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Geo-Ref Information Services-USA, List B of Scientific
Journals, Poland, Directory of Research Journals

International Journal of Earth Sciences and Engineering

www.cafetinnova.org

ISSN 0974-5904, Volume 09, No. 03

June 2016, P.P.426-431

Experimental Studies on the Effect of Bagasse Ash and M-Sand on Mechanical Behaviour of Concrete

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Abstract: Concrete is the most commonly used construction material. Its usage by the communities across the globe is second to water. Cement is the main constituent of concrete which is used as the binder in concrete. Every tonne of cement produced emits same amount of CO2.Also, depletion of river sand which is used as fine aggregate in concrete is at its peak. Hence there is a need for alternative cement and sand. The past researches either deals with either partial replacement of cement with sugar cane bagasse ash or replacement of fine aggregate with M sand in concrete separately, but the current paper covers the mechanical properties of concrete mixes prepared by the combination of partial replacement of cement with sugar cane bagasse ash and complete replacement of river sand with M sand in the same mix. Increase in mechanical properties was observed with the partial replacement of OPC with sugar cane baggase ash and complete replacement of river sand with M sand. Thus it is highly efficient and sustainable to replace cement and sand with sugar cane baggase ash and manufactured sand respectively.

Keywords: *Baggase ash, M- sand, compressive strength, flexural strength, elastic modulus*

1. Introduction

In recent years, the research related to agricultural wastes is intensifying with the aim of evaluating their potential for recycling as well as the elimination of the landfills [1]. On the other hand Concrete is the most commonly used construction material, its usage by the communities across the globe is second to water [2]. Cement (used as binder in concrete) production involves significant CO_2 emissions, which is known as the green- house gas mostly important for the global warming. Each tonne of cement produces approximately one tonne of CO_2 and the cement industry is responsible for about 5% of global anthropogenic CO_2 emissions [3]. Also in some regions, river sand (used as filler in concrete) has been excessively exploited, which has endangered the stability of river banks and the safety of bridges, and creates environmental problems [4].

Hence, there is an urgent need for an alternative cement and sand. Bagasse ash, a combustion byproduct of sugar cane bagasse in sugar mill industries, has been accepted as a pozzolanic material to partially replace Portland cement in concrete [5] and it was identified that the alternative materials for river sand include manufactured sand (M-sand) [6]. Manufactured sands are produced by crushing rock depositions to produce a fine aggregate which is generally more angular and has rougher surface texture than naturally weather sand particles [7]. Thus it is highly efficient and sustainable to replace cement and sand with sugar cane baggase ash and manufactured sand respectively.

2. Past Research

G.C. Cordeiro et al., [8] has used sugar cane baggase ash as partial replacement to cement to find its characteristics in concrete and has reported positive results in terms of rheological and mechanical properties. Guilherme Chagas Cordeiro et al [9] have reported improved rheological properties and resistance to penetration of chloride ions when cement was partially replaced with bagasse ashin mortars and concrete.

Yogesh Aggarwal et al.,[10] have used foundry sand as fine aggregate and has reported no change in strength properties of concrete. D.D. Cortes et al [11] have adopted M sand to replace fine aggregate in mortar and reported increase in rheology and compressive strength.

The past researches either deals with either partial replacement of cement with sugar cane bagasse ash or replacement of fine aggregate with M sand in concrete separately, but the current paper covers the mechanical properties of concrete mixes prepared by the combination of partial replacement of cement with sugar cane bagasse ash and complete replacement of river sand with M sand in the same mix.

3. Experimental Investigation

3.1 Cement

Ordinary Portland cement of 53 grade obtained from Ultratech Ltd and conforming to IS 12269-1987 was as the binder. The physical properties are given in Table 1.

***Table 1** Physical Properties of Cement*

Sl. No.	Properties	Test Value
1	Specific gravity	3.15
2	Normal Consistency	29.33%
3	Initial Setting time	30 Min
4	Final Setting time	443 Min

3.2 Sugar Cane Bagasse Ash

The sugar cane bagasse ash (SCBA) obtained from the Chengalpattu Sugar factory was used as the replacement of cement in binder. Table 2 shows the physical properties of SCBA.

***Table 2** Physical Properties of SCBA*

Sl. No.	Properties	Test Value
1	Specific gravity	2.74
2	Colour	Black
3	Density (gm/cm³)	1.2
4	Moisture Content	3.50%

3.3 Micro Silica Fume

Silica fume obtained from industries as a by-product of Silicon or Ferro-Silicon alloy and conforming to IS 15388:2003 was used as the replacement of cement in binder. Its physical properties are indicated in Table 3.

***Table 3** Physical Properties of Micro silica fume*

Sl. No	Type of test conducted	Results obtained
1	Physical state	Micronized powder
2	Appearance	White color powder
3	Odor	Odorless
4	Density	0.76 g/cc
5	PH value	6.90
6	Specific gravity	2.20
7	Moisture	0.058%

3.4 Ground Granulated Blast Furnace Slag (GGBS)

Ground granulated blast furnace slag (GGBS) obtained from the local industries conforming to IS 12089:1987 was used as the replacement of cement in binder. The physical properties of GGBS are given in Table 4.

***Table 4** Physical Properties of GGBS*

Sl. No	Type of test conducted	Results obtained
1	Physical state	Micronized powder
2	Appearance	Ash White color powder
3	Odor	Odorless
6	Specific gravity	2.92
7	Moisture	0.25%

3.5 Fine and Course Aggregate

River sand and crushed granite stone of maximum size is 12.5mm was used as fine aggregate and course aggregate respectively. Their physical properties given in Table 5 and 6 are conforming to IS 2386(Part I) 1963.

***Table 5** Physical Properties of Fine Aggregate*

Sl. No	Properties	Test Value
1	Specific gravity	2.61
2	Water absorptions (%)	1.14
3	Sieve Analysis	Zone II

***Table 6** Physical Properties of Course Aggregate*

Sl. No	Properties	Test Value
1	Shape	Angular
2	Specific gravity	2.74
3	Water absorptions (%)	0.58%
4	Flakiness Index	14.3
5	Elongation Index	18.6

3.6 Manufacturing Sand

Manufacturing sand or M sand obtained from Ultratech Ltd was used as the replacement of river sand in the filler material. The physical properties of M sand are given in Table 7.

***Table 7** Physical properties of M-Sand*

Sl. No	Properties	Test Value
1	Specific gravity	2.71
2	Water absorptions (%)	2.36
3	Sieve Analysis	Zone II

3.7 Admixtures (Super Plasticizers)

High Range Water Reducer (HRWR) and retarding admixtures conforming to IS 9103:1999 was used as Chemical admixtures and super plasticizers to reduce the amount of water by 10% to 15% while maintaining a certain level of consistency and to increase workability for reduction in w/c ratio. The properties of the superplasticizer used are given in Table 8.

***Table 8** Properties of Admixture*

Sl. No	Properties	Test Value
1	Aspect	Light brown liquid
2	Relative Density	1.08

3.8 Water

Fresh portable water with pH value less than 7 and free from organic matter was used.

3.9 Mix Design

Based on the trial mixes the final design mix was prepared for M60 grade of concrete as **1:1.9:2.5** with water cement ratio 0.35 as per IS 10262:2009[13]. The concrete mix proportions are shown in Table 9.

***Table 9** Mix propertions*

Identification Mark	Wt of Cement (Kg/m^3)	Wt of Bagasse Ash (Kg/m^3)	Wt of GGBS (Kg)	Wt of River Sand (Kg)	Wt of M-Sand (Kg)	Wt of Agg 12.5mm (Kg)	Wt of Water (Kg)	Wt of Admixture (Kg)	Slump in (mm)
A-0 (River sand)	25.701	0	1.52	1.52	0	1070.069	8.498	0.147	60
B-0 (M Sand)	25.701	0	1.52	1.52	55.548	1070.069	8.498	0.147	55
A-1 (SCBA 10%)	23.131	2.57	1.52	1.52	0	1070.069	8.498	0.147	50
B-1 (SCBA 10%)	23.131	2.57	1.52	1.52	55.548	1070.069	8.498	0.147	50
A-2 (SCBA 20%)	20.561	5.14	1.52	1.52	0	1070.069	8.498	0.147	50
B-2 (SCBA 20%)	20.561	5.14	1.52	1.52	55.548	1070.069	8.498	0.147	45
A-3 (SCBA 30%)	17.991	7.71	1.52	1.52	0	1070.069	8.498	0.147	45
B-3 (SCBA 30%)	17.991	7.71	1.52	1.52	55.548	1070.069	8.498	0.147	45
A-4 (SCBA 40%)	15.421	10.281	1.52	1.52	0	1070.069	8.498	0.147	45
B-4 (SCBA 40%)	15.421	10.281	1.52	1.52	55.548	1070.069	8.498	0.147	50

4. Test for Mechanical Strength

4.1 Compressive Strength

The compressive strength test was performed on cubes in a compression testing machine (CTM) of 200 tones capacity (Fig 1) at the age of 7 and 28 days respectively. The reported strengths are the average of three test specimens.

***Fig 1** Compressive strength set up*

4.2 Flexural Strength

The flexural strength of PFRC was found out by subjecting the simply supported prism to two-point loading on a CTM of 200 tones capacity at the age of 7 and 28 days. The reported strengths are the average of three test specimens.

***Fig 2** Flexural strength set up*

4.3 Split Tensile Strength

The split tensile test on cylinders was also carried out at the age of 7 and 28 days by placing the cylinders horizontally on a CTM of 200 tones capacity. The reported strengths are the average of three test specimens. The test set up is shown in figure 3.

Fig 3 *Split tensile strength*

4.4 Modulus of Elasticity

Modulus of elasticity of control and RFRC cylinders were determined at the age of 28th day placing the cylinders vertically in Universal Testing Machine (UTM) with the help of strain gauge. The test set up is shown in figure 4.

Fig 4 *Elastic modulus test set up*

5. Results and Discussion

5.1 Compressive Strength

The compressive strength of high strength concrete with bagasse ash as replacement of OPC with river sand and M sand as fillers at the 7 days and 28 Days is shown in table10 and figure.

Table 10 *Compressive Strength results*

Sample ID	Descriptions	Compressive Strength at the age of (N/mm²)	
		7th day	28th day
A0	0% SCBA With River Sand	51.133	70.067
A1	10% SCBA With River Sand	58.378	78.178
A2	20% SCBA With River Sand	45.022	52.622
A3	30% SCBA With River Sand	41.267	49.667
A4	40% SCBA With River Sand	36.533	40.111
B0	0% SCBA With M- Sand	40.622	62.778
B1	10% SCBA With M- Sand	42.222	70.222
B2	20% SCBA With M- Sand	35.489	58.778
B3	30% SCBA With M- Sand	35.267	53.222
B4	40% SCBA With M- Sand	33.333	42.444

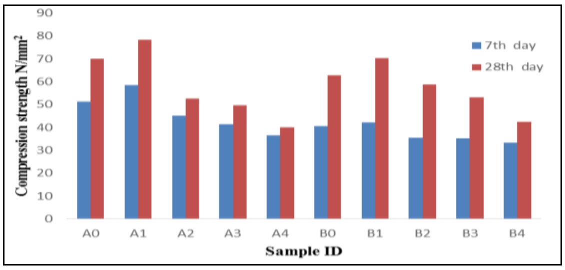

Fig 5 *Compressive strength results*

It is observed from table 10 and figure 5 that with the replacement of OPC with 10% SCBA 12.41%, 3.79% and 10.38%, 10.61% increase in compressive strength was noticed at the age of 7 days and 28 days when river sand and M sand was used as fillers respectively, also decrease of compressive strength by 11.95%,19.29%,28.55% and 12.64%,13.18%,17.94% for 7th day and 24.89%,29.11%,42.75% and 6.37%,15.22%,32.39% for 28th day was noted with replacement of OPC with 20%,30%, 40% SCBA when river sand and M sand was used as fillers respectively. The results are in good agreement with Nuntachai Chuslip[12] and Raffat Siddique[13].

5.2 Flexural Strength

It is clearly evident from Table 11 and figure 6 that with the replacement of OPC with 10% SCBA 5.26%,6.16% and 2.71%,6.67 % increase in flexural strength was noticed at the age of 7 days and 28 days when river sand and M sand was used as fillers respectively, also decrease of compressive strength by 11.11%, 14.81%, 20.74% and 9.78%, 15.76%, 22.46% for 7th day and 18.1%, 31%, 33.97% and 18.7%, 23.66%, 30.27% for 28th day was noted with replacement of OPC with 20%, 30%, 40% SCBA when river sand and M sand was used as fillers respectively. Flexural strength of concrete follows the same pattern as that of compressive strength.

Table 11 *Flexural strength results*

Sample ID	Descriptions	Flexural Strength at the age of (N/mm²)	
		14th day	28th day
A0	0% SCBA With River Sand	5.4	6.74
A1	10% SCBA With River Sand	5.7	6.928
A2	20% SCBA With River Sand	4.8	5.52
A3	30% SCBA With River Sand	4.6	4.65
A4	40% SCBA With River Sand	4.28	4.45
B0	0% SCBA With M- Sand	5.18	6.328

B1	10% SCBA With M- Sand	5.52	6.78
B2	20% SCBA With M- Sand	4.98	5.512
B3	30% SCBA With M- Sand	4.65	5.176
B4	40% SCBA With M- Sand	4.28	4.728

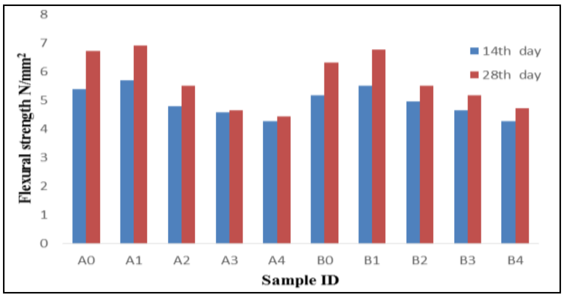

***Fig 6** Flexural strength results*

5.3 Split Tensile Strength

It is clearly observed from Table 12 and figure 7 that the increase in SCBA as replacement to OPC, decreases the split tensile strength of conventional concrete with the use of both the type of fillers i.e., river sand and M sand. Decrease in split tensile strength of 33.3%, 36.07%, 44.06%, 53.89% and 43.25%, 45.54%, 52.41%, 56.07% at the age of 7 days and 10.13%, 23.76%, 37.97%, 45.79% and 9.22%, 12.05%, 37.59%, 55.67% at the age of 28days was observed when partial replacement of OPC with 10%, 20%, 30%, 40% sugar cane bagasse ash while river sand and M sand was used respectively.

***Table 12** Split tensile strength results*

Sample ID	Descriptions	Split Tensile Strength at the age of (N/mm²)	
		7^{th} day	28^{th} day
A0	0% SCBA With River Sand	7.771	10.987
A1	10% SCBA With River Sand	5.414	9.873
A2	20% SCBA With River Sand	4.968	8.376
A3	30% SCBA With River Sand	4.347	6.815
A4	40% SCBA With River Sand	3.583	5.955
B0	0% SCBA With M- Sand	6.959	8.981
B1	10% SCBA With M- Sand	3.949	8.153
B2	20% SCBA With M- Sand	3.79	7.898
B3	30% SCBA With M- Sand	3.312	5.605
B4	40% SCBA With M- Sand	3.057	3.981

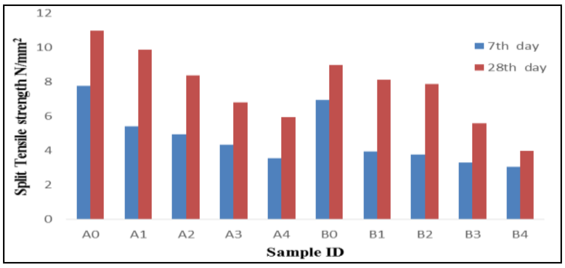

***Fig 7** Split tensile strength results*

5.4 Modulus of Elasticity

It is clearly evident from table 13 and figure 8,9 that the elasticity of concrete is more in A1 and B2 i.e., when river sand and M sand was used as fine aggregate, upto 10% and 20% replacement of OPC with SCBA respectively makes the concrete more elastic.

***Table 13** Modulus of elasticity results*

Sample ID	Descriptions	Elastic Modulus at the age of ($\times 10^4$ N/mm²)
		28^{th} day
A0	0% SCBA With River Sand	2.36
A1	10% SCBA With River Sand	2.48
A2	20% SCBA With River Sand	2.42
A3	30% SCBA With River Sand	2.23
A4	40% SCBA With River Sand	1.97
B0	0% SCBA With M- Sand	1.59
B1	10% SCBA With M- Sand	2.23
B2	20% SCBA With M- Sand	2.48
B3	30% SCBA With M- Sand	1.72
B4	40% SCBA With M- Sand	2.1

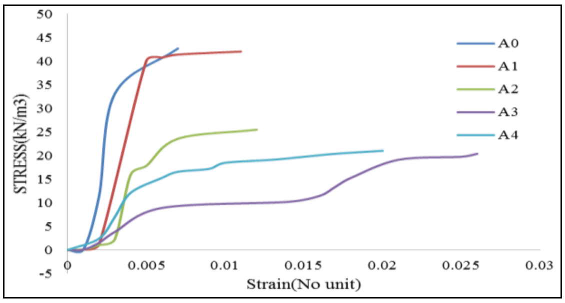

***Fig 8** Modulus of elasticity results of concrete with river sand*

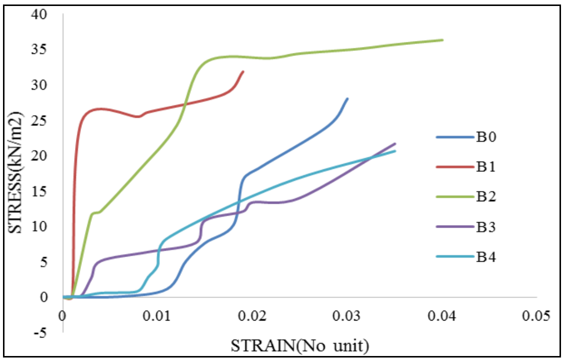

***Fig 9** Modulus of elasticity results of concrete with M sand*

6. Conclusion

1) Partial replacement of OPC with sugar cane baggase ash and complete replacement of river sand with M sand enhances the mechanical properties of concrete.
2) Increase in compressive strength of 12.41%, 3.79% and 10.38%, 10.61% was noticed at the age of 7 days and 28 days when river sand and M sand was used as fillers respectively, when OPC was replaced with 10% SCBA, also decrease of compressive strength by 11.95%,19.29%,28.55% and 12.64%,13.18%,17.94% for 7th day and 24.89%,29.11%,42.75% and 6.37%,15.22%,32.39% for 28th day was noted with replacement of OPC with 20%,30%, 40% SCBA when river sand and M sand was used as fillers respectively.
3) The replacement of OPC with 10% SCBA 5.26%,6.16% and 2.71%,6.67 % increase in flexural strength was noticed at the age of 7 days and 28 days when river sand and M sand was used as fillers respectively, also decrease of compressive strength by 11.11%,14.81%,20.74% and 9.78%,15.76%,22.46% for 7th day and 18.1%,31%,33.97% and 18.7%,23.66%,30.27% for 28th day was noted with replacement of OPC with 20%,30%, 40% SCBA when river sand and M sand was used as fillers respectively.
4) The increase in SCBA as replacement to OPC, decreases the split tensile strength of conventional concrete with the use of both the type of fillers i.e., river sand and M sand. Decrease in split tensile strength of 33.3%, 36.07%, 44.06%, 53.89% and 43.25%, 45.54%, 52.41%, 56.07% at the age of 7 days
5) and 10.13%, 23.76%, 37.97%, 45.79% and 9.22%, 12.05%, 37.59%, 55.67% at the age of 28days was observed when partial replacement of OPC with 10%,20%,30%,40% sugar cane bagasse ash while river sand and M sand was used respectively.
6) The elasticity of concrete is more when river sand and M sand was used as fine aggregate, upto 10% and 20% replacement of OPC with SCBA respectively makes the concrete more elastic.
7) Thus it is highly efficient and sustainable to replace cement and sand with sugar cane baggase ash and manufactured sand respectively.

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