Evaluation of Sorptivity and Water Captivation of Concrete with Partial Replacement of Cement by Hypo Sludge

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Abstract. Environ have important influences on the water captivation of concrete materials. This paper presents an investigational study on partial replacement of cement by hypo sludge (paper industry waste) influence of sorptivity and water captivation on the permanence of concrete materials. The sorptivity test measures the rate of movement of water front through the concrete under capillary suction. The waste product from paper industry i.e hypo sludge (HS) is causing serious pollution problem. In this paper the study of sorptivity and water absorption properties of hypo sludge concrete. The cement has been replaced by hypo sludge in the range of 0\%, 10\%, 20\%, 30\% and 40\% by weight of cement for the M25 and M40 mix. Concrete mixtures were produced, tested and compared in terms of sorptivity and water absorption to the conventional concrete. The mix design was carried out for 1:1.50:3.36 (M25) and 1:0.80:2.29 (M40) proportions of cement concrete on the basis of IS: 10262 -2009. The results show that the % water captivation and sorptivity of hypo sludge concrete shows higher % water captivation and sorptivity than conventional concrete.

1. Introduction
Concrete should withstand the conditions for which it has been designed, without descent over of a period of years. Such concrete is said to be durable. The useful life of concrete may be reduced by the environs to which the concrete is exposed or by internal causes within the concrete itself. Due to green awareness the world is increasingly turning to researching properties of industrial wastes and finding solutions on using their valuable component parts so that those might be used as secondary raw material for other industrial applications.

Eco-Friendly Concrete is a concept of thoughtful environs into concrete considering every aspect from raw materials manufacture over mixture design to structural design, construction, and service life [1, 4]. Eco-Friendly Concrete is very often also cheap to produce, because, for example, waste products are used as a partial substitute for cement, charges for the disposal of waste are avoided, energy consumption in production is lower, and durability is greater [3, 4]. Sustainable construction materials are composed of renewable, rather than non-renewable resources. Sustainable materials are environmentally responsible because impacts are considered over the life of the product. Depending upon project specific goals, green materials may involve an evaluation of one or more of the following criteria: Locally available, Salvaged, re-furnished or re-manufactured, Reusable or recyclable, Resource and Energy efficiency, Indoor air quality, Water conservation.

Concrete basically has porous structure. This porous nature of the concrete allows the penetration of the gases or fluid through it. If see microstructure of concrete; it consists aggregates, cement paste entrapped air voids. The cement paste may have the micro-cracks due to the volumetric changes in it.
If these cracks are getting interconnected, then they allow the water to penetrate through it. The phenomenon that governs the rate of flow of a fluid into a porous concrete is said to be its permeability. The permeability of concrete thus depends up on the pore structure. The porosity of concrete is directly related to the porosity. Thus, if perviousness of the concrete can be control, its durability can be increase. Hence, there is a need to study the parameters responsible for perviousness of concrete how the perviousness can be control. Sorptivity is a measure of the capacity of concrete to absorb water under capillary forces. Table 1 shows the acceptance Criteria for durability indexes.

![Table 1. Acceptance criteria for durability indexes [5]](image)

| Acceptance Criteria         | Oxygen Permeability Index (OPI) (log scale) | Sorptivity (mm/h) |
|-----------------------------|---------------------------------------------|-------------------|
| Workroom concrete           | > 10                                        | < 6               |
| As-built Structures         | 100% recognition                            | > 9,4             |
| 50% recognition             | 9,0 to 9,4                                  | 9 to 12           |
| Helpful measures            | 8,75 to 9,0                                 | 12 to 15          |
| Elimination                 | < 8,75                                      | > 15              |

2. Materials

2.1. Hypo sludge
Hypo sludge produced in a large amount as by product of paper industry and is usually used in concrete production as partial replacement of cement. It contains low calcium and minimum amount of silica and it’s due to presence of silica and magnesium properties that it behaves like cement. The hypo sludge is procured from Songadh, Gujarat State. Hypo sludge becomes a new novelty material that can be used as material for masonry to support the sustainable technology. The chemical properties of ordinary Portland cement (OPC) SiO$_2$-21.77%, CaO-57.02%, MgO-2.71%, SO$_3$ -2.41%, Al$_2$O$_3$-2.59%, Fe$_2$O$_3$ - 0.65%, LoI-2.82% and hypo sludge SiO$_2$-5.28%, CaO-47.84%, MgO-6.41%, SO$_3$ - 0.19%, Al$_2$O$_3$-0.09%, Fe$_2$O$_3$-0.73%, Loss on Ignition-38.26% from baroda, gujarat.

2.2. Cement
OPC 53 grade conforming to IS: 8112-1989 was used in this work. The testing results of cement for specific gravity 3.15, consistency test 28%, initial setting time test 35min, final setting time 178 min, compressive strength 7days 38.49 N/mm$^2$.

2.3. Coarse aggregate
The coarse aggregates from crushed basalt rock with specific gravity 2.76, conforming to is: 383 are to be used as a coarse aggregate that passed through 20 mm sieve and retained 4.75 mm. the flakiness and elongation indices were maintained well below 15%.

2.4. Fine aggregate and water
The waterway sand is being used in combination as FA with specific gravity 2.38 conforming to the requirements of IS 383- 1970 are to be used as a FA that passed through 4.75 mm sieve and retained 150 microns. Locally available water in the laboratory was used in this research work.
3. Methodology and Mix Proportions

3.1. Mix Proportions

Design mix proportion for M25 and M40 grade was considered as per IS 10262:2009 is shown in Table 2 and the same was used to prepare the test samples.

| Concrete mix | Water/ cement ratio | Concrete mix proportion (kg) | Cement replacement by hypo sludge |
|--------------|---------------------|-----------------------------|----------------------------------|
| A1(0%)       | 0.500               | 372.0 558.6 1251.9          | -                                |
| C1(10%)      | 0.500               | 334.8 558.6 1251.9          | 37.2                             |
| C2(20%)      | 0.500               | 297.6 558.6 1251.9          | 74.4                             |
| C3(30%)      | 0.500               | 260.4 558.6 1251.9          | 111.6                            |
| C4(40%)      | 0.500               | 223.2 558.6 1251.9          | 148.8                            |
| A2(0%)       | 0.380               | 473.6 341.9 1419.3          | -                                |
| C5(10%)      | 0.380               | 426.3 341.9 1419.3          | 47.3                             |
| C6(20%)      | 0.380               | 378.9 341.9 1419.3          | 94.7                             |
| C7(30%)      | 0.380               | 331.5 341.9 1419.3          | 142.1                            |
| C8(40%)      | 0.380               | 284.2 341.9 1419.3          | 189.4                            |

3.2. Water captivation test

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

Water captivation (%) = \[\frac{(W₂ - W₁)}{W₁}\] x 100

\[W₁ = \text{oven dry wt of cylinder (gms)}, \ W₂ = \text{after 3.5 hours wet wt of cylinder (gms)}\]
3.3. Sorptivity test

The sorptivity can be determined by the measurement of the capillary rise absorption rate on reasonably homogeneous material. The cylinders after casting were absorbed in water for 90 days preserving. The specimen size 10cm diameter x 5cm height after drying in oven at temperature of 100 + 10 °C were drowned as shown in fig. 4 with water level not more than 5 mm above the base of sample 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 allowance the specimen (as shown in figure 3) on a top pan balance weighting up to 0.1 mg. surface water on the specimen was wiped off with a dampened tissue and each allowance operation was completed within 30 seconds.

Sorptivity (S) is a material property which characterizes the inclination of a porous material to absorb and transmit water by capillarity. The cumulative water captivation increases as the square root of elapsed time (t)

\[ I = S \cdot t^{1/2} \]
\[ S = \frac{I}{t^{1/2}} \quad (2) \]

Where; S= sorptivity in mm, t= elapsed time in mint.

\[ I = \frac{\Delta w}{Ad} \quad (3) \]

\[ \Delta w = W_2 - W_1 \]

W1 = Oven dry wt of cylinder (gms), W2 = Wt of cylinder after 30 minutes capillary suction of water (gms), A= surface area of the specimen through which water penetrated, d= density of water.

4. Experimental results and discussion

Table 3 shows the average water absorption assessment outcomes of percentage auxiliary of HS in concrete for 90 days curing for M25 and M40. The comparison of water captivation in percentage of various mixes of HS in M25 grade concrete results are sketchily shown in figure 5 and comparison of water captivation in percentage of various mixes of hypo sludge in M40 grade concrete results are sketchily shown in figure 6.

Table 3. Average % water captivation at 90 days for M25 and M40

| Concrete mix | Dry weight (grams) (W1) | Wet weight (grams) (W2) | Water captivation (%) |
|--------------|-------------------------|-------------------------|----------------------|
| A1           | 929.67                  | 934.67                  | 0.54                 |
| C1           | 1005.67                 | 1017.00                 | 1.13                 |
| C2           | 919.67                  | 933.33                  | 1.49                 |
| C3           | 869.00                  | 899.67                  | 3.52                 |
| C4           | 850.67                  | 887.33                  | 4.31                 |
| A2           | 968.67                  | 972.67                  | 0.41                 |
| C5           | 956.67                  | 971.33                  | 1.53                 |
| C6           | 920.67                  | 936.00                  | 1.67                 |
| C7           | 905.00                  | 932.00                  | 2.99                 |
| C8           | 773.33                  | 813.00                  | 5.12                 |
Table 3 shows the average water captivation assessment outcomes of percentage auxiliary of HS in concrete for 90 days preserving for M_{25} and M_{40} increases. Compare to M_{25} and M_{40} % water absorption decreases.

Table 4 shows the average sorptivity test results of percentage replacement of hypo sludge in concrete for 90 days curing for M_{25} and M_{40}. The assessment of sorptivity in % age of various mix of hypo sludge in M_{25} grade concrete assessment outcomes are sketchily shown in figure 7 and assessment of sorptivity in % age of various mix of HS in M_{40} grade concrete outcomes are skethily shown in figure 8.

Table 4. Sorptivity at 90 days for M_{25} and M_{40}

| concrete mix | dry wt in gms (W_1) | wet wt in gms (W_2) | sorptivity value in 10^{-5} mm/min^{0.5} |
|-------------|---------------------|---------------------|-------------------------------------|
| A1          | 987.00              | 988.00              | 2.33                                |
| C1          | 1008.33             | 1009.60             | 2.95                                |
| C2          | 924.00              | 925.37              | 3.18                                |
| C3          | 880.00              | 881.70              | 3.95                                |
| C4          | 864.33              | 866.07              | 4.03                                |
| A2          | 969.33              | 969.83              | 1.16                                |
| C5          | 965.67              | 966.13              | 1.09                                |
| C6          | 925.00              | 925.92              | 2.13                                |
| C7          | 920.00              | 921.23              | 2.87                                |
| C8          | 768.00              | 769.70              | 3.95                                |

Table 4 shows the average sorptivity assessment outcomes of percentage auxiliary of HS in concrete for 90 days curing for M_{25} and M_{40} increases. Compare to M_{25} and M_{40} % sorptivity decreases.
5. Conclusion
From the experimental results, the percentage water captivation and sorptivity of HS concrete shows higher % water captivation and sorptivity than conservative concrete. The % water captivation and sorptivity of M25 HS concrete is lower % water captivation and sorptivity than M40 concrete. HS can be complementary cementitious building material but careful assessments are to be taken by engineers.

6. References
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