Strength Assessment of Hypo Sludge Concrete with Water Containing Sodium Hydroxide

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Abstract. This paper presents the effect of sodium hydroxide (NaOH) present in the curing water on the strength of hypo sludge cement concrete. The concrete is produced by mixing of percentage replacement of cement by hypo sludge and curing water containing NaOH of 5% concentration with constant dosages. This research paper describes the feasibility of using the hypo sludge in concrete production as partial replacement of cement by weight. The cement has been replaced by hypo sludge accordingly in the range of 0%, 10%, 20%, 30% and 40% by weight of cement for M40 mix. The compressive strengths were evaluated for 56 days of normal curing and 28 days normal and 28 days 5% NaOH contain water curing. Compressive strengths of hypo sludge Cement Concrete compared with the control specimens. By using Regression Models predict the compressive strength value and the ratio with predicted values.

1. Introduction

Cement concrete is admixture of hard inorganic materials called aggregates such as gravel, fine aggregate, crushed stone, slag etc cemented to gather with portland cement and water paste. After the water, Concrete is the most commonly consumed material in the world. The cement water paste has its role to bind the aggregates to form a strong rock like mass, after hardening as a consequence of the chemical reaction between cement and water.

When we build any structure of concrete, we expect it to last a long time, that is, we expect it to be durable. The durability of concrete may be realized as the resistance the concrete can offer against deteriorating influences to which it is exposed. Durability is related to a number of properties like strength, shrinkage, water tightness and surface condition of concrete and also to the structural design, the materials and workmanship as well as exposed conditions. No doubt concrete tends to undergo deterioration with age as it is put to continued service or exposed continuously to the action of weather. What is expected is that a concrete structure should serve satisfactorily for a long period. It should be not only strong enough to resist the various types of loadings likely to act upon it but should also be able to offer satisfactory resistance against various weathering actions and should stay stable serving efficiently. Durability of a concrete structure is not only related to its structural design but also to the various properties of the constituents of the concrete of which it is made and its resistance to actions of various natural and atmospheric agents. It is also related to the efficiency with which the concrete mix is made, transported, placed, compacted, finished and cured. In short, a concrete structure durable has the ability to resist all weathering actions, chemical attacks and all other forces of deterioration and maintains its original quality form and its utility.
2. Materials
2.1 Supplementary cementitious material: hypo sludge
The hypo sludge is procured from J. K. Papers mill Pvt. Ltd. Plant, Songadh, Gujarat State. 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%. Loss on Ignition-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 Geo Test House, Vadodara, 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 test 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
The river sand is be used in combination as fine aggregate with Specific Gravity 2.38 conforming to the requirements of IS 383-1970 are to be used as a fine aggregate that passed through 4.75 mm sieve and retained 150 micron.

2.5 Water
Curing water containing 5% concentrated NaOH solution with constant dosages is used.

3. Design mix methodology
3.1 Design Mix
Mix design and proportions for M40 grade was designed as per IS 10262:2009 is shown in Table 1 and the same was used to prepare the test samples.

| Mix designation | Mix design and proportions by Weight (kg) | % Replacement of Cement by Hypo Sludge |
|-----------------|------------------------------------------|---------------------------------------|
|                 | Water/Cement Ratio | Cement | Fine Aggregate | Coarse Aggregate | by Weight |
| A2              | 0.38                  | 473.68 | 341.91         | 1419.30          | 0% (0 kg) |
| C5              | 0.38                  | 426.31 | 341.91         | 1419.30          | 10% (47.37 kg) |
| C6              | 0.38                  | 378.94 | 341.91         | 1419.30          | 20% (94.74 kg) |
| C7              | 0.38                  | 331.58 | 341.91         | 1419.30          | 30% (142.10 kg) |
| C8              | 0.38                  | 284.21 | 341.91         | 1419.30          | 40% (189.47 kg) |

3.2 Alkali Attack Test
To determine the resistance of various concrete mixtures to alkali attack, the residual compressive strength of concrete mixtures of 100 mm diameter and 200 mm height cylinders immersed in alkaline water having 5% of sodium hydroxide (NaOH) by weight of water was found. The concrete cylinders which were cured in water for 28 days were removed from the curing tank and allowed to dry
for one day. The weights of concrete cube specimen were taken. Then the cubes were immersed in alkali water continuously for 56 days. The alkalinity of water was maintained same throughout the test period. After 56 days of immersion, the concrete cylinders were taken out of alkali water. Then, the specimens were tested for compressive strength. The resistance of concrete to alkali attack was found by the % loss of weight of specimen and the % loss of compressive strength on immersion of concrete cylinders in alkaline water. [2] Figure 1 shows the test setup for alkali attack.

![Figure 1. Test setup for alkali attack](image)

4. Results and discussion

4.1 Effect on weight of hypo sludge Cement Concrete

The effect of NaOH on weight of hypo sludge cement concrete is shown in Table 2, from which it is observed that with increases in percentage replacement of cement by hypo sludge, the percentage loss in weight also increases.

| Mix designation | Percentage Replacement of Cement by Hypo Sludge | Oven Dry Weight (Grams) (W1) | Wet Weight (Grams) (W2) | Loss in Weight Percentage |
|------------------|-----------------------------------------------|-----------------------------|--------------------------|----------------------------|
| A2               | 0 %                                           | 3.937                       | 3.930                    | - 0.17                     |
| C5               | 10 %                                          | 3.858                       | 3.850                    | - 0.21                     |
| C6               | 20 %                                          | 3.666                       | 3.658                    | - 0.22                     |
| C7               | 30 %                                          | 3.648                       | 3.637                    | - 0.28                     |
| C8               | 40 %                                          | 3.550                       | 3.538                    | - 0.35                     |
Figure 2. % Replacement of cement by hypo sludge v/s Loss in weight (%)

4.2 Effect on compressive strength of hypo sludge cement concrete

The effect of NaOH concentration on the compressive strength Hypo Sludge Cement Concrete is presented in Table 3.

Table 3. Compressive strength of hypo sludge cement concrete corresponding to NaOH contain curing

| Mix designation | Percentage Replacement of Cement by Hypo Sludge | Hypo Sludge Cement Concrete | Percentage Change in Compressive Strength |
|------------------|-----------------------------------------------|-----------------------------|------------------------------------------|
|                  | Compressive Strength N/mm² (P1) 100X200        | Compressive Strength N/mm² (P2) 100X200 | Compressive Strength % age (P2- P1/P1) x 100 100X200 | Compressive Strength N/mm² (P1) 100X200 |
|                  | With normal curing of 56 days                 | With 28 days normal curing and 28 days NaOH contain curing | With normal curing of 56 days | With 28 days normal curing and 28 days NaOH contain curing |
| A2               | 0 %                                           | 31.00                       | 30.57                                    | - 1.39                                   | 0                                    |
| C5               | 10 %                                          | 37.79                       | 31.85                                    | - 15.72                                  | 21.90                                |
| C6               | 20 %                                          | 33.97                       | 28.03                                    | - 17.49                                  | 9.58                                 |
| C7               | 30 %                                          | 29.72                       | 25.05                                    | - 15.71                                  | - 4.12                               |
| C8               | 40 %                                          | 27.60                       | 24.20                                    | - 12.32                                  | - 10.96                              |

- 18.05
Figure 3. % Replacement of cement by hypo sludge V/S Compressive strength (N/mm²) P1 and P2

Decrease in compressive strength of specimens cured with NaOH solution is observed. The rate of decrease in compressive strength also gradually increases with an increase in the percentage of hypo sludge in the concrete. With the percentage replacement of cement by hypo sludge 0 %, 10%, 20%, 30% and 40% with normal curing after 56 days the compressive strength of cylinders is decreased but parallel the compressive strength with 56 days (28 days normal and 28 days 5% NaOH contain) curing also deceased. The decrease in compressive strength is 20.83% for 56 day concrete

4.3 Regression models

To estimate the compressive strength of hypo sludge cement concrete exposed to NaOH, two regression models have been developed one each for 56 days M40. The regression models are given below.

\[
f_{ck56} = 34.99 - 0.1487 \times C \quad (1)
\]

\[
F_{ck56} = 31.848 - 0.1954 \times C \quad (2)
\]

Where,

- \( f_{ck56} \) = Compressive strength of hypo sludge concrete in N/mm² with normal curing of 56 days
- \( F_{ck56} \) = Compressive strength of hypo sludge concrete in N/mm² with 28 days curing and 28 days 5% NaOH contain curing
- \( C \) = % replacement of cement by hypo sludge

The coefficient of co-relation factor for regression equations 1 and 2 is 0.3512 and 0.857 respectively. The performance of regression models is presented in table 4.
Table 4. Performance of regression models for compressive strength

| % Replacement of Cement by Hypo Sludge | Compressive Strength of Hypo Sludge Concrete in Mpa with Normal Curing of 56 days | Compressive Strength of Hypo Sludge Concrete in Mpa with 28 days Normal Curing and 28 Days NaOH Solution Curing |
|----------------------------------------|--------------------------------------------------------------------------------|--------------------------------------------------------------------------------|
|                                        | Experimental (EXP) | Regression Model (RM) | R.M./ EXP | Experimental (EXP) | Regression Model (RM) | R.M./ EXP |
| 0 %                                    | 31.00              | 34.99                  | 1.13      | 30.57              | 31.84                  | 1.04      |
| 10 %                                   | 37.79              | 33.50                  | 0.89      | 31.85              | 29.89                  | 0.94      |
| 20 %                                   | 33.97              | 32.01                  | 0.94      | 28.03              | 27.94                  | 1.00      |
| 30 %                                   | 29.72              | 30.52                  | 1.03      | 25.05              | 25.98                  | 1.04      |
| 40 %                                   | 27.60              | 29.04                  | 1.05      | 24.20              | 24.03                  | 0.99      |

From this table the ratios between experimental compressive strength value and the value predicted by the regression model for with normal curing of 56 days are about 0.89 to 1.13 and with 28 days normal curing and 28 days 5% NaOH solution curing are about 0.94 to 1.04 respectively. This implies the proposed models made a good agreement with experimental values.
5. Conclusions

The following conclusions were made from the experimental work.

- Continuous loss in weight hypo sludge cement concrete specimens prepared with 0% to 40% replacement of hypo sludge by 0.17% to 0.35%.
- Continuous decrease in compressive strength of hypo sludge cement concrete specimens prepared with 0% to 40% replacement of cement by hypo sludge when cured by % NaOH contain solution is 1.39% to 17.49%.
- The proposed regression models shown good performance to predict the compressive strength.

6. References

[1] IS 456 2000 Indian Standard Plain and Reinforced Concrete - Code of Practice, *Bureau of Indian Standards*, New Delhi, India.
[2] IS 516 1959 Indian Standard Methods of Tests for Strength of Concrete, *Bureau of Indian Standards*, New Delhi, India.
[3] IS 10262 2009 Indian Standard for Concrete Mix Proportioning - Guidelines, *Bureau of Indian Standards*, New Delhi, India.
[4] Pitroda J R, Roghelia A N 2013 Strength assessment of fly ash concrete with water containing sodium hydroxide. *Int J of Civil, Struct, Env and Infra Eng Res. and Deve* 3(5) 45-52.
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