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Behavior of Concrete under Partial Replacement of Hypo-Sludge & Foundry-Sand

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Abstract

Concrete is exclusive construction material which extensively used world widely. It is a mixture of cement, sand, aggregate, admixtures and water. The manufacturing of Portland cement which is the main ingredient of concrete releases a large amount of greenhouse gases especially CO2. On the other side, dumping of wastes produced from various industries, corporations and municipalities causes major environmental pollution issues. To minimize these effects, researchers are trying to use waste materials from industries as replacement material for cement or coarse aggregate or fine aggregates. During this research work an attempt has been made for simultaneous replacement of cement with hypo-sludge and fine aggregate with foundry sand. The present dissertation work is directed towards developing low cost concrete from paper industry waste, and foundry industry waste. The work is carried out with M30 grade concrete. The hypo sludge& foundry sand was replaced within the range of 10-30% by weight of cement& fine aggregate respectively. Cubes of 150mm x 150mm x 150mm in size, Cylinders of 150 mm diameter and 300 mm height, beams of 150mm x 150mm x 700mm were casted. In the present study, four different mixes are tested for parameters like: compressive strength, flexural strength and split tensile strength.
Keywords: Concrete, Fine Aggregates, Foundry-Sand, Hypo-Sludge, Strength, Water-Cement Ratio

I. Introduction

Concrete is exclusive construction material which extensively used world widely. It is a mixture of cement, sand, aggregate, admixtures and water. The manufacturing of Portland cement which is the main ingredient of concrete releases a large amount of greenhouse gases especially CO2. On the other side, dumping of wastes produced from various industries, corporations and municipalities causes major environmental pollution issues. To minimize these effects, researchers are trying to use waste materials from industries as replacement material for cement or coarse aggregate or fine aggregates. During this research work an attempt has been made for simultaneous replacement of cement with hypo-sludge and fine aggregate with foundry sand. The hypo sludge or paper mill sludge is a major waste and environmental pollutant from the paper and board industry. The material is a by-product of the deinking and re-pulping of paper. Investigations were undertaken to produce low cast concrete by blending various ratios of cement with hypo sludge. Metal foundries use large amounts of sand as part of the metal casting process sand consists primarily of silica sand, coated with a thin film of burnt carbon, residual binder (betonies, sea coal, resins) and dust. Foundry sand can be used in concrete to improve its strength and other durability factors. Foundry Sand can be used as a partial replacement of fine aggregates or total replacement of fine aggregate and as supplementary addition to achieve different properties of concrete.

II. Methodology

A. Introduction

Physical properties of hypo sludge and other materials were determined by performing tests & results. Various partial replacement proportions of hypo sludge & foundry sand were fixed. Based on the result a mix design of M30 grade was formulated according to the standards of IS 10262- 2009. About 4 different concrete samples of M30 grade were casted & cured for about 7 & 28 days including cubes, cylinders & beams. These specimens were used to find the important properties like compressive strength, flexural strength and split tensile strength.

B. Details of Project

Chemical composition of hypo sludge & specific gravities of coarse aggregate, fine aggregate, hypo sludge & foundry sand were determined.

1) Chemical Properties of Hypo-Sludge

The chemical properties & their percentage amount of the constituents of hypo sludge were tested in a lab. These chemical properties of PPC & Hypo sludge were compared.

Table – 1
Comparison of Chemical Properties of Cement & Hypo Sludge

Chemical Properties	*Cement*	*Hypo Sludge*
Calcium (CaO)	*60*	*12.01*
Magnesium (MgO)	*0.1*	*07.56*
Silica (SiO2)	*17*	*07.28*
Sulphur (SO3)	*1.3*	*07.74*
Alumina (Al2O3)	*3*	*03.06*
Iron Oxide (Fe2O3)	*0.5*	*01.18*
Sodium (Na2O	*0.4*	*03.50*
Potassium (K2O)	*0.4*	*00.38*
Loss on Ignition	*2*	*43.32*

2) Specific Gravity

Specific gravity can be defined as the ratio of the weight of a given volume of material to the weight of an equal volume of water. Specific gravities of coarse aggregate, fine aggregate, hypo sludge& foundry sand were determined which were further used in mix design calculations. The experiment was carried out with help of the pycnometer.

Specific gravity of various materials was calculated with help of pycnometer & by using expression,

$$G = \frac{M2-M1}{(M2-M1)-(M3-M4)}$$

Where,
M1 = mass of empty Pycnometer,
M2 = mass of the Pcynometer with material,
M3 = mass of the Pcynometer and material and water,
M4 = mass of pyconmeter filled with water only.

Table – 2
Comparison of Chemical Properties of Cement an&d Hypo Sludge

Material	*Specific gravity*
Coarse aggregate	*3.03*
Fine aggregate	*2.57*
Hypo-sludge	*1.64*
Foundry sand	*2.36*

III. CONCRETE MIX DESIGN

Concrete mix design for M30 concrete,

1) Stipulations for Proportioning
- Grade Designation: M30
- Type of cement: PPC 53 grade
- Maximum nominal size of aggregate: 20mm
- Minimum cement content: 220 Kg/m3
- Workability: 70 mm (slump)
- Exposure Condition: Mild
- Degree of supervision: Good
- Type of aggregate: Crushed Angular

2) Test Data for Materials
- Specific gravity of cement = 3.15
- Specific gravity of coarse aggregate = 3.03
- Specific gravity of fine aggregate = 2.57
- Specific gravity of hypo-sludge = 1.64
- Specific gravity of foundry sand = 2.36

3) Target Strength for Mix Proportioning

$$f_{ck} = f_{ck} + k\sigma$$

$$= 30 + (1.65 * 5) = 38.25\ N/mm^2$$

4) Selection of Water-Cement Ratio

From Table 5 of IS 456, maximum water-cement ratio = 0.60

Hence we adopt water-cement ratio as 0.45.

5) Selection of Water Content

From Table 2, of IS 10262-2009 maximum water content for 20 mm aggregate = 186 lit (for 25 to 50 mm slump range)

Estimated water content for 70 mm slump = 186 + 186 * 0.03 = 191.58 lit.

6) Selection of Cement Content
Water Cement Ratio = 0.45
Cement content = $\frac{191.58}{0.45}$
= 425.73 Kg/m3
From Table 5 of IS 456, minimum cement content for 'mild' exposure condition = 220 Kg/m^3
425.73 kg/ m^3 > 220 kg/m^3, Hence, O.K.
7) Proportion of Volume of Coarse and Fine Aggregates Content
From Table 3, of IS 10262-2009 volume of coarse aggregate corresponding to 20 mm size aggregate and fine aggregate (Zone I) for water-cement ratio of 0.50 =0.60.

In the present case water-cement ratio is 0.45. Therefore volume of coarse aggregate is required to be increased to decrease the fine aggregate content. As the water-cement ratio is lower by 0.05 the proportion of volume of coarse aggregate is increased by 0.01
= 0.60 + ($\frac{0.01}{0.05}$ * 0.05)
= 0.61
Therefore, volume of coarse aggregate = 0.61.
Volume of fine aggregate content =1 - 0.61 = 0.39.
8) Mix Calculations
The mix calculations per unit volume of concrete shall be as follows:
a) Volume of concrete = 1 m^3
b) Volume of cement = $\frac{\text{mass of cement}}{\text{specific gravity of cement}} * \frac{1}{1000}$
= $\frac{425.73}{3.15} * \frac{1}{1000}$ = 0.134 m^3
c) Volume of water = $\frac{\text{mass of water}}{\text{specific gravity of water}} * \frac{1}{1000}$
= $\frac{191.58}{3.15} * \frac{1}{1000}$ = 0.191 m^3
d) Volume of all in aggregates = [a-(b+c)] = [1-(0.134-0.194)] = 0.675 m^3
e) Mass of coarse aggregate = (d x volume of coarse aggregate x specific gravity of coarse aggregate x 1000)
= 0.675 * 0.6* 3.03 * 1000
= 1247.60 kg
f) Mass of fine aggregate = (d x volume of fine aggregate x specific gravity of fine aggregate x 1000)
= 0.675 x 0.39 x 2.57 x 1000
= 676.55 kg
9) Mix Proportions

Table – 3
Mix Design for Various Proportions

Mix design type	*Cement (kg/m^3)*	*Water (kg/ m^3)*	*C.A. (kg/ m^3)*	*F.A (kg/ m^3)*
Conventional	*425.73*	*191.56*	*676.55*	*1247.60*
	1	*-*	*1.58*	*2.93*
10% replacement	*393.71*	*196.48*	*654.50*	*1206.93*
	1	*-*	*1.66*	*3.06*
20% replacement	*351.17*	*197.53*	*641.47*	*1182.91*
	1	*-*	*1.82*	*3.36*
30% replacement	*311.88*	*200.05*	*621.42*	*1145.94*
	1	*-*	*1.99*	*3.67*

IV. RESULTS & DISCUSSION

A. *Compressive Strength*

Compressive strength test was carried out on cube specimens of size 150mm x 150mm x 150mm which were casted & cured for 7 & 28 days. The cubes were casted by using M30 grade concrete & respective mix proportions from the mix design. The partial replacement of hypo sludge & foundry sand was 10%, 20%, 30% respectively. There was also a set of conventional concrete blocks for the comparison of the results thus obtained. The test was carried out as per guidelines of IS 516 1959.

Table – 4
Average Compressive Strength of Cube Specimens

Types of concrete sample	*Average Compressive Strength (N/mm^2)*	
	7 Days	*28 Days*
Conventional Concrete	*19.65*	*34.83*
10% Replacement	*19.71*	*35.24*
20% Replacement	*17.22*	*33.66*
30% Replacement	*12.55*	*23.75*

B. Flexure Strength

The flexure strength on a concrete slab is called upon to resist tensile stresses from two principal sources wheel loads & volume change in the concrete. The flexure strength test was carried out on the beam specimens of size 150mm x 150mm x 700 mm. This test was carried out by Centre-point loading method on UTM. This test was also carried on conventional & partial replaced specimens of M30 grade & respective proportions from mix design. The beam specimens were casted & cured for 7 & 28 days. The test procedure was carried out as per the guidelines of IS 516 1959.

Table – 5
Average Flexure Strength of Cube Specimens

Types of concrete sample	*Average Flexure Strength (N/mm^2)*	
	7 Days	*28 Days*
Conventional Concrete	*3.15*	*4.51*
10% Replacement	*2.86*	*4.09*
20% Replacement	*2.78*	*3.98*
30% Replacement	*2.58*	*3.69*

C. Split Tensile Strength

The determination of split tensile strength of concrete is necessary to determine the load at which the concrete may crack due to tension. These tests were carried out on the cylindrical specimens of size 300 mm depth & 150 mm diameter casted & cured for 7 & 28 days for conventional & different partial replacements concrete samples.

Table – 6
Average Split Tensile Strength of Cube Specimens

Types of concrete sample	*Average Flexure Strength (N/mm^2)*	
	7 Days	*28 Days*
Conventional Concrete	*1.60*	*2.29*
10% Replacement	*1.41*	*2.01*
20% Replacement	*1.35*	*1.93*
30% Replacement	*0.93*	*1.33*

V. CONCLUSION

Based on the limited experimental investigation concerning the compressive, flexural, split tensile strength, following conclusions are drawn:

- Hypo sludge possesses cementitious properties therefore it is feasible construction material, for partial replacement of cement.
- Foundry Sand, a byproduct of metal industry, contains silica sand which aids in increasing strength and durability of concrete, and therefore is feasible for use as construction material, for partial replacement of fine aggregate.
- After a 10% of partial replacement of hypo sludge exceeds, as the percent partial replacement of hypo sludge and foundry sand is increased, there is reduction in strength of concrete.

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