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A study on the Mechanical Properties of Concrete with partial replacement of Fine aggregate with Sugarcane bagasse ash

T. SHAFANA, R.VENKATASUBRAMANI
Department of Civil Engineering, Sri Krishna College of Technology, Coimbatore, Tamil Nadu, India
Email: sana.drew28@gmail.com

Abstract: The construction industry is the largest consumer of natural resources which led to depletion of good quality natural sand (fine aggregate). This situation compels us to explore alternative materials and sugarcane bagasse ash, a waste industrial byproduct is one such material identified for use as a replacement of natural sand. Sugarcane bagasse ash (SCBA) generated from sugar mills is fibrous waste-product usually delivered to landfills for disposal. Using of sugarcane bagasse ash in concrete is an interesting possibility for economy and conservation of natural resources. This research work examines the possibility of using sugarcane bagasse ash as replacement of fine aggregate in concrete. We partially replaced 10%, 15%, 20%, 25% and 30% of natural sand with SCBA. We compared compressive strength, tensile strength and flexural strength with those of concrete made with natural fine aggregate. We also studied chemical properties of SCBA. The test results indicate that it is possible to manufacture concrete containing sugarcane bagasse ash with characteristics similar to those of natural river sand aggregate concrete, provided that the percentage of sugarcane bagasse ash as fine aggregate is limited to 10 percent.

Keywords: *Sugarcane bagasse ash, fine aggregate replacement*

Introduction:

The Conventional concrete is a mixture of cement, natural sand and coarse aggregate. Properties of aggregate affect the durability and performance of concrete and the fine aggregate is an essential component of concrete. The most commonly used fine aggregate is natural river or pit sand. Fine and coarse aggregate constitute about 75% of total volume. It is therefore, important to obtain right type and good quality aggregate at site.

The demand of natural sand is quite high in the developing countries due to the rapid infrastructural growth. In this situation developing country like India is facing shortage of good quality natural sand. In India natural sand deposits are being depleted and causing serious threat to environment as well as the society. Increasing extraction of natural sand from river beds causes many problems such as loosing water retaining sand strata, deepening of the river courses and causing bank slides, loss of vegetation on the bank of rivers, exposing the intake well of water supply schemes, disturbance to the aquatic life and affecting agriculture due to lowering of underground water table. In the past decade variable cost of natural sand used as fine aggregate in concrete has increased the cost of construction many folds. In this situation research began for inexpensive and easily available alternative material to natural sand.

Some alternative materials have already been used as a part of natural sand. Flyash, slag, limestone and siliceous stone powder were used in concrete mixtures as a partial replacement of natural sand. However, scarcity in required quality is the major limitation in some of the above materials. Now a day's sustainable infrastructural growth demands the alternative material that should satisfy technical requisites of fine aggregate and at the same time it should be available abundantly.

I. Sugarcane Bagasse Ash:

A. Sugarcane bagasse ash in India

Sugarcane is one of the major crops grown in over 110 countries and its total production is over 1500 million tons. In India sugarcane production is over 300 million tons/year that cause around 10 million tons of sugarcane bagasse ash as an un-utilized and waste material. After the extraction of all economical sugar from sugarcane, about 40-45 percent fibrous residue is obtained, which is reused in the same industry as fuel in boilers for heat or power generation leaving behind 8 -10 percent ash as waste, known as sugarcane bagasse ash (SCBA).

B. Advantages of using sugarcane bagasse ash

Land pollution: Primarily the ash disposal problem from sugar industry is reduced since it is usually disposed off in open land area.

Economy: Due to the non-availability of fine aggregate, the price of natural sand which is used as fine aggregate has increased by three folds in the past few months. Hence the overall cost involved in the construction is reduced.

Future demand: Partial replacement will also help in meeting the increasing demand for fine aggregate in future.

II. Materials Used:

C. Cement

Portland-Pozzolana cement of grade 53 was used for casting all the specimens confirming to IS 1489 (Part 1): 1991. Portland-pozzolana cement can be produced either by grinding together Portland cement clinker and pozzolana with addition of gypsum or calcium sulphate, or by intimately and uniformly blending Portland cement and fine pozzolana. Portland-pozzolana cement produces less heat of hydration and offers greater resistance to the attack of aggressive waters than normal Portland cement. Moreover, it reduces the leaching of calcium hydroxide liberated during setting and hydration of cement. Specific gravity and fineness modulus of the cement is 3.15 and 7.5 respectively.

D. Fine aggregate

Clean and dry river sand available locally was used. Sand passing through IS 4.75 mm sieve was used for casting all the specimens. Specific gravity and fineness modulus are 2.64 and 2.79 respectively.

E. Coarse aggregate

Coarse aggregate passing through 20 mm sieve and retained on 12.5 mm sieve as given in IS 383 – 1970 was used for all the specimens. In addition to cement paste- aggregate ratio, aggregate type has a great influence on concrete dimensional stability. Specific gravity and fineness modulus are 2.60 and 5.96 respectively.

F. Sugarcane bagasse ash

Sugarcane bagasse ash was collected from M/s Kothari Sugars and Chemical (P) Ltd., Kattur, Tiruchirappalli District of Tamil Nadu. The chemical and physical properties of the random ash samples were analysed.

Table I - Mix Design

Cement	Fine aggregate	Coarse aggregate	Water
1	1.42	2.5	0.45

Table II - Mix Proportion Details

Mix	Cement kg/m^3	CA kg/m^3	FA kg/m^3	SCBA % of FA	W/C ratio
Control	445.6	1110	634	0	0.43
10BA	445.6	1110	570.6	10	0.43
15BA	445.6	1110	538.9	15	0.43
20BA	445.6	1110	507.2	20	0.44
25BA	445.6	1110	475.5	25	0.44
30BA	445.6	1110	443.8	30	0.45

SCBA = sugarcane bagasse ash, W/C ratio= water/cement ratio, CA = coarse aggregate, FA = fine aggregate; m = meter, kg = kilogram.

G. Water

In this project, casting and curing of specimens were done using potable water free from deleterious materials. Water plays an important role in concrete production (mix). It starts the reaction between the cement and aggregates. It helps in hydration of the mix.

III. Mix Design:

Mix design is the process of selecting suitable ingredients of the concrete and determining their relative proportion with object of producing concrete possessing certain minimum desirable properties like workability in fresh state, minimum desirable strength and durability in hardened state. Using the properties of materials the mix design has been adopted from IS 10262: 2009 to design for M30 grade of concrete as given in Table I and Table II.

IV. Method of Experiment:

It is important that the constituent materials of concrete remain uniformly distributed within the concrete mass during the various stages of handling and full compaction is achieved, and making sure that the characteristics of concrete which affect full compaction like consistency, mobility and compatibility are in conformity with relevant codes of practice.

The tests were carried out in accordance with relevant IS Standards. The aggregates were tested for physical properties such as specific gravity and particle distribution test. The fresh concrete was subjected to slump test followed by casting of concrete in moulds for further investigation. For carrying out the strength investigations a total 36 numbers of concrete cubes, prisms and cylindrical specimens were cast. Based upon the quantities of ingredient of the mixes, quantities of sugarcane bagasse ash for 0, 10, 15, 20, 25 and 30 percent replacement by volume of sand were estimated. The water cement ratios used were 0.43, 0.44 and 0.45. The cast concrete specimens were cured under standard condition in the laboratory and compressive strength test, flexural strength test and split tensile test were done in the hardened state of the concrete after 7 days and 28 days.

V. Results and Discussion

A. *Properties of sugarcane bagasse ash and natural sand*

We investigated the following physical and chemical properties of SCBA and natural sand in the laboratory and the results are as shown below in Table III and Table IV.

Table III - Chemical Properties of Sugarcane Bagasse Ash

Compound		Percent by weight
Calcium Oxide	(CaO)	4.68
Silicon di Oxide	(SiO_2)	77.86
Aluminum Oxide	(Al_2O_3)	2.85
Magnesium Oxide	(MgO)	3.61
Phosphorus	(P_2O_5)	0.23
Ferric Oxide	(Fe_2O_3)	4.76
Potassium Oxide	(K_2O)	3.19
Sodium Oxide	(Na_2O)	0.53
Loss on ignition	(LOI)	1.86

Table IV - Physical Properties of Sugarcane Bagasse Ash and Natural Sand

Property	Natural sand	SCBA	Test method
Specific gravity	2.64	1.63	IS 2386 (Part III) - 1963
Fineness modulus	2.79	1.42	IS 2386 (Part I) - 1963
Sieve analysis for grading	II	Nearly IV	IS 2386 (Part I) – 1963 & IS 383 – 1970

Fine aggregate affects many concrete properties, including workability and finishability. Experience has shown that very coarse sand or very fine sand produces poor concrete mixes. Coarse sand results in harsh concrete mixes prone to bleeding and segregation. Fine sand requires a comparatively large amount of water to achieve the desired concrete workability, is prone to segregation, and may require higher cement contents. SCBA have low fineness modulus than natural sand and hence it requires more cement paste to maintain workability.

B. *Slump test*

Table V - Compressive Strength Test Results

Mix	SCBA by % of fine aggregate	Average compressive strength MPa 7 days	Average compressive strength MPa 28 days
Control	0	14.22	31.33
10BA	10	13.33	32.44
15BA	15	12	31.78
20BA	20	11.56	30.88
25BA	25	10.22	30
30BA	30	10.22	29.33

SCBA = sugarcane bagasse ash, M = mega, Pa = pascal.

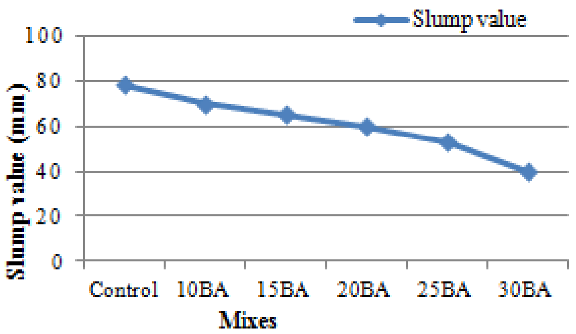

Fig. 1 Slump value for different % of SCBA

As stated by M. Sivakumar and N. Mahendran, (2013) all of the mixes that contained SCBA required more water than control [21]. Furthermore, to maintain the desired slump flow, the amount of water needed for mixes containing SCBA was found to increase as the proportion of SCBA increased. This increased water requirement may be due to the porous nature of the bagasse particles, which have a larger surface area and average size leading to enhanced absorption of water.

C. Compressive strength test

Compressive strength was performed on cube specimens of size 150 mm x 150 mm x 150 mm. Compressive strength for concrete with replacement of natural sand with bagasse ash of 10%, 15%, 20%, 25% and 30% at the age of 7 and 28 days are shown in Table V and Fig.2.

Table VI - Split Tensile Strength Test Results

Mix	SCBA by % of fine aggregate	Average spilt tensile strength MPa 7 days	Average spilt tensile strength MPa 28 days
Control	0	2.6	3.96
10BA	10	2.55	4.1
15BA	15	2.5	3.89
20BA	20	2.33	3.82
25BA	25	2.12	3.75
30BA	30	2.05	3.6

SCBA = sugarcane bagasse ash, M = mega, Pa = pascal.

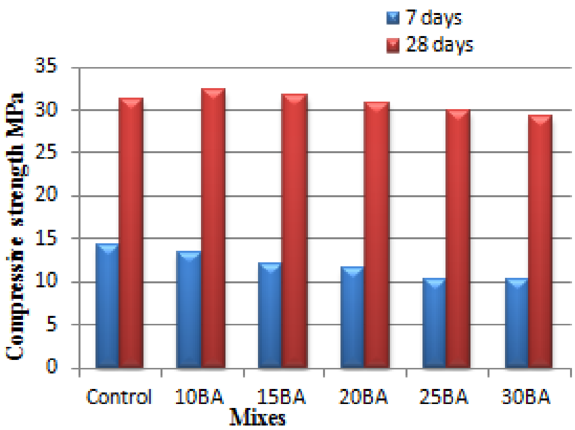

Fig. 2 Comparison of compressive strength for different % of SCBA

Compressive strength continued to increase as the curing period increased. The control mix had a compressive strength of 32.44 MPa at 28 days. Addition of increasing amounts of SCBA generally decreased the strength at a given age due to the greater porosity of the material as indicated by higher water requirement. The greatest compressive strength was achieved when the mixture contained SCBA of 10% of fine aggregate replacement with the water cement ratio of 0.43. Improvement stemmed from the void-filling ability of the smaller particles and was more pronounced at lower w/c ratios.

D. Split tensile strength

Split tension test was performed on cylinder specimens of size 150 mm diameter and 300 mm length. The results are shown in Table VI and Fig. 3.

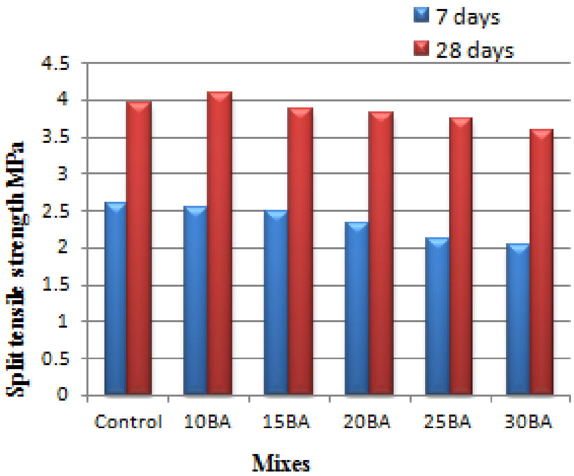

Fig. 3 Comparison of split tensile strength for different % of SCBA

We observed that tensile strength of mixes decreases as the replacement of SCBA increases. But with 10 % of SCBA gives higher strength compared to control mix.

E. Flexural strength test

Beam specimens of size 100 mm x 100 mm x 500 mm was cast to test the flexural strength of the concrete. After casting the test specimen it was cured for 7 days and 28 days and tested for maximum load. The results are given the Table VII. Fig. 4 shows the variation in flexural strength for different replacement with respect to controlled concrete for 7 days and 28 days.

Table VII - Flexural Strength Test Results

Mix	SCBA by % of fine aggregate	Average flexural strength MPa 7 days	Average flexural strength MPa 28 days
Control	0	3.5	4
10BA	10	3.4	4.1
15BA	15	3.35	3.9
20BA	20	3.25	3.85
25BA	25	2.9	3.75
30BA	30	2.75	3.5

SCBA = sugarcane bagasse ash, M = mega, Pa = pascal.

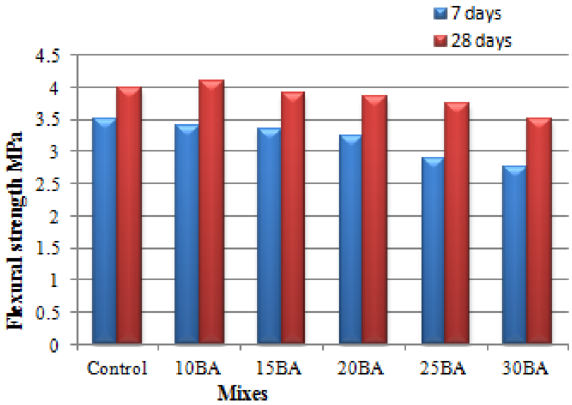

Fig. 4 Comparison of flexural strength for different % of SCBA

F. *Discussion*

The results reveal that the SCBA as partial replacement of fine aggregates in concrete has resulted in significantly higher compressive strength, split tensile strength and flexural strength compared to that of the concrete without SCBA. 20 percent of SCBA decreases the compressive strength to a value which is near to the control concrete. This may be due to the fact that the quantity of SCBA present in the mix is higher than the amount required to combine with the liberated lime during the process of hydration thus leading to excess silica leaching out and causing deficiency in strength as stated by R. Srinivasan and K. Sathiya (2010) [22]. Also, it may be due to the defects generated in dispersion of SCBA that causes weak zones.

V. Conclusion:

From the experiments and analysis of results of findings in this research work, we established the following facts. Due to non availability of natural sand at reasonable cost as finer aggregate in cement concrete for various reasons, search for alternative material like SCBA qualifies itself as a suitable substitute for sand at low cost. Fineness modulus of natural sand and SCBA were 2.79 and 1.42 respectively. SCBA belongs to zone lV as per IS code. Water requirement increased as the percentage of SCBA increased. Unit weight of the mixture produced decreased as the percentage of SCBA increased. Workability of the mixtures depended primarily on the percentage of SCBA used. This is consistent with the porous nature of SCBA particles whereby a greater surface area and larger average particle size serve to enhance absorption of water. Only the slump properties of the control and 10 percent SCBA mixture were acceptable, while the other mixtures were compromised by a decrease in slump relative to the amount of SCBA present.

The compressive strength results represent that the strength of the mixes with 10% and 20% bagasse ash increased at later days (28 days) as compared to 7 days that may be due to pozzolanic properties of bagasse ash. The greatest compressive strength, split tensile strength and flexural strength were achieved when the mixture contained 10% of fine aggregate replacement of SCBA with the water cement ratio of 0.43.

Hence we concluded that the fine aggregate upto 10% can be effectively replaced with sugarcane bagasse ash without considerable loss of workability and strength.

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