Durability of concrete with Partial Replacement of Cement by Paper Industry Waste (Hypo Sludge)

Jayeshkumar Pitroda, L. B. Zala, F. S. Umrigar

ABSTRACT- Durable concrete is one that performs satisfactorily under the exposed environmental condition during its service life span. Concrete requires to little or zero maintenance and normal environment. Main characteristic influencing the durability of concrete is itspermeability to the ingress of water. When excess water in concrete evaporates, it leaves voids inside the concrete element creating capillaries which are directly related to the concrete porosity and permeability. By proper selection of ingredients and 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. There is a need for another type of test rather than the absorption test and permeability tests to measure the response of concrete to pressure. 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 Paper Industry Waste (Hypo Sludge)concrete to check durability. The mix design was carried out for M25 and M40 grade concrete as per IS: 10262-2009.

Key words-durability, capillary suction, sorptivity, water absorption, hypo sludgeconcrete

I. INTRODUCTION

Concrete is strength and tough material but it is porous material also which interacts with the surrounding environment.The durability of concrete depends largely on the movement of water and gas enters and moves through it. The permeability of concrete depends on its pores structure even the best of concrete is not gas tight or water tight. The permeability is an indicator of concrete's ability to transport water more precisely with both mechanism that is controlling the uptake 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 (radius, tortuosity and continuity of capillaries) 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. The porous structure of concrete is intimately related with its permeability. A low water/cement ratio results in concrete structures which are less permeable because they are characterized by having small pores which are not interconnected.

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Table 1: Acceptance limits for durability indexes

Acceptance Criteria		OPI (log scale)	Sorptivity (mm/h)
Laboratory concrete		>10	< 6
As-built Structures	Full acceptance	> 9,4	< 9
	Conditional acceptance	9,0 to 9,4	9 to 12
	Remedial measures	8,75 to 9,0	12 to 15
	Rejection	< 8,75	>15

II. DESIGN MIX MATERIALS

a) Supplementary cementitious material: Hypo Sludge

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. Hypo sludge contains, low calcium and maximum calcium chloride and minimum amount of silica. Hypo sludge behaves like cement because of silica and magnesium properties. This silica and magnesium improve the setting of the concrete.

b) Cement

The most common cement used is an Ordinary Portland Cement (OPC). The Ordinary Portland Cement of 53 grade (Hathi OPC) conforming to IS:8112-1989 is used. Many tests were conducted on cement; some of them are specific gravity, consistency tests, setting time tests, compressive strengths, etc.

Table 2 Properties of HATHI Cement (OPC 53 grade)

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 (hours, min)	35 min	30 minimum
4	Final setting time (hours, min)	178 min	600 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

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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 from the strength giving cement gel, the quantity and quality of water is required to be looked into very carefully. Water cement ratio used is 0.40 for M25 and 0.30 for M40 concretes.

III. DESIGN MIX METHODOLOGY

a) Design Mix

A mix 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 type	Concrete Design Mix Proportion (By Weight)				Cement Replacement by Hypo Sludge
		W/C ratio	C	F.A.	C.A.	
1	A1-M25	0.40	1.00	1.01	2.50	-
2	C1-M25	0.40	0.90	1.01	2.50	0.10
3	C2-M25	0.40	0.80	1.01	2.50	0.20
4	C3-M25	0.40	0.70	1.01	2.50	0.30
5	C4-M25	0.40	0.60	1.01	2.50	0.40
6	A2-M40	0.30	1.00	0.44	2.17	-
7	C5-M40	0.30	0.90	0.44	2.17	0.10
8	C6-M40	0.30	0.80	0.44	2.17	0.20
9	C7-M40	0.30	0.70	0.44	2.17	0.30
10	C8-M40	0.30	0.60	0.44	2.17	0.40

W= Water, 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.

% water absorption = [(W2 – W1) / W1] x 100

Where,

W1 = Oven dry weight of cylinder in grams

W2 = After 3.5 hours wetweight 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 heightafter 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.

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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)

$I=S.t^{½}$ therefore $S=I/t^{½}$

Where;

S= sorptivity in mm,

t= elapsed time in mint.

$I=\Delta w/Ad$

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

IV. EXPERIMENTAL RESULTS

Table-5 and 6 gives the water absorption and Sorptivity test results of % replacement of Paper Industry Waste (Hypo Sludge) in concrete for 90 days curing. The % replacement vs % water absorption and Sorptivity results are graphically shown in figure 5 and 6.

Table 5 Average % water absorption at 90 days for M25 and M40

Concrete grade	Concrete Type	Dry wt in grams (W1)	Wet wt in grams(W2)	% water absorption
M25	A1-M25	929.67	934.67	0.54
	C1-M25	1005.67	1017.00	1.13
	C2-M25	919.67	933.33	1.49
	C3-M25	869.00	899.67	3.52
	C4-M25	850.67	887.33	4.31
M 40	A2-M40	968.67	972.67	0.41
	C5-M40	956.67	971.33	1.53
	C6-M40	920.67	936.00	1.67
	C7-M40	905.00	932.00	2.99
	C8-M40	773.33	813.00	5.12

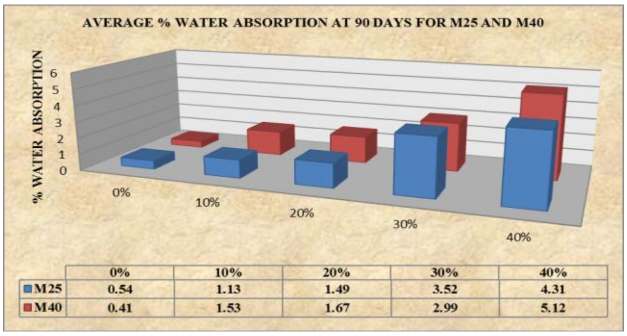

Fig. 5: % Replacement of cement versus % water absorption

Table 6 Sorptivity at 90 days for M25 & M40

Concrete grade	Concrete Type	Dry wt in grams (W1)	Wet wt in grams (W2)	Sorptivity value in 10^{-5} $mm/min^{0.5}$
M25	A1-M25	979.00	980.00	2.32
	C1-M25	1012.50	1013.50	2.32
	C2-M25	917.50	919.50	4.65
	C3-M25	884.00	890.00	13.95
	C4-M25	866.50	873.50	16.28
M 40	A2-M40	979.00	979.50	1.16
	C5-M40	959.00	961.00	4.65
	C6-M40	928.50	931.00	5.81
	C7-M40	920.50	927.00	15.11
	C8-M40	769.50	780.00	24.42

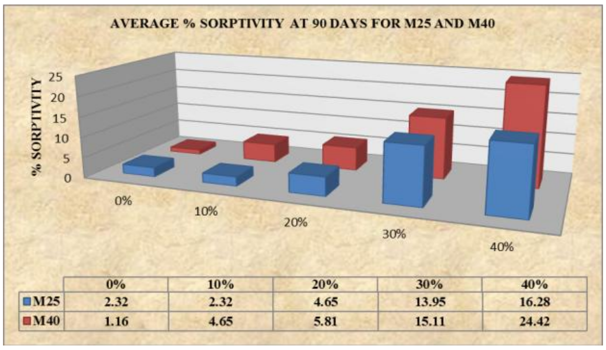

Fig. 5: % Replacement of cement versus sorptivity

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 Paper Industry Waste (Hypo Sludge) for M25 and M40 grade concrete:

(a) The water absorption and sorptivity of Paper Industry Waste (Hypo Sludge) concrete shows lower water absorption and sorptivity at 10% replacement with Paper Industry Waste (Hypo Sludge) for M25 and M40 grade concrete. There after the water absorption and sorptivity shows an increasing trend.

(b) For 90 days, where percentage decreases in water absorption is found to be 1.13% for M25 and 1.53% for M40 and sorptivity is found to be 2.32 $mm/min^{0.5}$ for M25 and

4.65mm/min$^{0.5}$ for M40 with respect to reference mix.

(c) The water absorption and sorptivity of Paper Industry Waste (Hypo Sludge) concrete shows lower water absorption and sorptivity at a replacement level of 10% with Paper Industry Waste (Hypo Sludge) for M25 and M40 grade concrete.

(d) The water absorption and sorptivity of Paper Industry Waste (Hypo Sludge) concrete shows higher water absorption and sorptivity than traditional concrete.

(e) The water absorption and sorptivity of M25 Paper Industry Waste (Hypo Sludge) concrete is higher than water absorption and sorptivity M40 grade concrete.

(f) The Paper Industry Waste (Hypo Sludge) can be innovative supplementary cementitious Construction Material but judicious decisions are to be taken by engineers.

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