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Investigating effect of Black Pulp Liquor on the Properties of Concrete

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Abstract— In the present scenario all over the world, there is trend to investigate the utilization of industrial byproducts in the concrete. In the present study attempt has been made to investigate utilization of Black Pulp Liquor, by product of paper and pulp industry, as plasticizer to reduce the cost of waste disposal and make positive environmental impact. By using Marsh Cone Test, optimum dosage of admixture of cement for the considered w/c ratio has been determined. In the experimental work, different six concrete mixes has been studied with partial replacement of natural coarse aggregate by steel slag by 0%, 30% and 50%. Also black pulp liquor as admixture has been used to improve the workability concrete upto its optimum dosage. In the experimental study slump test, compacting factor test and compressive strength test, split strength test were performed to determine the fresh properties of concrete and the hardened properties of concrete at 7 day and 28 day respecctively.

Index Terms— Black Pulp Liquor, Plasticizer, Marsh Cone Test, Optimum Dosage, Steel Slag, Workability, Compressive strength , Split Tensile Strength

1 INTRODUCTION

DUE to increasing demand of performance of concrete in the present scenario, fresh and hardened properties needs to be studied. With the rapid growth of industrialization there is increase in industrial by product. Disposal of these wastes in one of the major issue in the present world, thus many researches had been carried to find the proper solution of these crises. Incresing usage of concrete put heavy burden on the usage of naturally available sources such as crushed stone. It is necessary to find replacement of these resources. *Steel slag is generated as a melt at about 1600°C during steelmaking from hot metal in the amount of 15%–20% per equivalent unit of steel* [1]. Due to high cost of disposal of steel slag there is need to find new field for its utilization. *Due to high hardness of steel slag its grinding turned out to be unprofitable to be used as cement addition* [1]. Thus rigorous research works were focused on the use of steel slag as an aggregate in concrete. *From a long time, pulp and paper industry produced huge amount of black liquor waste. The black liquors of the pulp industryare still not used efficiently* [2].
Therefore this research studies the possibility of utilization of black pulp liquor, received from local paper industry, as concrete admixture and also the steel salg as partial replacement of coarse aggregate in the concrete to create positive environmental impact.
It also provides the preferred solution of the disposal of such industrial waste.

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2 MATERIALS AND MIX PROPORTIONS

2.1 Experimental Materials

In the experimental work, The cementitious materials used were Ordinary Portland Cement (OPC), Black Pulp Liquor as admixture, Steel Salg of maximum size 20 mm as replacement of coarse aggregate, naturally available crushed aggregate and fine aggregate having maximum size 4.75 mm.

2.1.1 Cement

All the mixes in the present work were prepared using Ordi-

TABLE 1
CHEMICAL AND PHYSICAL PROPERTIES OF CEMENT

Properties of Cement (OPC-53 grade)		
Sr No	Particulars	Test Result Obtained
A. Chemical Properties		
1	Lime Saturation Factor (LSF)	0.92
2	Alumina to iron Oxide Ratio % (A/F)	1.19
3	Insoluble Residue (% by mass)	1.10
4	Magnesia - MgO (% by mass)	3.73
5	Sulfuric Anhydride - SO_3 (% by mass)	2.48
6	Total loss on ignition (% by mass)	1.37
7	Maximum Chloride (% by mass)	0.05
B. Physical Properties		
1	Fineness (Blaine) 1. Specific Surface (m^2/kg)	340
2	Soundness : Expansion by	
	1.Le-chatelier Method (mm)	1.80
	2.Auto clave (%)	0.18
3	Compressive strength (MPa)	
	1. 3 Days	30.0
	1. 7 Days	42.0
	1. 28 Days	59.0

nary Portland Cement-53 Grade (OPC-53 Grade).

The Chemical and physical properties of cement are given in Table 1. The obtained results of cement satisfied the criteria as per IS 12269:1987.

2.1.2 Fine Aggregate

The fine aggregate used throughout the experimental investigation were alluvial sand from single source. Sieve analysis of fine aggregate was performed to determine the particle size distribution of fine aggregate. As per IS: 383-1970 grading zone of fine aggregates were confirmed as Zone III.

2.1.3 Coarse Aggregate

The coarse aggregate used throughout the experimental investigation were naturally irregular and partly rounded at the edge having 10-20 mm size of aggregate. Also coarse aggregate (grit) having size 5-10 mm were considered for the study. Sieve analysis of coarse aggregate was performed on both the samples to determine the particle size distribution of coarse aggregate. As per IS: 383-1970 grading of coarse aggregates were confirmed as well graded aggregate for both sample.

2.1.4 Steel Slag

Since steel slag has low pozzolanic activity it could be use as aggregate. In the present work, the possibility of steel slag utilization instead of aggregates in concrete is studied by partially replacing natural aggregate with steel slag. The steel slag used was of uniform size passing through 20 mm sieve.

2.1.5 Black Pulp Liquor

In the present experimental work, to alter the fresh properties of concrete, Black pulp liquor was used as admixture. Characterization of the black pulp liquor was carried out by determining the relevant parameters which are mention in Table 2. Optimum dosage of this admixture has been applied to different mixes of concrete.

TABLE 2
PROPERTIES OF BLACK PULP LIQUOR

Properties of Black Pulp Liquor		
Sr.No	Particulars	Test Result Obtained (gm per kg of dry solid Content)
1	Potassium K	3.34
2	Sulfur total S_{tot}	5.5
3	Carbon total C_{tot}	0.41
4	Sulfide S^{2-}	1.93
5	Sodium Hydroxide NaOH	1.1
6	Carbonate CO_3^{2-}	6.2
7	Sodium sulfite Na_2SO_3	0.1
8	Sodium thiosulfate $Na_2S_2O_3$	2.13
9	Sodium sulfate Na_2SO_4	1.23
10	Carbon (C) Content	31.9
11	Hydrogen (H) Content	3.33
12	Nitrogen (N) Content	0.08

2.2 Mix Design

Mix design for different concrete mixes were prepared according to IS 10262:2009 (first revision), for each concrete of a cubic meter. The water/cement ratio of concrete was taken as 0.45 for all mixes of M25 grade of concrete. Consequently, the dosage of admixture (Black Pulp Liquor) varied according to the mix to alter the fresh properties of concrete. Concrete composition for mix is been given in Table 3.

The modification was made by replacing the natural aggregate with steel slag by proportion of 0%, 30% and 50%.

TABLE 3
CONCRETE MIX DESIGN

Mix Proportions of Concrete containing different levels of steel slag and Black Pulp Liquor							
Sr No	Mix Proportions	Concrete Mixes					
		B0S0	B0S30	B0S50	B2.5S0	B2.5S30	B2.5S50
1	Cement (kg/m^3)	320	320	320	320	320	320
2	Fine Aggregate (kg/m^3)	866	866	866	866	866	866
3	Coarse Aggregate (kg/m^3)	1143	800	572	1143	800	572
4	Steel Slag (kg/m^3)	0	343	571	0	343	571
5	Black Pulp Liquor (% by weight of cement)	0	0	0	2.5	2.5	2.5
Considered water/cement ratio = 0.45 for all mixes							

3 SPECIMEN PREPARATIONS AND TESTING PROCEDURE

3.1 Specimens

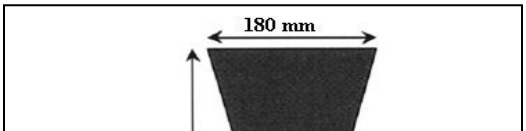
In the present experimental work to study the fresh properties of concrete, slump cone test was performed for all mixes. Also in order to study and compare compressive strength and split tensile strength for each mix of concrete, cube of size 150mm x 150 mm x 150 mm and cylinder of size with diameter of 150 mm and length of 300 mmwere casted in gunmetal moulds. After being de-moulded at the age of one day, all specimens were cured in water at room temperature until the age of 7 and 28 days. Using compression tesing machine having capacity of 3000 kN, compressive strength at 7 and 28 day and split tesnsile strength 28 day were measured. The results reported are the average of three specimens.

3.2 Tests

To investigate effect of black pulp liquor in concrete, slump cone test, compressive strength and split tensile test were performed to evaluate the fresh and hardened properties of concrete mix.

3.2.1 Marsh Cone Test

The Marsh cone test is non-standard test most typically used to investigate the fluidity of cement pastes and cement mortars. In the present work, water/cement ration was considered as 0.45 and marsh cone used was a type of funnel having neck with opening of 8 mm for cement paste mixes as shown in Fig 1.In this study, cement paste mixes were prepared by varying the percentage dosage of admixture by weight of cement. For the experiment, an initial volume of 1000 ml of paste was poured into the cone and the time required for 500 ml of it to flow out was measured.



Marsh test gives the fluidity of the paste in terms of the flow time, higher the flow time, lower is the fluidity of the paste. The saturation point is the dosage beyond which further addition of admixture does not increase fluidity significantly but can produce segregation [3].

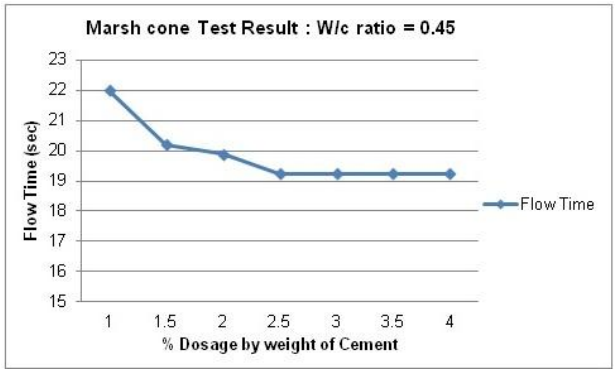


Fig.2. Marsh Cone Test results

From the observed test results shown in Fig 2 the saturation dosage of 2.5% can be taken as the optimum dosage admixture of for a given cement paste mixes. The observed amount optimum dosage of admixture was used in the concrete mixes to increase the workability.

3.2.2 Slump Cone Test

As per the IS 1199:1959, standard slump cone test is used to measure the workability of concrete mixes.

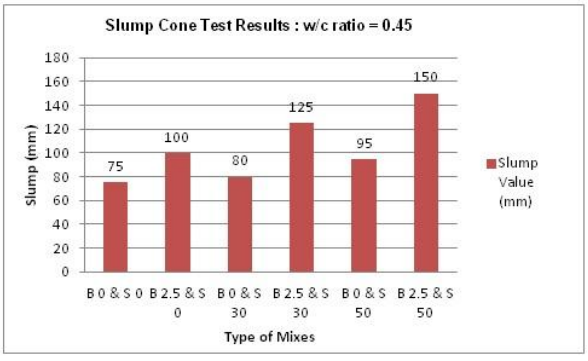


Fig.3. Slump Cone Test results

From the observed result of slump cone test is been shown in Fig 3. The workability of concrete mix is been improved by adding the admixture.

3.2.3 Compressive Strength Test

The cube specimen were subjected to a sustained varying compressive force until there ultimate load carrying capacity or failure of specimen. The observed result of compressive strength test is been shown in Fig 4 A and Fig 4 B.

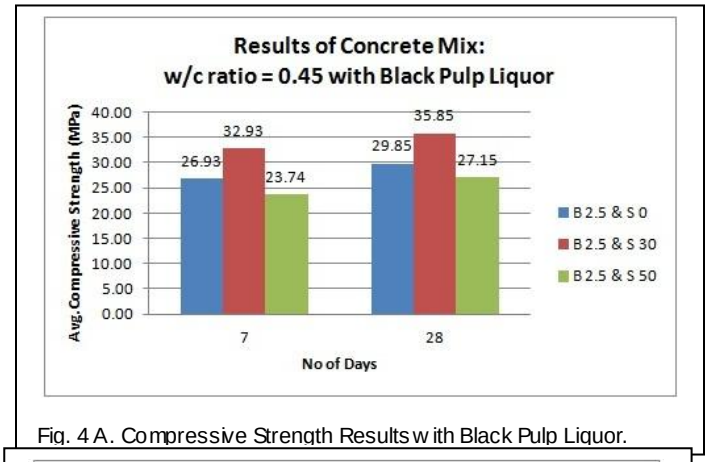


Fig. 4 A. Compressive Strength Results with Black Pulp Liquor.

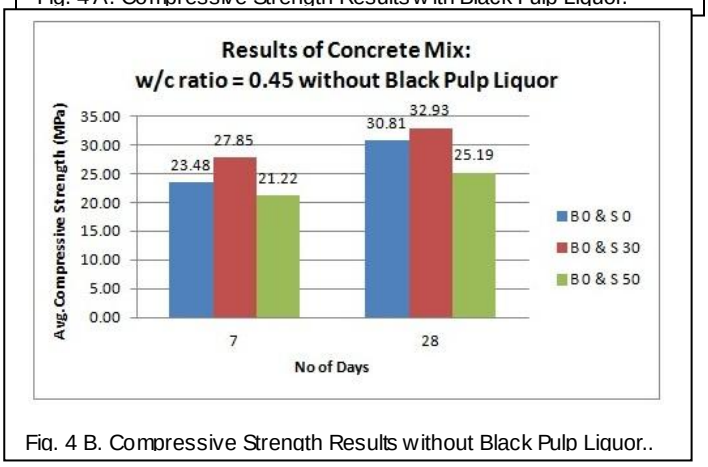
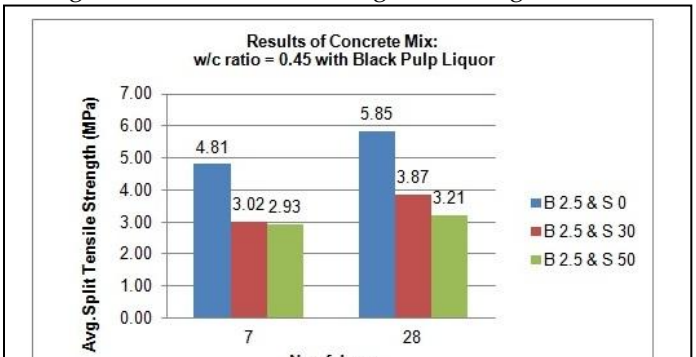


Fig. 4 B. Compressive Strength Results without Black Pulp Liquor..

In the present work, compressive strength was determined according to IS 516:1959 at various ages of a period of 7 and 28 days.

3.2.4 Split Tensile Strength Test

The cylindrical specimen were subjected to a sustained varying tensile force until there ultimate load carrying capacity or failure of specimen. The observed result of compressive strength test is been shown in Fig 5 A and Fig 5 B.



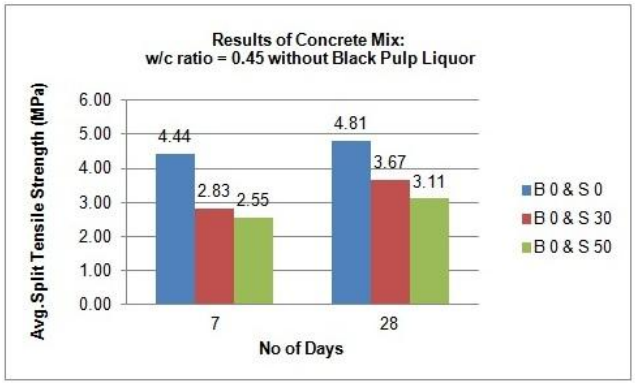


Fig. 5 B. Split Tensile Strength Results without Black Pulp Liquor

In the present work, split tensile strength was determined according to IS 5816:1999 at ages of a period 28 days.

4 Results and Discussion

4.1 Workability of fresh concrete

From the results shown in figure 3, it can be observed that the mixes incorporating admixture demonstrate better dispersion of cement particle hence improved workability of concrete mix. Also, from the experimental results it can be observed that there is increase in workability of concrete mix in which natural aggregate is replace by steel slag by 0%, 30% and 50% respectively. This type of pattern is been observed in all the mixes of concrete.

4.2 Compressive Strength

For concrete cube specimen cured in water, the result of compressive strength with ages is shown in figure 4. It can be observed that the compressive strength increases upto certain replacement of natural aggragate with steel slag. Also addition of admixture, black pulp liquor, in concrete mixtes shows increase in strength in early period and upto upto certain replacement of natural aggragate with steel slag.

Therefore, the inclusion of black pulp liquor in concrete mix, mainly affects short-term strength of concrete. Considering the same mix proportion obtained results shows increase in strength as 7% and 20% without and with addition of black pulp liquor for the 30% replacement of natural aggregate by steel slag. By increase in the replacement upto 50% it reduces upto 24% in both cases.

4.3 Split Tensile Strength

For concrete cylinder specimen, the result of split tensile strength with 28 day age is shown in figure 5. It can be observed that split tensile strength decreases with increasing replacement of natural aggragate with steel slag. Addition of admixture, black pulp liquor, in concrete mixtes shows very few variations in the test results. For the same mix proportion obtained results shows decrease in strength as 24% and 34% without and with addition of black pulp liquor for the 30% replacement of natural aggregate by steel slag. By increase in the replacement upto 50% it reduces upto 15% and 17% in both cases respectively.

5 Conclusions

The influence of steel slag and black pulp liquor in concrete were evaluated in this study and the following findings are concluded:

- The workability (Slump value) of concrete mix fairly increases as the ratio of replacement of natural aggregate to steel Slag increases as 0%, 30% and 50% without using admixture.
- By addition of admixture (Black pulp liquor) results shows prompt increase in workability as the ratio of replacement of natural aggregate to steel Slag increases as 0%, 30% and 50%.
- Steel slag meets the requirements to be used as aggregate in concrete mixes partly upto 30%.
- The maximum compressive strength value occurs at 30% replacement of natural aggregate by steel slag and the results declines beyond the 30% replacement ratio.
- The result obtained indicates the improvement of compressive strength for replacement of natural aggregate by steel slag ratio is been from 0-30%.
- The result obtained indicates decrease in split tensilr strength by incresing replacement ratio of as 0%, 30% and 50% natural aggregate by steel slag.
- Addition of admixture (Black pulp liquor) in concrete mix fairly affects the split tensile strength of concrete.

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