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Controlling Environmental Pollution Through Concrete Technology

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ABSTRACT

The increasing amount of wastes is a concerning reality that has arose the sustainability issues for the environment. Large amount of wastes such as fly ash (from thermal plant), hypo sludge (from paper mill industry) etc. is generated annually which are generally disposed off by landfills leading to environmental pollution. Hypo plant in the paper industry generates large volume of waste in the form of a slurry. This solid waste directly affects the soil properties and contributes to the soil pollution. Also, the production of cement accounts for the global warming by releasing carbon dioxide in the atmosphere. Therefore, the formulation of concrete with industrial waste can help in minimizing the environmental problem. In this study, hypo sludge was used as a replacement of cement in concrete. Polypropylene fibre (PPF) was added to strengthen the concrete. In this research work 25 mixes were prepared at different replacement levels of hypo sludge (0%, 5%, 10%, 15%, 20%) and polypropylene fibre (0%, 0.25%, 0.5%, 0.75%, 0.10%) for M-20 mix. Workability was determined; the compressive strength and splitting tensile strength of concrete were tested after 7, 14 and 28 days of curing.

INTRODUCTION

Disposal of industrial waste has become the major problem to the environment. To approach sustainable development, industrial waste must be utilized in an innovative way. The use of these wastes offer environmental advantages like divert the material from the waste stream, reduce the energy used in processing virgin materials, use of virgin materials, and decreasing pollution. Paper mill sludge is a major economic and environmental problem for the paper and board industry. The material is a by-product of the de-inking and re-pulping of paper (Solanki & Pitroda 2013a). Three mills among eight mills are using calcium hypo chlorite in final stage for bleaching. Solid wastes generated during calcium hypo chlorite generation are called hypo sludge (Alam & Berera 2015). The paper mill sludge consumes a large percentage of local landfill space for disposal every year. Hypo sludge is directly polluting the environment through its disposal on land, causing soil pollution, its incineration causing air pollution, or its disposal in streams causing water pollution. Hypo sludge behaves like cement because of silica and magnesium properties which improve the setting of the concrete. Paper fibre can be recycled only a limited number of times before they become too short or weak to make high quality of paper. Hypo sludge contributes beneficial properties to the concrete while helping to maintain economy and saving the environment. Many researchers have investigated the feasibility of using the paper industry waste in concrete production as partial replacement of cement. The use of hypo sludge in concrete can save the paper industry disposal costs and produces a green concrete for construction (Solanki & Pitroda 2013b). Moreover, all the generated residues from cellulose and paper manufacturing are classified as not dangerous in the Catalogue of European Residues (CER). The current residues produced in the manufacture of paper, which are used in the ceramics industry and in agricultural compost, are catalogued as clean (Garcia et al. 2007).

Concrete made with Portland cement is relatively strong in compression but weak in tension and tends to be brittle. Another fundamental weakness of concrete is that cracks start to form as soon as concrete is placed and before it has properly hardened. So the failure of concrete can be minimized by the inclusion of a sufficient volume of certain fibres. Polypropylene is a synthetic hydrocarbon polymer, the fibre of which is made using extrusion processes by hot drawing the material through a die. Its use enables reliable and effective utilization of intrinsic tensile and flexural strength of the material along with significant reduction of plastic shrinkage cracking and minimizing of thermal cracking (Ahmed et al. 2006). Therefore, one of the useful and cost benefit ways to increase strength and corrosion resistance, and reduce cracks extension is the usage of PPF in the mixture of concrete (Ramezanianpour et al. 2013).

The present study has been accomplished in attempt to reduce pollution due to hypo sludge. The workability and strength characteristics were studied.

MATERIALS USED

Cement: Cement conforming to specifications given in BIS: 8112-1989 was used. Cement was carefully stored to prevent the deterioration in its properties due to contact with the moisture. It was free and free from lumps. Ordinary Portland cement (OPC) of grade 43 from a single lot was used in this study. Table 1 shows the properties of OPC 43 grade.

Fine aggregates: Fine aggregates were collected from Chakki River (Pathankot). It was coarse sand, brown in colour. Specific gravity of fine aggregates was experimentally determined as 2.72. Fine aggregates are conforming to grading zone II as per BIS-383:1970 as presented in Table 2.

Coarse aggregates: The coarse aggregates used were a mixture of two locally available crushed stone of 10 mm and 20 mm size in 50:50 proportions. The aggregates were washed to remove dirt, dust and then dried to surface dry condition. Specific gravity was found to be 2.65. Coarse aggregates are conforming to grading zone II as per BIS-383:1970 as given in Table 3.

Hypo sludge: Hypo sludge, obtained from Shreyans Paper Mill Ltd. (Ahmedgarh), was used in this study. The slurry from the hypo plant of paper mill was collected in the brick pits. After that, the slurry was allowed to evaporate in sun, till the moisture exhausts. Then it was ground and sieved. The properties of hypo sludge and its comparison with cement are given in Table 4.

Polypropylene fibres (PPF): Polypropylene fibres, obtained from Forta Corporation (Brand name: ECONO-NET), were used in this study. Polypropylene fibre was used to enhance the strength of concrete. Its properties are given in Table 5.

Water: Fresh and clean tap water was used for casting the specimens in the present study. The water was relatively free from organic matter, silt, oil, sugar, chloride and acidic material as per BIS: 456-2000.

Table 1: Properties of OPC 43 grade cement.

Sr. No.	Characteristics		Value obtained experimentally	Values specified by IS: 8112-1989
1.	Specific gravity		3.15	-
2.	Standard consistency		31.5%	-
3.	Initial setting time		140 minutes	30 minutes (minimum)
4.	Final setting time		270 minutes	600 minutes (maximum)
5.	Compressive strength,	3 days	24.60 N/mm^2	23 N/mm^2
		7 days	35.87 N/mm^2	33 N/mm^2
		28 days	48.45 N/mm^2	43 N/mm^2

Table 2: Sieve analysis of fine aggregates.

Total weight of sample = 500 g					
IS-sieve designation	Weight retained on sieve (g)	% weight retained on sieve	Cumulative % weight retained on sieve	% passing	% passing for grading zone-II as per IS: 383-1970
10 mm	Nil	Nil	Nil	100	100
4.75 mm	40	8.00	8.00	92.00	90-100
2.36 mm	23	4.60	12.60	87.40	75-100
1.18 mm	73	14.60	27.20	72.80	55-90
600 micron	111	22.20	49.40	50.60	35-55
300 micron	123	24.60	74.00	26.00	8-30
150 micron	120	24.00	98.00	2.00	0-10

Table 3: Sieve analysis of proportioned of coarse aggregates.

IS-sieve designation	Weight retained on sieve (10 mm agg.) (g)	Weight Retained on sieve (20 mm agg.) (g)	50:50 Proportion (10 mm: 20 mm) weight retained	Cumulative weight retained (g)	Cumulative % weight retained	% passing	BIS: 383-1970 requirements
80 mm	Nil	Nil	Nil	Nil	Nil	100	100
40 mm	Nil	Nil	Nil	Nil	Nil	100	100
20 mm	8	5	5.60	5.60	0.28	99.72	95-100
10 mm	587	1973	1278	1283.6	64.18	35.82	26-55
4.75 mm	1265	22	646.5	1930.1	96.50	3.50	0-10

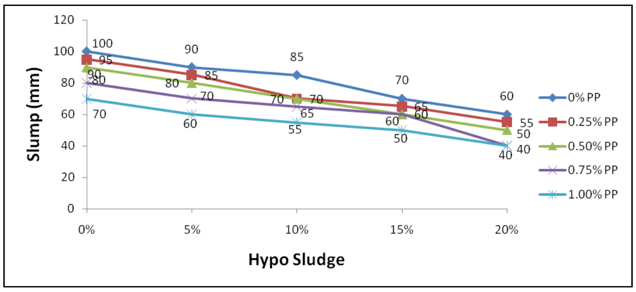

Fig. 1: Degree of workability of various mixes using slump test.

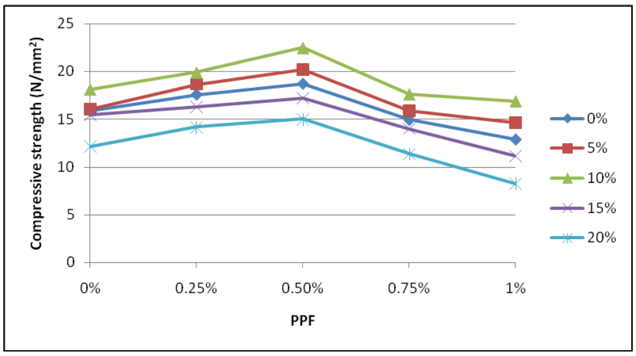

Fig. 2: Compressive strength of different mixes at 7 days.

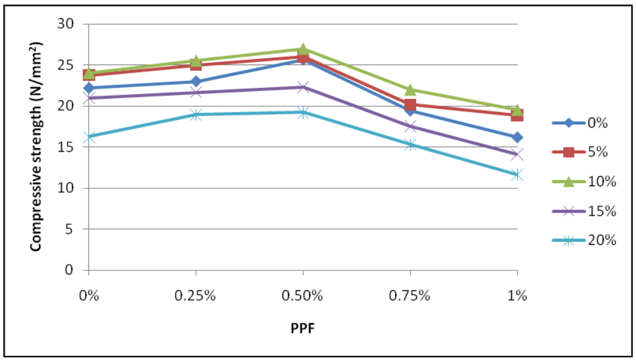

Fig. 3: Compressive strength of different mixes at 14 days.

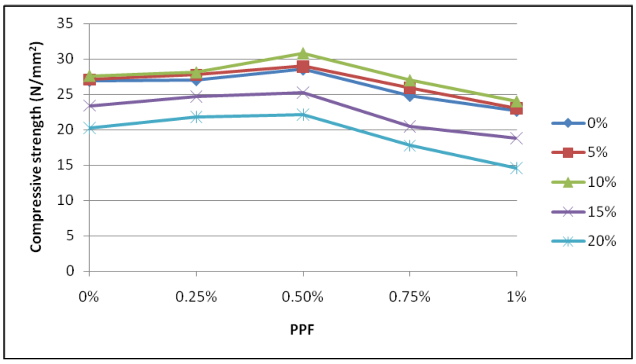

Fig. 4: Compressive strength of different mixes at 28 days.

LABORATORY TESTING PROGRAM

Mix design and sample preparation: Control mix, following the guidelines of BIS 10262- 2009, was selected after different trials. Then 24 mixes were prepared other than the control mix at different replacement levels of hypo sludge (0%, 5%, 10%, 15%, 20%) and polypropylene fibre (0%, 0.25%, 0.5%, 0.75%, 0.10%). First 5 mixes were prepared with variation of hypo sludge keeping PPF 0%. Similarly, other mixes were prepared by increasing the fibre content. Cement was replaced with hypo sludge and polypropylene fibre (PPF) was used as an additive in concrete. The water/cement (w/c) ratio and water content were kept 0.55 and 186 litres/m^3 respectively. The compressive strength and splitting tensile strength was determined after 7, 14 and 28 days of curing. The workability of concrete was determined using slump test. The workability of concrete decreases as the content of hypo sludge and polypropylene fibre increases, as shown in Fig. 1. This is due to the higher water absorption capability of hypo sludge and increase in voids due to the addition of PPF.

RESULTS AND DISCUSSION

Compressive strength and splitting tensile strength of concrete: To determine the compressive strength (as per BIS: 516 -1959) and splitting tensile strength (as per BIS: 5816: 1999), the cubes of size 150 mm were casted under Universal Testing Machine (UTM). The values of average compressive strength and splitting tensile strength for different replacement levels of hypo sludge (0%, 5%, 10%, 15%, 20%) and polypropylene fibre (0%, .25%, 0.50%, 0.75%, 1.00%) at the end of different curing periods (7 days, 14 days, 28 days) are shown in Fig. 2 to Fig. 7.

Results showed that the change in compressive strength and splitting tensile strength was minor up to 10% of hypo sludge but beyond 10% of hypo sludge, there was a significant reduction in strength due to water absorbing capability of hypo sludge, which disturbed the water cement ratio. At higher dosage of sludge, cement content decreases which leads to the weak bonds especially around sludge particles. This eventually caused early crack development during the testing. It was observed that the addition of PPF up to 0.5% showed the increase strength of concrete. After that the strength decreases for 0.75% and 1% of PPF. This is due to the fact that PPF attributes towards a good cohesion with other aggregates. But at higher dosage of fibre due to the formation of air voids, the concrete becomes stiff and difficult to compact, which tends to decrease the strength. The combined effect of the combination, 10% of hypo sludge and 0.50% PPF, showed the maximum compressive strength that is 30.79 N/mm^2 and splitting tensile strength

Table 4: Comparison of the properties of hypo sludge with cement.

Serial no.	Constituents	Cement (%)	Hypo sludge (%)
1	Lime (CaO)	62	46.2
2	Silica (SiO_2)	22	9.00
3	Magnesium oxide (MgO)	5	3.33
4	Aluminum ($Al2O_3$)	1	3.60
5	Calcium sulphate (Ca_2SO_4)	4	4.05

Source: Experimental investigation in developing low cost concrete from paper industry waste.

that is 4.98 N/mm^2. This is because at higher dosage of sludge and PPF concrete loses its ability to adhere properly.

Coefficient of brittleness: Coefficient of brittleness is the value of the compressive strength divided by splitting tensile strength of the concrete (Altindag 2003). The coefficient of brittleness at 28 days is shown in Fig. 8.

The coefficient of brittleness is decreasing with increase in percentage of hypo sludge up to 10% beyond that coefficient of brittleness increases. This is because at higher dosage of sludge, cement content decreases which leads to the weak bonds especially around sludge particles. The coefficient of brittleness is decreasing with increase in percentage of polypropylene fibre up to 0.5%, beyond that coefficient of brittleness increases. Because of the formation of air voids at higher dosage of fibre, the concrete becomes stiff and difficult to compact. From Fig. 8 it is recommended that the Mix M13 (10% hypo sludge and 0.5% polypropylene fibre) is best suited with least coefficient of brittleness that is 6.18. This is due to the fact that higher dosage of hypo sludge and polypropylene fibre affected the ability of concrete to adhere properly.

CONCLUSIONS

- The environmental pollution due to the disposal of waste from the paper mill industry can be minimized through this approach.
- This is an innovative step to reduce the global warming effect due to the production of cement. The amount of carbon dioxide released can be minimized.
- The workability of concrete decreases from medium to low with the increase in content of hypo sludge and PPF.
- Up to 10% of hypo sludge and 0.50% of PPF gives the maximum compressive strength and splitting tensile strength. M13 is best suited accordance with coefficient of brittleness.
- Hypo sludge is economically feasible for the temporary shelters during natural disasters where strength is not a considerable factor.

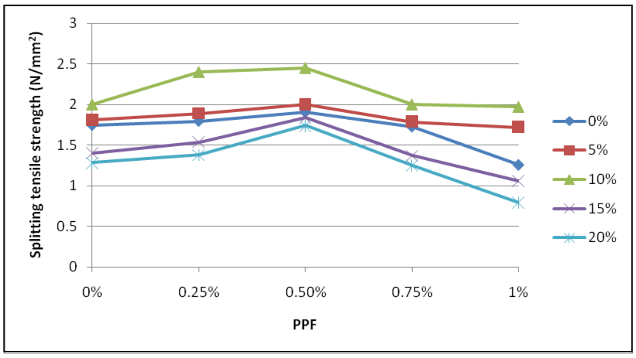

Fig. 5: Splitting tensile strength of different mixes at 7 days.

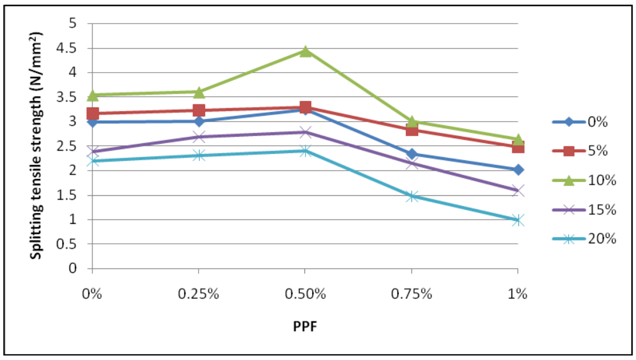

Fig. 6: Splitting tensile strength of different mixes at 14 days.

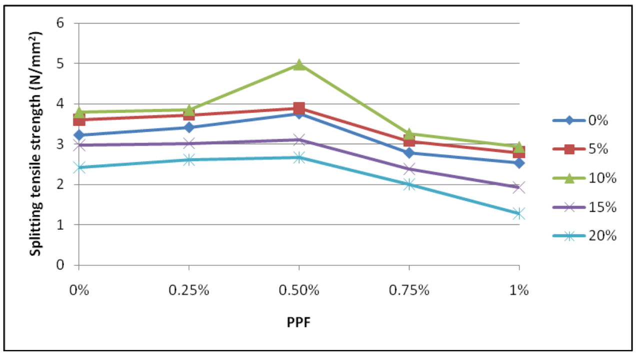

Fig. 7: Splitting tensile strength of different mixes at 28 days.

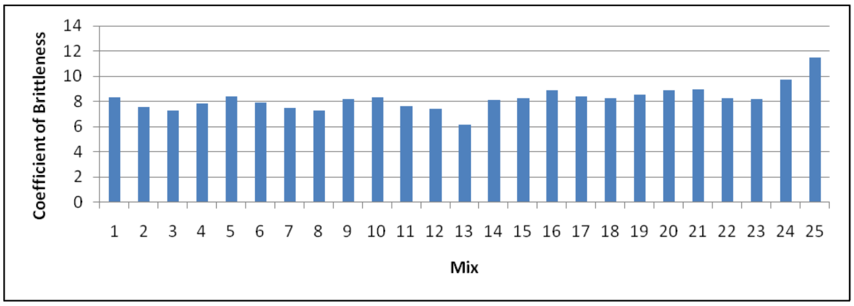

Fig. 8: Variation of coefficient of brittleness for different mixes at 28 days of curing.

- Results indicate that the compressive strength and the splitting tensile strength are in phase with each other. At the higher dosage of hypo sludge and PPF, concrete becomes brittle and hence the strength decreases.

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