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Experimental Investigation on the Behaviour of Bagasse Ash Reinforced Concrete Structural Members

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Abstract: With the increasing demand and consumption of cement, researchers and scientist are in search of developing alternate binders that are ecofriendly and contribute towards waste management. The utilization of industrial and agricultural waste produced by industrial processes has been the focus on waste reduction. One of the agro wastes such as Sugarcane Bagasse Ash (SCBA) is a fibrous waste product obtained from sugar mills as byproduct. An experimental investigation has been carried out to study the behaviour of structural members using bagasse ash as partial replacement of cement by 10%, 20% and 30%.Test results indicated that the optimum dosage of 10% bagasse ash as a partial replacement of cement has higher load carrying capacity than 20% and 30% and also with nominal concrete. Thus the structural members were cast for the optimized percentage of bagasse ash. The performances of bagasse ash reinforced concrete structural members were compared with the reinforced concrete structural members based on the load-deflection, failure modes and axial -shortening.

Keywords: *Concrete, Bagasse ash, Compressive strength, Split tensile strength*

1. Introduction

Ordinary Portland cement is most extensively used as construction material throughout the world and it is most expensive of all other material. In addition there is environmental concern in the production of cement. It is responsible for about 5% to 8% of CO_2 emission. This environmental problem will most likely be increased due to exponential demand of Portland cement. Researchers focusing on ways of utilizing industrial and agricultural waste as a source of raw materials for cement (1). Industrial wastes, such as blast furnace slag, fly ash and silica fume are being used as supplementary cement replacement material. Currently, there has been an attempt to utilize the agricultural waste as a replacement material. One of the agro wastes such as Sugarcane Bagasse Ash (SCBA) is a fibrous matter that remains after sugarcane is crushed to extract their juice. SCBA is a by-product of sugar factories found after burning sugarcane bagasse which itself is found after the extraction of all economical sugar from sugarcane. It can be used as a building material in the construction industry (2). For each 10 tonnes of sugarcane crushed, a sugar factory produces nearly 3 tonnes of wet bagasse. Since bagasse is a by-product of the cane sugar industry, the quantity of production in each country is in line with the quantity of sugarcane produced. The SCBA having amorphous silica which has pozzolanic properties can be used as cement replacement material. A few studies have been carried out on the ashes obtained directly from the industries to study pozzolanic activity and their suitability as binders, partially replacing cement (3). Therefore it might be possible to use SCBA as cement replacement material to improve quality and reduce the cost of construction materials such as mortar, concrete pavers, concrete roof tiles and soil cement interlocking block etc. (4). India being one of the largest producers of sugarcane in the world produces 300 million tons per year and large quantity of sugarcane bagasse is available from sugar mills. Sugarcane bagasse is partly used as fuel at the sugar mill (5). An investigation is made to evaluate bagasse ash as supplementary cementitious material with reference to mechanical properties of hardened concrete and identify the optimal level of replacement. The significance of this study focuses on the reuse of agricultural wastes such as bagasse ash as a sustainable construction material. The density of concrete decreases with increase in bagasse ash content. Thus the usage of bagasse ash plays a significant role in producing light weight concrete structural members.

2. Experimental Work

2.1 Materials

All the materials used during this experimental programme comply with standard specifications. Ordinary Portland Cement (OPC) of Grade53 was used. 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 of size 12mm with specific gravity of 2.60, conforming to IS 383-1970 was used. The bagasse ash obtained as by-product of sugar industry is normally black in color. The sugarcane bagasse consists of approximately 50% of cellulose, 25% of hemicelluloses and 25% of lignin. Each ton of sugarcane generates approximately 26%

of bagasse (at a moisture content of 50%) and 0.62% of residual ash. The residue after combustion presents a chemical composition dominates by silicon dioxide (SiO2) (6). For this experimental work, the bagasse ash was obtained from Dharani sugar mills, Sangarankoil, Tamil Nadu.

2.2 Study on Mechanical and Durability properties

Specimens like cubes and cylinders were cast for concrete grade of M40 and cured to study the mechanical properties using compressive strength test and split tensile strength test as shown in figure 1 and figure 2. The durability properties of the concrete are studied using rapid chloride penetration test as shown in figure 3. The compressive, split tensile strength and chloride penetration of the concrete mixes are obtained after 28 days of curing. Rapid chloride penetration test is done as per ASTM C 1202. (7). In this test, the specimen is subjected to a 60 V applied DC voltage for 6 hours. The cell consists of two chambers consisting of 3 % NaCl solution and 0.3 M of NaOH solution respectively. The interpretation of the test results indicates that larger the coulomb number, greater the permeability of the sample.

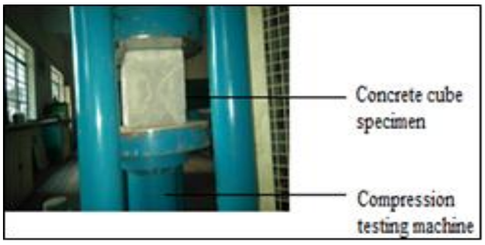

Figure 1 *Test setup to determine compressive strength*

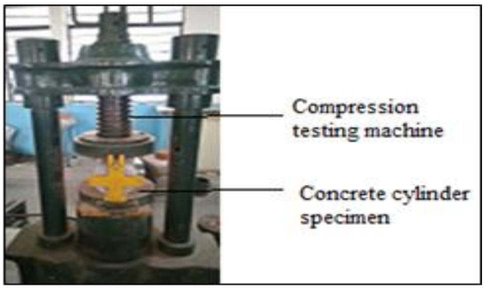

Figure 2 *Test setup to determine splitting tensile strength*

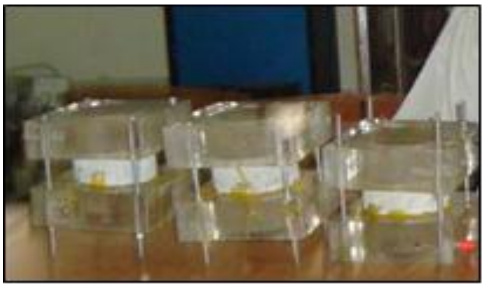

Figure 3 *Test setup to determine rapid chloride penetration*

2.3 Casting and Testing of Specimens

Based on the mechanical and durability properties, the optimum dosage of bagasse ash was chosen to cast reinforced concrete members. The specimen details are given in table 1. The beams are to be tested with simply supported conditions under two point loading as shown in figure 4 to measure the deflection at the mid span using linear variable differential transducers. The columns are to be tested under axial loading as shown in figure 5 to measure the axial shortening and to observe the failure modes of the columns.

Table 1: *Specimen details*

Specimen	Size (mm)	Ast (mm^2)
CB 1	150x150x1000	2 Nos of 12Ø as Ast and 2 Nos of 10Ø as Asc and 8Ø as stirupps
CB 2	150x150x1000	
BB 1	150x150x1000	
BB 2	150x150x1000	
CC 1	150x150x700	4 Nos of 10Ø and 8Ø as lateral ties
CC 2	150x150x700	
BC 1	150x150x700	
BC 2	150x150x700	

Fc_k = 40 MPa
f_y = 415
CB 1 – Control beam without bagasse ash.
CB 2 – Control beam without bagasse ash.
BB 1 – Bagasse ash beam .
BB 2 – Bagasse ash beam.
CC 1 – Contol column without bagass ash.
CC 2 – Control column without bagasse ash.
BC 1 – Bagasse ash column.
BC 2 – Bagasse ash column.

Figure 4 *Test setup for beam*

Figure 5 *Test setup for column*

3. Results and Discussions

3.1 Mechanical and durability properties

The results obtained from the experimental investigation are tabulated. All the values are the average of two specimens tested in each case during the testing program of this study. Mechanical properties such as compressive strength, splitting tensile strength results are shown in table 2. From the test result tabulated in table 1, it is understood that specimens with 10% of bagasse ash have been improved 1.21 and 1.04 times for compressive strength and splitting tensile strength respectively. The 20% and 30% replacement of SCBA shows reduction in mechanical properties with brittle failure. Durability test results are shown in table 3. From the test results obtained it is inferred that the durability property has been improved 0.74 times than the control specimens. Thus the 10% of bagasse ash is taken as the optimal percentage for further casting of structural members and the results were compared with control specimens.

Table 2: *Mechanical properties of concrete mixes*

Mix	Bagasse ash (%)	Compressive strength (MPa)	Split tensile strength (MPa)
CM	0	51	3.05
BA1	10	62	3.19
BA2	20	48	3.12
BA3	30	43	2.98

Table 3: *Durability property of the concrete mixes*

Mix	Bagasse Ash (%)	Charge passed (coulombs)	Chloride penetration as per ASTM C 1202
CM	0	5200	High
BA1	10	3865	Moderate
BA2	20	4143	High
BA3	30	4765	High

3.2 Failure Modes

The beam specimens were subjected to two point loading. The first crack appeared for CB1and BB2 at a distance of 335mm and 378mm with corresponding load of 27kN and 29kN respectively from the support B. The load was applied until the failure of specimen occurred at the ultimate load of 80kN and 86kN with a maximum deflection of 0.389mm and 0.328mm for CB1 and BB2 respectively which is shown in figure 6. The ultimate load carrying capacity and their corresponding deflection are shown in table4. The columns were tested under uniaxial compression. The first crack for CC1 and BC1 appeared at the column head at a load of 183kN and 204kN respectively. With further application of axial load CC1 and BC1 failed at a load of 409kN and 449kN with a maximum axial shortening of 0.427mm and 0.39mm respectively which are shown in figure 9.

Table 4: *Results of reinforced concrete beams and bagasse ash beams*

Mix	Bagasse Ash (%)	Ultimate load (kN)	Deflection (mm)
CB 1	0	80	0.389
CB 2	0	78	0.378
BB 1	10	83	0.328
BB2	10	86	0.34

Table 5*: Results of reinforced concrete columns and bagasse ash columns*

Mix	Bagasse Ash (%)	Axial load (kN)	Axial Shortening (mm)
CC 1	0	409	0.427
CC 2	0	405	0.421
BC 1	10	449	0.39
BC 2	10	443	0.384

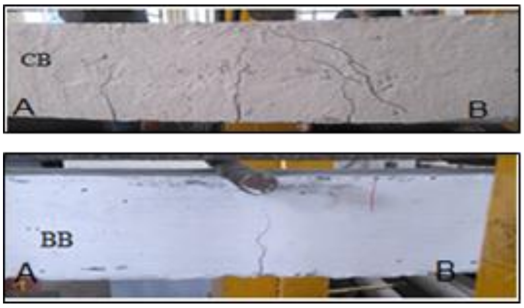

Figure 6 *Crack patterns observed in CB1 and BB2*

CC1 BC1

Figure 7 *Crack patterns observed in CC1 and BC1*

3.3 Behaviour of Structural Members

The load deflection curve shown in figure 8 revealed that the graph plotted for all the beam specimens has similar pattern in which CB1 and BB2 shows better structural performance Therefore the average values were taken and a separate graph is plotted for CB1 and BB2 as shown in figure 9 revealed that BB2 has ultimate load carrying capacity 1.075 times greater than CB1 and the deflection 0.87 times lesser than that of CB1 of same area of steel which shows that bagasse ash reinforced beams have better load carrying capacity. The load versus axial shortening curve shown in figure 10 revealed that all the columns have similar pattern of curves in which CC1 and CB1 shows better structural performance. Therefore the average values were taken and a separate graph is plotted for CC1 and CB1as shown in figure 11 revealed that BC1 have load carrying capacity 1.097 times greater than CC1 and axial shortening 0.91 times lesser than CC1 which shows that bagasse ash columns have better structural performance than the conventional reinforced concrete columns.

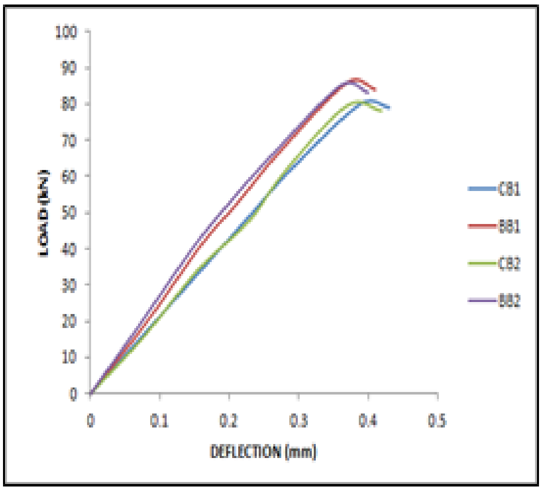

Figure 8 *Load -deflection curve for beams*

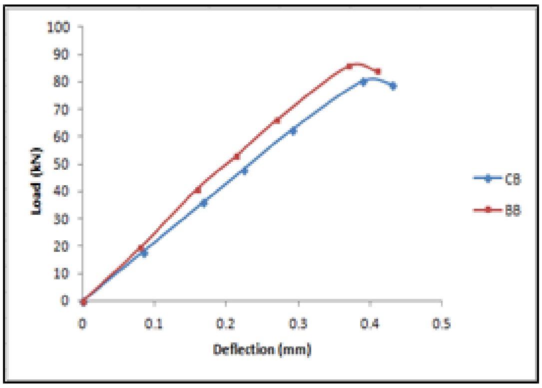

Figure 9 *Load deflection curve for CB1 and BB2*

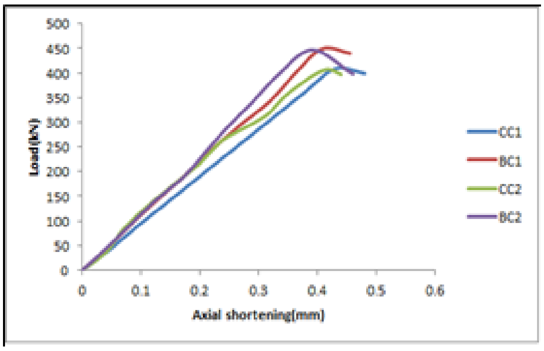

Figure 10 *Load –axial shortening curve for columns*

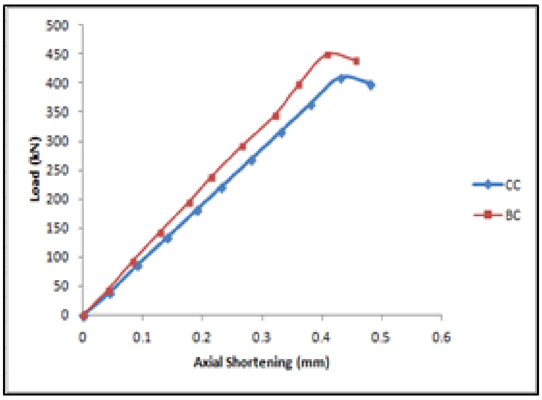

Figure 11 *Load - axial shortening curve for CC1 and BC1*

4. Conclusions

Based on the experimental study carried out, the following conclusions were drawn.

The specimen with 10% of bagasse ash shows good results in mechanical properties such as compressive strength and splitting tensile strength when compared to other specimens. It can be seen that the compressive strength and splitting tensile strength have improved 1.21 and 1.04 times respectively for BA1 compared to CM and it is due to the high pozzolanic action in bagasse ash concrete. With the 10% addition of bagasse ash, the concrete shows less permeability to chloride ions and thus it improves the durability of the concrete members. With the addition of bagasse ash, the ultimate load carrying capacity of the beam has improved 1.075 times the control beam.

The maximum axial load obtained for bagasse ash column has improved 1.097 times the control column. These results indicated that the load carrying capacity of bagasse ash reinforced concrete members are higher than the conventional reinforced concrete members. From this study it is inferred that the bagasse ash can be used as a sustainable construction material.

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