Study on the Mechanical and Flexural Properties of Concrete by the Addition of Black Liquor Sludge as Admixture

Nikhil NadhV. S., Jayasree S.

***Abstract:** Water cement ratio is one of the main factors which control the strength of concrete. Though workability of concrete increases due to the increase in water cement ratio strength of concrete decreases considerably. For increasing the workability with minimum water cement ratio, admixtures are used. It is necessary to note that the addition of these admixtures should not decrease strength and durability properties of concrete. Commonly used chemical admixtures are costly. Black liquor sludge is a waste product from paper industry causes environmental pollution, which may be considered to use as a workability aid. This project work is intended to find the amount of black liquor sludge to be added in M30 and M50 concrete mixes for getting a slump of 100 mm with a water cement ratio of 0.35 for medium workability and to study its mechanicaland flexural properties. All the results showed that, black liquor sludge is an effective material for the replacement of current chemical admixtures for improving workability.*

***Index Terms**: Black liquor sludge, workability, mechanical properties, flexural property*

I. INTRODUCTION

Concrete admixture is defined as a material other than water, aggregates or cement, used as an ingredient of concrete and added to the batch immediately before or during its mixing to modify one or more of the properties of concrete in the plastic or hardened state. They are used to modify the properties of concrete to achieve desired workability in case of low water cement ratio and to enhance setting time of concrete for long distance transportation of concrete.

The disposal of waste material is a major problem faced by the industries. If this waste can be used in construction industry as a replacement material, then it will become a solution to the problem. Some of the industrial waste and byproducts were used as concrete admixture such as iron splinters, minced rubber, polymer fibres, mineral dust, calcium carbonate etc [1, 2, 3]. Some natural products were also used as concrete admixture like broiler hen egg and Gum Acacia Karroo (GAK) [4, 5].

Super plasticizers are added to concrete with a low water-cement ratio to make high-slump flowing concrete. The commonly used superplasticizers are ligno-sulphonates and hydrocarbolic acid salts. They are usually based on lignosulphonate, which is a natural polymer, derived from wood processing in the paper industry. The disadvantages of using most of chemical admixtures like super plasticizers are its high cost, lack of availability etc.

In the present experimental investigation, improvement of workability of concrete with a minimum water cement ratio by using black liquor sludge as admixture was studied. Black liquor sludge is a waste product of paper industry during Kraft process. This is a process for conversion of wood into wood pulp, which consists of almost pure cellulose fibers, the main component of paper. One of the main ingredients in it is lignin, the material in trees that binds wood fibers together and makes them rigid. Approximately 7 tonnes of black liquor sludge is produced in the manufacture of one tonne of pulp. It is discharged to watercourses causing toxic to aquatic life. Hence studies can be conducted to find the suitability of black liquor sludge in construction industry as admixture. This approach will help to eliminate the environmentally polluting black liquor sludge waste. Samar et al. (2011) conducted an experiment on utilization of black liquor, produced by the pulp and paper industry, as a workability aid and retarder admixture. The properties of black liquor and its performance on concrete at two different water cement ratio were studied. Water is replaced by black liquor for 5, 10, 15, 20 percentage of water. The results showed that black liquor increases concrete workability, improve compaction and reduce honeycombing when 15% water replaced by black liquor [6]. The objectives of this study are: i) To develop concrete mixes of BLC30 and BLC50 (concrete of grade M30 and M50 with Black liquor sludge as admixture) for a slump of 100 mm with water cement ratio of 0.35.
ii) To find the mechanical and flexural properties of BLC30 and BLC50.

II. MATERIAL PROPERTIES AND MIX PROPORTION

Portland Pozzolana Cement, crushed stones of 20 mm coarse aggregate, manufactured sand passing through sieve of size 4.75 mm and confirming to zone II of IS 383-1970 (reaffirmed 2002) as fine aggregates were used [7]. Black liquor sludge procured from Hindustan newsprint limited, Vellore, Kerala, India was used as super plasticizer. The mix design was done as per IS 10262-2009, to obtain a M30 and M50 grades of concrete [8]. The mix proportion thus obtained was 1:2.1:4.1 for M30 and 1:1.1:3.2 for M50. Laboratory tests were conducted on black liquor sludge to determine the different chemical properties and the results are shown in Table 1.[9]

Revised Manuscript Received on June 23, 2018.

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TABLE 1.PROPERTIES OF BLACK LIQUOR SLUDGE

Properties	Values
pH	8
Bio-chemical oxygen demand (BOD) (mg/l)	16000
Chlorides (mg/l)	375
Sulphides (mg/l)	300
Total solids (mg/l)	9105
Total dissolved solids (mg/l)	2115
Total suspended solids (mg/l)	6990

III. EXPERIMENTAL PROGRAM

A. Fresh and Harden Properties

The workability of concrete was determined by slump test [10].The different mechanical properties such as cube compressive strength, splitting tensile strength, flexural strength, cylinder compressive strength and modulus of elasticity were determined [11], [12].

B. Flexural Behaviourof RCC Beams

Beam specimens were used to determine the flexural strength which are subjected to two point loading using Universal Testing Machine of 1000kN capacity. Three numbers of beams were prepared for CB30 (control beam of M30 mix), CB50 (control beam of M50 mix), BLC30 and BLC50 mixes. The beam is of100 x 150 x 1000 mm size which are provided with reinforcement as per IS 456 - 2000 [13]. The clear cover provided on all the sides was 25mm. Two numbers of 10mm diameter bars were used as tension reinforcement, 8mm diameter bars as compression reinforcement and 6mm diameter 2 legged stirrup holders at 90mm c/c. Dial gauges were used to measure the deflection and the values obtained were used to plot the load-deflection graph. Strain gauges were placed on the tension and compression reinforcement to measure the strainsand to plot the moment-curvature relationship.Fig 1. represents the detailing of beam specimen.

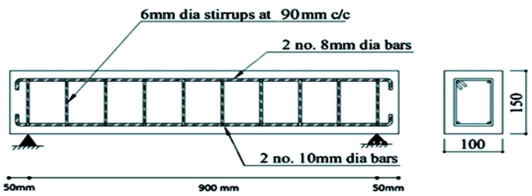

Fig 1. Details of reinforcement in beam specimen

C. *Test set up*

The beams were tested under two point loading in a Universal Testing Machine. Dial gauges and strain gauges were used to measure the mid span deflection and strain respectively. Fig 2. represents the test setup. The value of moment is given by:

$$M = \frac{Pl}{6} \qquad (1)$$

Where,

M =Moment at mid span
P =Applied load
l =Span of the beam between the supports

The curvature was obtained by:

$$\phi = \frac{\epsilon_s + \epsilon_c}{d} \qquad (2)$$

Where,

ϕ =Curvature
ϵ_s =Tension steel strain
ϵ_c =Tension steel strain [14]

Fig 2. Testing of Beam

IV. RESULTS AND DISCUSSION

A. Workability test

The amount of black liquor sludge were added for M30 and M50 control mixes by replacing water for getting a slump of 100 mm are given in Table 2.From the workability test results, the percentage of black liquor sludge to be added for M30 mix was selected as 20% by replacing water and for M50 it was 25% for getting a slump of 100mm. The increase in slump may be due to the ability of black liquor sludge to act as a dispersing agent by neutralizing the electrostatic charges of the concrete mixture, especially the cement. This neutralization minimizes assemblage of the solid particles allowing them to mix better with water.

TABLE 2. PERCENTAGE OF BLACK LIQUOR SLUDGE ADDED IN M30 AND M50 MIX

Black liquor sludge(% replacement of water) for M30 mix	Slump (mm)	Black liquor sludge (% replacement of water) for M50 mix	Slump (mm)
1	15	10	40
5	35	15	63
10	50	20	80
15	80	22	88
16	84	23	95
18	92	24	97
19	96	25	100
20	100	-	-

B. Mechanical properties

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The mechanical properties of control BLC30 and BLC50 are shown in Table 3.All the hardened properties such as compressive strength, splitting tensile strength, flexural strength, cylinder compressive strength and modulus of elasticity are within acceptable limit for all mixes. Also all these values satisfies the IS specification.

TABLE 3. MECHANICAL PROPERTIES OF CONCRETE

Properties	M30 C	BLC30	M50 C	BLC50
Compressive strength (N/mm^2)	38.44	39.12	59.11	57.85
Splitting tensile strength (N/mm^2)	3.25	3.32	5.09	4.95
Flexural strength (N/mm^2)	4.40	4.80	6.00	5.80
Cylinder compressive strength (N/mm^2)	29.60	29.37	44.80	43.58
Modulus of elasticity (N/mm^2)	2.72 x 10^4	2.71x 10^4	3.55 x 10^4	3.54x 10^4

C. Flexural Behaviour of RCC Beams

Crack Pattern

The crack pattern obtained after testing of beams was shown in Fig 3 and Fig 4. From the figures it can be seen that, Most of the cracks initiated from the bottom of the beam and propagated to the top of the beam. Crack pattern of BLC beams were almost similar to the control beam.

Fig 3. Crack pattern of CB30 and BLC30 beams

Fig 4. Crack pattern of CB50 and BLC50 beams

Crack Width Propagations

The crack width propagation of various mixes is shown in Fig 5. The crack width propagation of BLC beams was slightly higher than control specimens but the final crack width was approximately same.

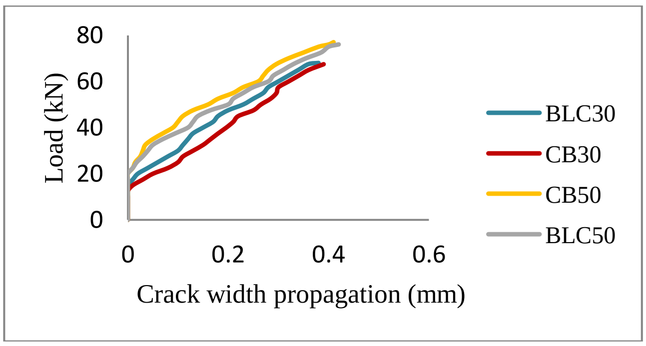

Fig 5. Crack width propagation of beams

Ultimate, Yield and Initial Crack Load

Table 4 shows the ultimate load, yield load and initial crack load of all the beams and it can be observed that ultimate load and initial crack load of BLC and control specimens were approximately same but the yield load of BLC specimens were less than control mixes.

TABLE 4. INITIAL CRACK, ULTIMATE AND YIELD LOAD OF BEAMS

Specimen	Initial crack load (kN)	Yield load (kN)	Ultimate load (kN)
CB30	18	51	68
M30 B	17.5	47.5	67.5
CB50	21	60	77
M50 B	20	57	76

Load Deflection Plot

The load-deflection curve for each beam specimens were plotted as shown in Fig 6. It was observed that the curves for BLC specimens showed similar load-deflection behaviour with control specimens. There is a linear portion till initial cracking and thereafter, non-linearly varying curve till the yield load. Beyond the yield point, the deflection of the beams increased considerably until the ultimate load was reached.

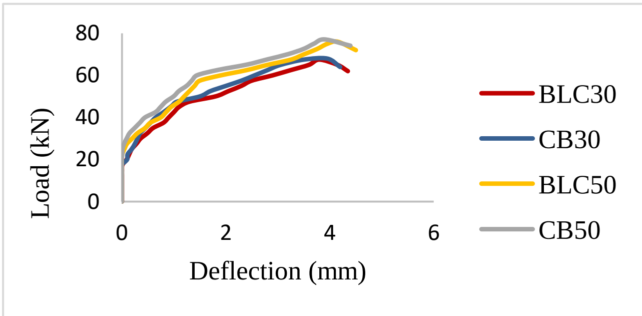

Fig 6. Load deflection plot of beams

Moment Curvature Relationship

The moment curvature obtained for control beam and BLC beams are shown in Fig 7. Moment curvature graph has three stages, first stage ends at initial crack of specimen then linearly increase due to the yielding of tension steel. Final stage is contributed by the limiting value of strain taken by the concrete. Similar trend is followed by the test specimen. It has a linear portion up to initial crack and comparatively after the formation of cracks and non-linear bending behaviour till the yield point and thereafter large deformations beyond yield load. Similar trend is followed by the test specimen. It was observed that the curves for BLC specimens showed similar moment curvature behaviour with control specimens.

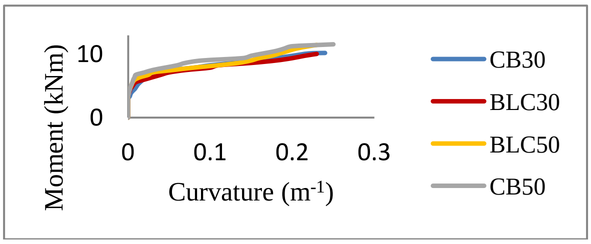

Fig 7.Moment - curvature graph

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Energy absorption and ductility indices

From the load-deflection and moment-curvature plots, the energy absorption characteristics, displacement ductility and curvature ductility for each specimen was derived. Energy absorbed by each specimen during the test was calculated by the area under the load-deflection curve. Due to the limitations in the experimental set up, the load deflection graph could be plotted only up to 80% of the peak load, in the descending portion of the curve. Thus, the energy absorption was calculated as the area under the curve up to the peak load and under the descending portion up to 80% of the peak load. The displacement ductility was calculated from the load deflection plot by the ratio of deflection at ultimate load to that at the yield load and the curvature ductility was computed from the moment-curvature plot by the ratio of curvature at ultimate load to corresponding curvature at yield load. The obtained values are given in Table 5. The results show that the energy absorption, ductility index slightly reduced in the case of BLC mixes than control specimens.

TABLE 5. ENERGY ABSORPTION CAPACITY AND DUCTILITY INDICES OF BEAMS

Specimen	Energy Absorption Capacity(kN mm)	Displacement ductility		Curvature ductility	
		Absolute	Relative	Absolute	Relative
CB30	211.41	3.54	1.00	4.66	1.00
BLC30	192.86	3.29	0.93	4.42	0.95
CB50	251.78	4.23	1.00	6.53	1.00
BLC50	245.88	4.12	0.97	6.26	0.96

V.CONCLUSIONS

From this experimental investigation, the following conclusions were obtained:

The addition of Black liquor sludge of 20 and 25% by replacing water provided a slump of 100 mm in M30 C and M50 C mixes respectively.

All the mechanical properties ofBLC30 and BLC50 mixeswere found to be within acceptable limit and satisfies IS specification.

The BLC30 and BLC50 beams showed similar behaviour with respect to control specimens.

Hence Black liquor sludge can be effectively used as admixture in concrete for increasing workability for both normal strength and high strength mixes. It can be also used for structural applications.

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