hypo sludge for M25 and M40 grade concrete. There after the water absorption and sorptivity shows a increasing trend.
- (b) For 90 days, 10% replacement with fly ash and hypo sludge increases in water absorption is found to be 1.23% for M25 and 1.07 for M40 and sorptivity is found to be 3.29 mm/min^{0.5} for M25 and 1.94 mm/min^{0.5} for M40 with respect to reference mix.
- (c) The water absorption and sorptivity of fly ash and hypo sludge concrete shows higher water absorption and sorptivity at a replacement level of 10% with fly ash and hypo sludge for M25 and M40 grade concrete.
- (d) The water absorption and sorptivity of fly ash and hypo sludge concrete shows lower water absorption and sorptivity than conventional concrete.
- (e) The water absorption and sorptivity of M25 fly ash and hypo sludge concrete is higher water absorption and sorptivity than M40 grade concrete.
- (f) The fly ash and hypo sludge can be innovative supplementary cementitious Construction Material but judicious decisions are to be taken by engineers.

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