STUDY ON MECHANICAL PROPERTIES OF CONCRETE WITH INDUSTRIAL WASTES

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Abstract

Utilization of Industrial waste, construction waste, agriculture waste, commercial waste etc... In concrete plays a vital role in minimizing the disposal problems. Over 300 million tons of industrial wastes are being produced per annum by chemical and agricultural process in India. These materials poses problems of disposal, health hazards and aesthetic problem. Hypo Sludge (HS) is a waste material produced from paper industry that can used as a cement replacement material in concrete since the lime content in the sludge is large. Copper slag is a waste material produced from copper manufacturing process and this can be used as a replacement material for fine aggregate (sand) since the particle size similar to sand. During the present study, an attempt had been made to study the mechanical properties of concrete in which Hypo sludge and Copper slag were as a replacement material for cement and fine aggregate respectively. Replacement percentage used during this study were 10%, 20% and 30% of Hypo sludge for cement. Fine aggregate was replaced with 30%, 40% and 50% of Copper slag. Compressive strength of cubes were found on 7th, 28th and 56th days. Split tensile strengths of the cylinders were found on 28th and 56th days. Flexural strengths of prism specimens were found on 28th day. It has been found that usage of Hypo sludge and Copper slag as a replacement material has beneficial effects on the Mechanical properties of concrete.

Keywords: *Hypo sludge, Copper slag, Compressive strength, Split tensile strength, Flexural strength.*

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1. INTRODUCTION

Concrete is a strong and versatile construction material. It is a mixture of cement, sand, aggregate water and admixtures. The manufacturing of using Portland cement (PC) which is the main ingredient of concrete releases a large amount of greenhouse gases specially CO_2. On the other side dumping of wastes produced from industries, Corporations or municipalities causes major environmental issues. To minimizing these effects, researchers are trying to use waste materials from industries as replacement material for cement or coarse aggregate or fine aggregate. Use of Industrial waste materials in concrete may change the workability and hardened properties based on the nature of the waste materials. Fly ash, Bottom ash, Bagasse ash, Ground Granulated Blast furnace Slag, Metakaolin, Silica fume etc… are being used as replacement materials for cement. Foundry sand, silica sand, quarry dust, manufactured sand etc… are being used as replacement material for fine aggregate. During this present investigation, an attempt has been made to simultaneous replacement of cement with hypo sludge and fine aggregate with copper slag.

2. LITERATURE REVIEW

Arivalagan .S, determined the Mechanical properties of concrete with copper slag as a replacement material for fine aggregate and the replacement percentage was varied from 0 to 100%. He concluded that 40% replacement of fine aggregate with copper slag yielded good compressive and flexural strengths and it is reported that the optimum replacement percentage is 40.

Brindha .D and Nagan .S, found the mechanical properties of concrete with copper slag as a replacement material for fine aggregate. They reported that upto 40% replacement, compressive and flexural strengths increases beyond that, strength was found to decrease.

Pavitha .G, et.al, determined the mechanical properties of concrete containing recron fibres and Hypo sludge. Hypo sludge was used to replace cement. They concluded that 30% replacement of cement with Hypo sludge yielded best results.

Zala L B and Umrigar F S investigated the mechanical properties of concrete with hypo sludge as a replacement material for cement. They concluded that 10% replacement of cement with hypo sludge gave highest flexural strength.

Karthickraja .R et.al, discovered the mechanical properties of concrete in which cement was practically replaced with hypo sludge. They concluded that at 10% replacement of cement with Hypo sludge yielded better Mechanical properties of concrete.

T. Ch. Madhavi, studied Mechanical properties of concrete in which copper slag was used as a replacement material for fine aggregate. She reported that 30% replacement of fine aggregate with copper slag gave maximum strength and she reported that beyond 50% replacement the strength decreases drastically.

3. MATERIAL PROPERTIES

3.1 Cement

Ordinary Portland Cement (OPC) is composed of calcium silicates, aluminates and aluminoferrite. It is obtained by blending predetermined proportions of limestone, clay and other materials in small quantities which are pulverized and heated at high temperature around 1500^{o}C to produce 'clinker'. The clinker is then ground with small quantities of gypsum to produce a fine powder called Ordinary Portland Cement. During this present work OPC conforming to IS 12269-1987 was used. Some of the physical properties of cement are listed in Table 1.

Table -1: Properties of Cement

Particulars	Test value
Fineness	5%
Specific gravity	3.15
Consistency	33%
Specific gravity	3.15
Initial setting time	125 min
Final setting time	260 min

3.2 Hypo Sludge

Hypo sludge (HS) consumes a large percentage of local landfill space for each and every year. It is a by-product of acetylene gas plant. In this type of sludge lime varies between 25% to 50%. By incinerating paper sludge at approximately 800°C, the resultant fly ash may contain reactive silica, magnesium and alumina (in the form of Metakaolin) as well as lime (CaO) which contributes chemical properties to the Portland cement. During this investigation Hypo sludge was used as a replacement material for cement because of both materials having Silica and Magnesium properties which improves the setting and workability properties of concrete. The properties of sludge are listed in Table 2.

Table -2: Constituent Percentage comparison between Hypo sludge & Cement

Constituent	% in Sludge	% in Cement
Moisture	56.8	-
Magnesium oxide (MgO)	3.3	1.1
Calcium oxide (CaO)	46.2	65.6
Loss on ignition	27.00	0.9
Acid insoluble	11.1	0.4
Silica (SiO_2)	9.0	21.0
R_2O_3	3.6	8.66

3.3 Fine Aggregate

Aggregates passing through 4.75mm sieve are defined as fine aggregate. Fine aggregate is added to concrete to assist workability and to bring uniformity in mixture. Usually, the natural river sand is used as fine aggregate. By conducting sieve analysis, it was found that sand used for this work conforms to grading zone II as per IS 383:1970 and fineness modulus of sand was found as 2.71. The specific gravity of fine aggregate is 2.62

3.4 Copper Slag

Copper slag (CS) is a by-product obtained during the copper smelting and refining process. In copper slag, CaO content is in the order of 0.15% to 3.30%. It indicates that the lime content is very low. Slag also exhibits pozzolanic properties since it contains low CaO. Since most of the properties of CS are similar to that of river sand, it can be used as a replacement material for sand/fine aggregate. The physical and chemical properties are listed in Table 3 & 4 respectively.

Table -3: Physical properties of CS

Physical property	Values/nature
Appearance	Black glassy granules
Shape	Granular
Specific gravity	3.6
Chloride content water soluble	11ppm
Bulk Density	1.8
Hardness	7 mhos scale

Table -4: Chemical properties of CS

Chemical property	Values
pH of aqueous solution of aqueous extract	6.9
Fe_2O_3	56.4%
SiO_2	28.7%
CaO	2.1%
Al_2O_3	3%
Cu	1%
Free moisture	1.3%

3.5 Coarse Aggregate

Coarse aggregate is a chemically stable material present in concrete. Presence of coarse aggregate reduces the drying shrinkage and other dimensional changes occurring an account of movement of moisture. Coarse aggregate contributes to impermeability of concrete, provided that is properly graded and the mix is suitably designed. In this present work 20mm angular size aggregate is used. The specific gravity of coarse aggregate is 2.67 and fineness modulus of coarse aggregate is 3.17.

3.6 Water

The water, which is used for making concrete should be clean and free from harmful impurities like oil, alkalis, acids etc. Ordinary potable water available in the laboratory was used for making and curing the concrete. The quality of water was found to satisfy the requirements of IS 456–2000.

4. EXPERIMENTAL INVESTIGATIONS

M25 grade mix was designed as per IS 10262-2009 and the mix proportion was found to be 1:1.80:2.95 with w/c ratio of 0.5. Hypo sludge was used as a replacement material for cement and copper slag was as a replacement material for fine aggregate. The replacement percentage adopted were 10%, 20% & 30% for Hypo sludge and 30%, 40% & 50% for copper slag. Specimens were casted and the Mechanical properties of concrete were determined.

The various percentage replacement of materials used in this present investigation are given in the Table 5:

Table -5: Details of the Specimen

Specimen Identity	Replacements Percentages			
Specimens	**Cement**	**Hypo sludge**	**Fine aggregate**	**Copper slag**
A1	100	0	100	0
A2	90	10	100	0
A3	80	20	100	0
A4	70	30	100	0
B1	100	0	70	30
B2	100	0	60	40
B3	100	0	50	50
C1	90	10	70	30
C2	90	10	60	40
C3	90	10	50	50
D1	80	20	70	30
D2	80	20	60	40
D3	80	20	50	50
E1	70	30	70	30
E2	70	30	60	40
E3	70	30	50	50

In order to investigate the mechanical property, cubes of 150 mm x 150 mm x 150 mm size, cylinders of 150mm diameter and 300mm length and prisms of 100 mm x 100 mm x 500 mm were cast. The total number of specimen cast were 144 cubes, 96 cylinders and 48 prisms. The specimens were cured, and tested as per relevant codal provisions.

4.1 Compressive Strength of Cubes

The compressive strength of concrete were determined by conducting tests on 150 mm x 150 mm x 150 mm cube specimens at 7^{th}, 28^{th} & 56^{th} days as per IS 516–1959. The test was carried out in the compression testing machine of 2000kN capacity. The cubes were placed in the compression testing machine and the load was applied at the rate of approximately 140N/mm^2/min until the failure of the specimen. The average value of three samples were taken as strength.

4.2 Split Tensile Strength of Cylinders

Split tensile strength is an indirect method of finding out the tensile strength of concrete. The test is carried out by placing the cylindrical specimens horizontally between the loading surfaces of the compression testing machine and the load is applied until the failure of the cylinder, along the vertical diameter. The test was as per IS 5816:1999 on the 28^{th} and 56^{th} days.

4.3 Flexural Strength of Prism

Flexural strength tests were carried out on 100 mm x100 mm x 500 mm beams on the 28^{th} day using a 100kN capacity Universal Testing Machine (UTM) apparatus. The system of loading used in finding out the flexural tension is two point loading as per IS 516–1959.

The values of the Compressive, Split tensile and Flexural strength of the specimens are given in the Table 6

Table -6: Compressive, Split tensile & Flexural Strength Test at 7^{th}, 28^{th} & 56^{th} days

Specimens	% Replacement Of HS & CS	Compressive Strength			Split tensile strength		Flexural strength
		7^{th} Day N/mm^2	**28^{th} Day N/mm^2**	**56^{th} Day N/mm^2**	**28^{th} Day N/mm^2**	**56^{th} Day N/mm^2**	**28^{th} Day N/mm^2**
A1	0	24.8	32.89	38.65	2.68	3.39	5.5
A2	10% HS	28.22	31.22	35.56	2.83	3.255	4.5
A3	20% HS	23.77	29.5	28.44	2.96	3.397	3.5
A4	30% HS	17.55	21.56	23.11	2.26	2.69	3.75
B1	30% CS	32.7	43.56	50	2.97	3.53	3.5
B2	40% CS	34.6	45.33	53.11	3.03	3.82	3
B3	50% CS	36.8	48.22	54.25	2.83	2.54	2.5
C1	10%HS-30%CS	26.00	32.89	41.33	3.11	3.255	3.5
C2	10%HS-40%CS	28.44	34.64	45.4	3.45	3.11	5
C3	10%HS-50%CS	31.66	36.31	36.22	2.83	2.83	6
D1	20%HS-30%CS	17.55	31.78	35.67	3.04	2.83	5.5
D2	20%HS-40%CS	24.22	33.6	38.74	3.22	2.97	4.5
D3	20%HS-50%CS	25.33	33.9	31.24	2.89	3.11	4

E1	30%HS-30%CS	18.01	20	23.56	2.69	2.54	4
E2	30%HS-40%CS	17.29	21	25.56	2.97	2.54	3.5
E3	30%HS-50%CS	19.23	21.56	20.55	2.26	2.69	3

5. RESULTS AND DISCUSSIONS

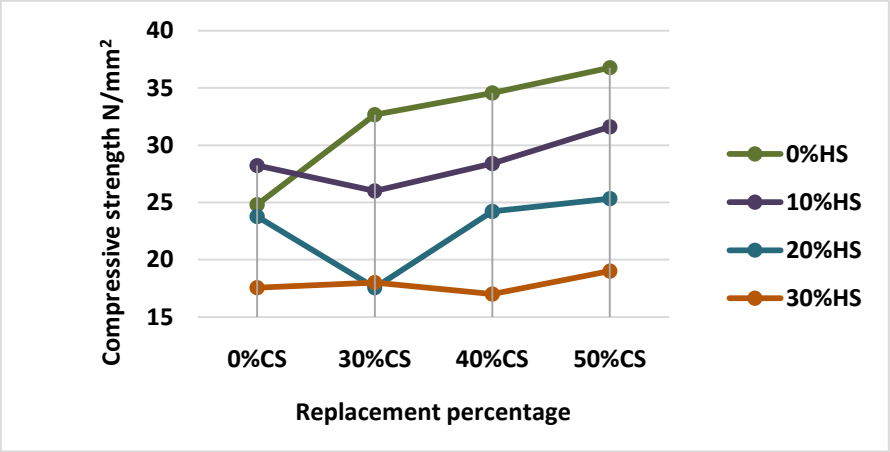

Chart -1 Compressive strength at 7th day

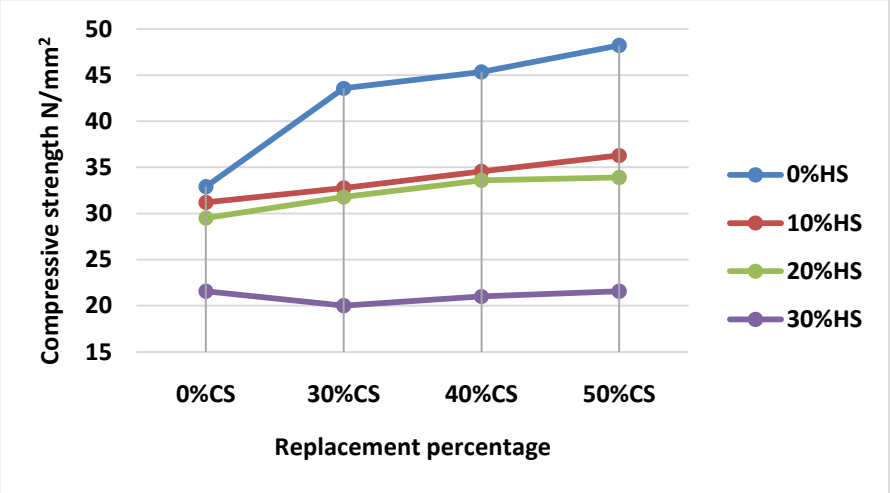

Chart -2 Compressive strength at 28th day

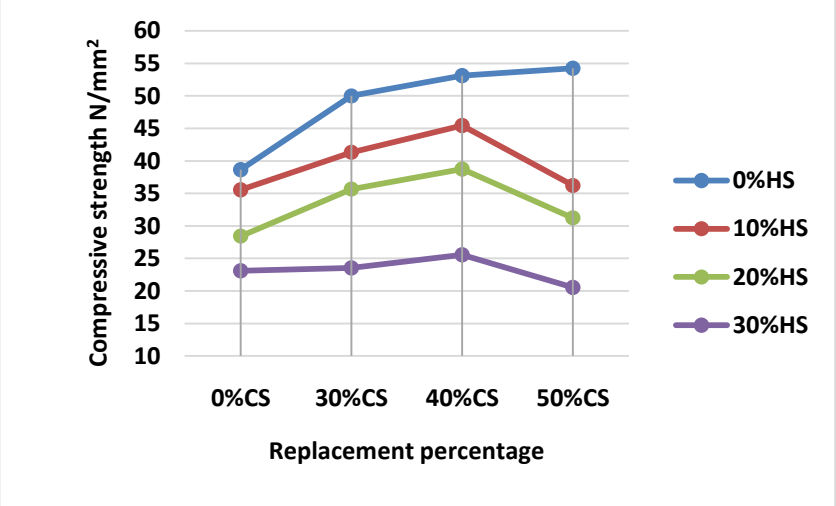

Chart -3 Compressive strength at 56th day

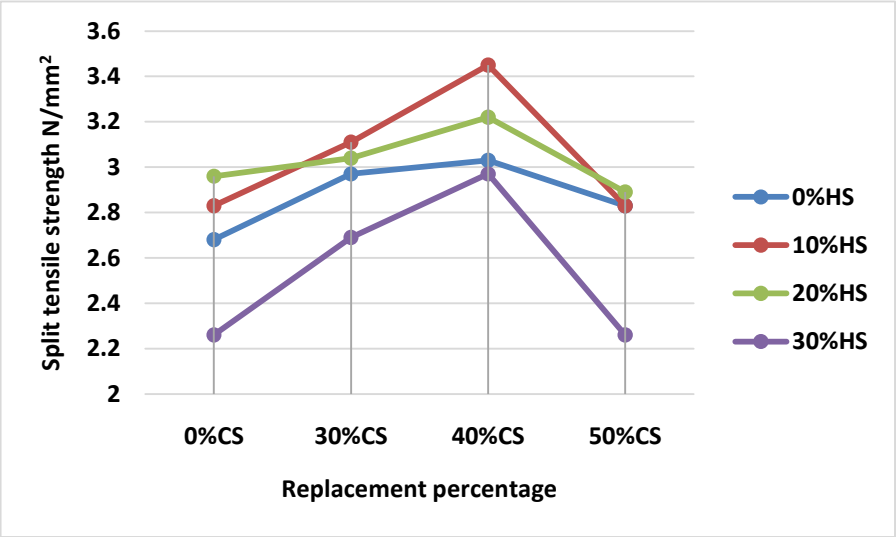

Chart -4 Split tensile strength at 28th day

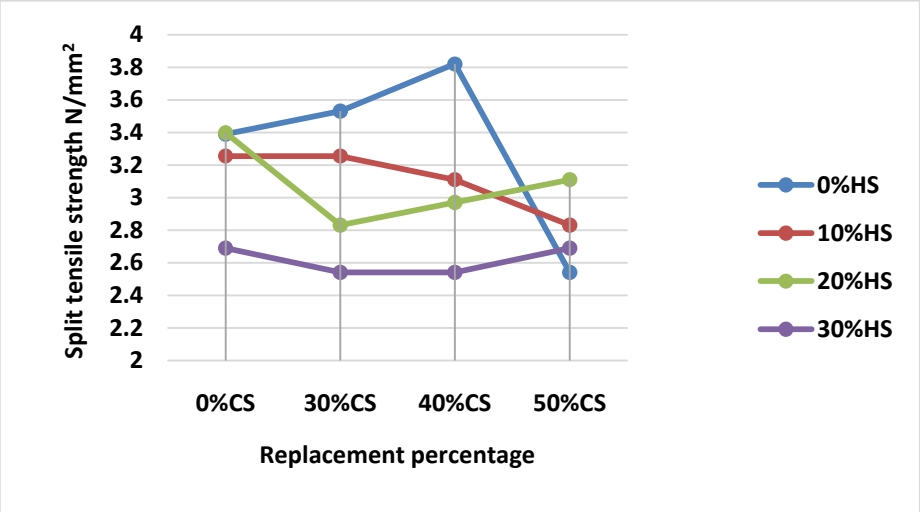

Chart -5 Split tensile strength at 56th day

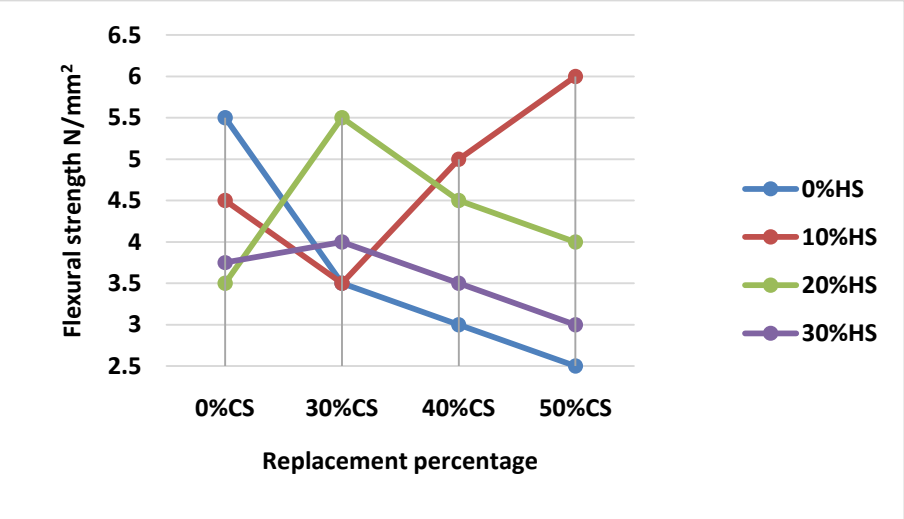

Chart -6 Flexural strength at 28th day

6. CONCLUSION

1. Optimum of 50% replacement of fine aggregate by copper slag shows increase in compressive strength when compared to conventional mix.
2. With 10% replacement of cement by Hypo sludge shows increase in compressive strength when compared to 20% and 30% replacement mix.
3. Optimum of 10% replacement of cement with Hypo sludge and 50% replacement of fine aggregate with Copper slag shows increase in compressive strength compared to other combinations.
4. 10% and 20% replacement of cement with HS shows little variation in compressive strength based on curing days.
5. With increase in curing days 40% replacement of fine aggregate with copper slag shows increase in split compressive strength.
6. Optimum of 10% replacement of cement with Hypo sludge and 40% replacement of fine aggregate with Copper slag shows increase in split tensile strength compared to conventional mix.
7. At 40% replacement of fine aggregate by copper slag shows increase in split strength.
8. With increase in curing days 30% replacement of cement with hypo sludge shows decrease in split tensile strength when compared to other combinations.
9. Optimum of 10% replacement of cement with Hypo sludge and 50% replacement of fine aggregate with Copper slag shows increase in flexural strength compared to conventional mix.

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