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EXPERIMENTAL INVESTIGATION ON BAGASSE ASH AS AN ECO-FRIENDLY BUILDING MATERIAL

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ABSTRACT

An experimental investigation has been carried out to study the behavior of Reinforced Concrete Beams under Flexure using Bagasse Ash as partial replacement of cement by 10%, 20% and 30%. The mix was designed based on ACI method to obtain a concrete grade of M30. The mechanical properties of the mixes were tested using auxiliary specimens by maintaining the Water Binder ratio at 0.50. Test results of the auxiliary specimens indicate that concrete containing Bagasse Ash to the extent of 10% and 20% shows better strength characteristics when compared to the concrete with 30%. Test results indicated that the specimen with 20% replacement of cement by Bagasse Ash has better ultimate load carrying capacity and durability. Thus the beam specimens were cast for the optimized percentage of 20% replacement of cement with Bagasse ash and tested under two point loading. The performances of Bagasse ash beam were compared with the control beam based on the Load-Deflection, Moment-Rotation, Moment- Curvature and Ductility.

INTRODUCTION

Ordinary Portland cement is recognized as the major construction material throughout the world. The production of conventional building materials such as cement, bricks and steel consume a lot of thermal and electrical energy and in turn pollute air, water and land. Disposal of solid waste generated from agricultural and industrial production activity is another serious problem in developing countries like India.

Industrial wastes, such as blast furnace slag, fly ash and silica fume are being used as supplementary cement replacement materials. In addition to these, agricultural wastes such as rice husk ash, wheat straw ash, and sugarcane bagasse ash, coconut husk are also being used as pozzolanic materials. Reuse of such

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wastes as a sustainable construction material appears to be viable solution not only to pollution problem but also to the problem of the land-filling and high cost of building materials. The objective of the present investigation is to evaluate Bagasse Ash (BA) as supplementary cementitious material with reference to mechanical properties of hardened concretes and identify the optimal level of replacement.

MATERIALS

All the materials used during this experimental programme comply with standard specifications. Ordinary Portland Cement (OPC) of Grade53 was used. Its properties are given in Table 1. Graded river sand finer than 4.75 mm with specific gravity of 2.67, conforming to IS 383-1970 was used as fine aggregate. The coarse aggregate was locally available blue granite stone aggregates of size 12.5 mm with specific gravity of 2.60, conforming to IS 383-1970 was used. In this study potable water is used for both manufacturing and curing of concrete. The Bagasse Ash (BA) obtained as by-product of sugar industry is normally black in color. The ash should be further grinded to fine particles and allowed to pass through 75 micron sieve and its properties are given in Table 1. BA was obtained from Salem Co-operative Sugar Mill, Mohanur, Namakkal.

Mix Proportioning

The detailed mix proportions were carried out based on ACI method and are given in Table 2. Each auxiliary specimen was designated using alpha numerals. The notation CM refers to control mix without Bagasse Ash. Whereas the notation BA1, BA2, BA3 refers to the auxiliary specimen containing 10%, 20% and 30% of Bagasse Ash respectively

Design Aspects of Beam

The beams were designed to obtain a cross section of 100 mm x 200 mm and an effective span of 1500 mm by using procedure specified in IS 456:2000. A clear cover of 20 mm was adopted for all the beams.

Grade of concrete	M 30
Grade of steel	Fe 415
Specimen size	100x200x 2000 mm
Effective span	1500 mm
Loading method	Two point load
End condition	Simply supported

The notation CB refers to control beam and BB refers to Bagasse ash beam. Four numbers of 12 mm diameter bars were provided as main bar. Lateral ties of 8 mm diameter bars at spacing 125 mm centre to centre with nominal cover 20 mm was provided.

Casting and Curing

Auxiliary specimens like cubes and cylinders were casted and cured to study the mechanical properties of the mix. Cube specimens were used for studying compressive strength and durability, whereas cylindrical specimens used to study the split tensile strength and stress-strain behaviour. All the beam specimens were cast in steel moulds sufficiently stiffened with angles, so as to maintain the dimensions as 100 mm x 200 mm x 2000 mm. A sufficient mixing time was allowed to produce a uniform and homogenous concrete. The prepared mix was poured into the moulds as layers and compacted well. After 24 hours of casting, the form work was removed and the specimens were allowed to cure for 28 days by providing wet gunny bags. The beam specimens were used to study the flexural as well as shear behaviour.

Testing Procedure

A loading frame of 1000 kN capacity was used for testing the beam specimens. The locations of the supports, dial gauge points to measure deflections were marked. These beams were tested on a effective span of 1500mm with simply supported conditions under two point loading. Deflections were measured under the loading point and also at the mid span using Lin-

Table 1. Material Properties

Parameter	OPC	BA
Loose density (g/cc)	1.16	0.41
Compacted density (g/cc)	1.56	0.50
Specific gravity	3.1	1.87
Fineness passing 45 μm	80	94
Specific surface (m^2/Kg)	326	835
Mean grain size	27	4

Table 2. Mix Proportions of the Concrete

Mix	Cement kg/m^3	BA kg/m^3	FA kg/m^3	CA kg/m^3	Water L/m^3
CM	370	-	569	1190	185
BA1	333	37	551	1190	185
BA2	296	74	548	1190	185
BA3	259	111	546	1190	185

Table 3. Mechanical Properties of Concrete Mixes

Mix	BA (%)	Compressive Strength (MPa) 28 days	Splitting Tensile Strength (MPa) 28 days	Water Absorption (%) 24 hours	Modulus of Elasticity (MPa) 28 days
CM	-	35.08	4.70	4.32	39844
BA1	10	36.65	4.87	4.23	32664
BA2	20	39.67	5.54	4.10	35475
BA3	30	32.48	4.04	4.26	30661

Table 4. Flexure Test Results

Beam Designation	BA (%)	First Crack load (kN)	Ultimate Load (kN)	Deflection at Ultimate Load (mm)
CB	0	15	50	8.4
BB	20	20	55	8.9

Table 5. Displacement Ductility

Beam Designation	Ultimate Displacement Δ_u (mm)	First Yield Displacement Ductility Δ_y (mm)	Displacement Ductility $\mu_\Delta = \Delta_u / \Delta_y$
CB	8.4	3.2	2.54
BA	8.9	2.8	3.17

Table 6. Rotation Ductility

Beam Designation	Maximum Rotation θ_u (rad)	First Yield Rotation θ_y (rad)	Rotation Ductility $\mu_\theta = \theta_u / \theta_y$
CB	0.0112	0.0042	2.67
BA	0.01187	0.0039	3.04

Table 7. Curvature Ductility

Beam Designation	Maximum Curvature φ_u (rad/mm) x 10^{-6}	Curvature at First Yield φ_y (rad/mm)x10^{-6}	Curvature Ductility $\mu_\varphi = \varphi_u / \varphi_y$
CB	152.5	92.5	1.65
BA	175	89.75	1.94

ear Variable Differential Transducers (LVDTs). A typical two point loading experimental set up is shown in the Figure 1. The crack patterns were also recorded at every load increment. All the beams were tested up to failure. The pivot arrangement for measuring strain is given in the Figure 2.

RESULTS AND DISCUSSION

The results obtained from the experimental investigations are tabulated and comparisons are presented in the form of graphs. All the values are the average of three specimens tested in each case during the testing program of this study. The results are discussed as follows.

Mechanical Properties

Mechanical properties such as compressive strength, splitting tensile strength, water absorption and modulus of elasticity of the auxiliary specimens were tested at the same testing age of beams. The compressive loading test was carried out on 100 mm x 100 mm x 100 mm size cube as per IS: 516-1959. A 2000 kN capacity standard Compression Testing Machine (CTM) was used to conduct the test. The Universal Testing Machine (UTM) of 400 kN capacity was used for the application of the load in the splitting tensile strength test. Cylinder specimens of 100 mm x 200mm were cast to determine split tensile strength. Test was carried out according to IS 5816-1970 to obtain the split tensile strength for various concrete mixes. The water absorption capacity of the specimen in 24 hours was carried out as per ASTMC-642. Addition of mineral admixtures to normal concrete reduces the porosity of concrete thus resulting in decreased water absorption capacity. The UTM was used for the application of the compressive load, and the compressometer was used to record the longitudinal strain of concrete to evaluate the modulus of elasticity of concrete. The cylinder was placed with the compressometer fixed, on the plate of the compression testing machine. The results are given in Table 3.

Behaviour of Beam

From the test result tabulated in Table 3 it is understood that specimens with 20% of Bagasse Ash shows better result in all the mechanical properties. Thus the 20% of Bagasse Ash is taken as the optimal percentage for further testing in beam specimen denoted as Bagasse Ash beam (BB). And the results were compared with control beam (CB). The various behaviours of the beam specimen were discussed as follows.

Deflection Behaviour and Ultimate load

All the beams are subjected to gradually increase two point load. The behavior of the beam was studied by measuring deflection and observing crack pattern. The load versus deflection curves for the test specimens are shown in the Figure 3. The first crack load and ultimate load was observed for test specimens. The results were shown in Table 4.

Moment – Curvature

The linear portion of the moment curvature graph shows the moment carrying capacity of the beam under consideration. The bilinear portion shows the yielding of the beam under the load increments also known as the plastic stage. The transformation point of the curve from linear to bilinear is approximately the yielding moment of the beam. More the slope of the curve more is the moment carrying capacity of the beam. It can be observed in Figure 4 that the slope of the curve of CB is less in comparison with other companion specimen. It can also be interpreted that in Figure 4 BB has more stiffness and the highest moment carrying capacity and yields later than CB.

Ductility

It is the ability to sustain inelastic deformation without substantial decrease in the load carrying capacity. This can be defined with respect to strains, rotations, curvatures or deflections. Strain based ductility definition depends almost exclusively on the material; while rotation or curvature based ductility definition also includes the effects of shape and size of the cross section. The various ductility parameters were shown in Table 5, 6 and 7.

Displacement ductility, $\mu_\Delta = \Delta_u / \Delta_y$

where, Δ_y is the yield deformation corresponding to yielding of the reinforcement in a cross section and Δ_u is the ultimate deformation beyond which the load deformation curve has a negative slope.

Curvature ductility, $\mu_\varphi = \varphi u / \varphi y$

Where, φ_y is the curvature corresponding to a major deviation from the linear M-φ curve for a member and φu is the curvature beyond which the M-φ curve has a negative slope.

Rotation ductility, $\mu_\theta = \theta_u / \theta_y$

Where θ_y is the curvature corresponding to a major deviation from the linear M-θ curve for a member and θ_u is the curvature beyond which the M-θ curve has a negative slope.

CONCLUSION

Based on the experimental study conducted and the results presented herein, following conclusions can be drawn.

1. The specimens with 20% of Bagasse ash (BA2) gives the good results in mechanical properties such as compressive strength, splitting tensile strength, and modulus of elasticity when compared to other specimens.

2. It can be seen that the compressive strength and splitting tensile strength have improved nearly 1.13 and 1.18 times respectively for BA2 compared to CM and it is due to the high pozzolanic action between admixtures and concrete.

3. Partial replacement of cement with Bagasse ash is optimized at 20% in this study and flexural behaviour was studied for the optimized replacement percentage only by comparing with control mix.

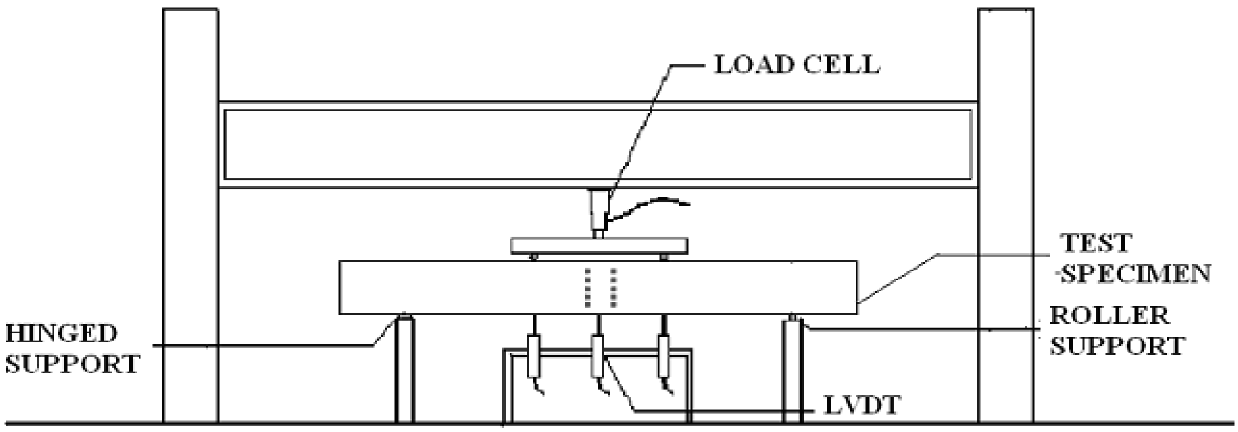

Fig. 1 Schematic Diagram of Test Setup for Beam Testing

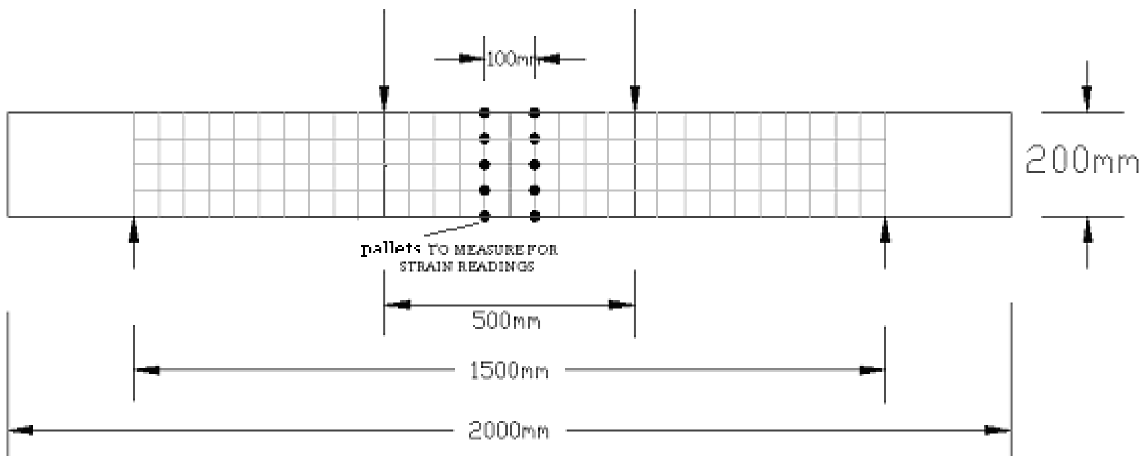

Fig. 2 Arrangement of Pivots

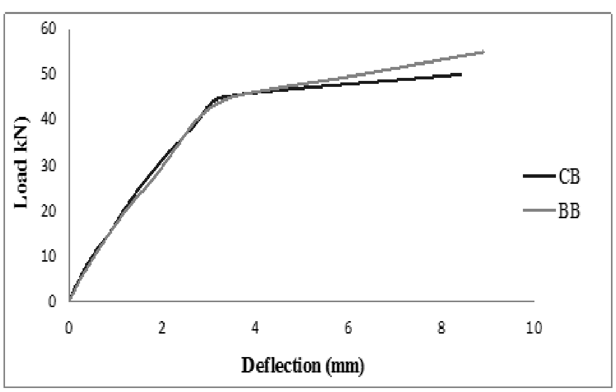

Fig. 3 Comparison of load-deflection curve of CB and BB

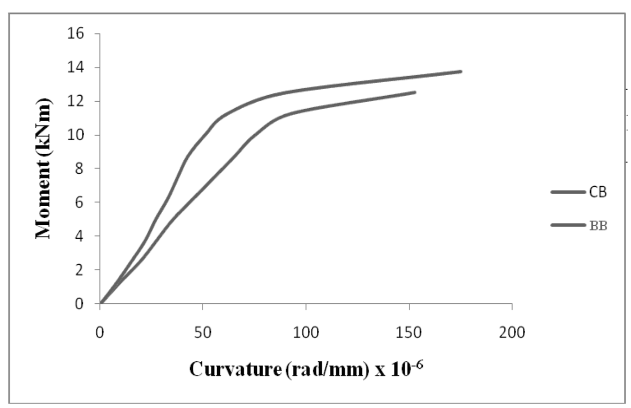

Fig. 4 Comparison of M-F curve of CB and BB

4. Addition of mineral admixtures to normal concrete reduces the porosity of concrete thus resulting in decreased water absorption capacity. BA2 shows minimum water absorption (%) than other specimens.

5. The ultimate load carrying capacity obtained experimentally is greater than the value obtained theoretically for flexure beams. The curvature is greater experimentally compared to that of theoretical values.

Due to this increase of curvature the deflection and the rotation also increased.

6. Bagasse ash beam undergoes more deformation than that of control beam of same area of steel which shows that Bagasse ash beams have better ductility.
7. In all the tests failure of the beams occurred by yielding of the steel in the tensile zone.

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