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Utilization of Bagasse Ash as a Partial Replacement of Fine Aggregate in Concrete

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Abstract

Today researches all over the world are focusing on ways of utilizing either industrial or agricultural wastes as a source of raw materials for the construction industry. These wastes utilization would not only be economical, but may also help to create a sustainable and pollution free environment. Sugar-cane bagasse is one such fibrous waste-product of the sugar refining industry, along with ethanol vapor. Bagasse ash mainly contains aluminum ion and silica. In this paper, untreated bagasse ash has been partially replaced in the ratio of 0%, 10%, 20%, 30% and 40% by volume of fine aggregate in concrete. Fresh concrete tests like compaction factor test and slump cone test were undertaken along with hardened concrete tests like compressive strength, split tensile strength and sorptivity. The result shows that bagasse ash can be a suitable replacement to fine aggregate.

Keywords: Bagasse ash, Concrete, Workability

Nomenclature

A	surface area in contact with water in cm,
Q	volume of water absorbed in cm^3,
S	sorptivity in ($cm/s^{1/2}$),
t	time in seconds
BA	bagasse ash
CA	coarse aggregate
CF	compaction factor
FA	fine aggregate
RS	river sand
SP	superplasticizer

1. Introduction

Sugarcane is one of the major crops grown in over 110 countries and its total production is over 1500 million tons. In India only, sugarcane production is over 300 million tons/year that cause about 10 million tons of sugarcane bagasse ash as an un-utilized and waste material [1,2]. After the extraction of all economical sugar from sugarcane, about 40-45% fibrous residue is obtained, which is reused in the same industry as fuel in boilers for heat generation leaving behind 8 -10 % ash as waste, known as sugarcane bagasse ash (SCBA)[3]. The SCBA contains high amounts of un-burnt matter, silicon, aluminum and calcium oxides. But the ashes obtained directly from the mill are not reactive because of these are burnt under uncontrolled conditions and at very high temperatures [4]. The ash, therefore, becomes an industrial waste and poses

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disposal problems. A few studies have been carried out in the past on the utilization of bagasse ash obtained directly from the industries to study pozzolanic activity and their suitability as binders by partially replacing cement. The present study was carried to study the use of SCBA as a partial replacement of fine aggregate in cement concrete since the availability of natural sand is on the cry off in the last decades as a result of ecological and environmental limitations. The experimental study examines the workability properties of fresh concrete such as slump and compaction factor and also 7 and 28 days compressive strength, 28 days tensile strength and sorptivity coefficients with 10%, 20%, 30% and 40% replacement of fine aggregate with bagasse ash by volume.

2. Materials

2.1 Cement

Ordinary Portland cement (Grade 53) was used. Its physical properties are as given in Table 1.

Table 1. Physical Properties of Cement

Physical property	Results obtained
Fineness (retained on 90-µm sieve) cm^2/gm	2940
Normal Consistency	29.5%
Vicat initial setting time (minutes)	75
Vicat final setting time (minutes)	370
Soundness (mm)	2
Compressive strength 28days(MPa)	57
Specific gravity	3.15

2.2 Aggregates

Locally available natural sand with 4.75 mm maximum size was used as fine aggregate, having specific gravity, fineness modulus and unit weight as given in Table 2 and crushed stone with 16mm maximum size having specific gravity, fineness modulus and unit weight as given in Table 2 was used as coarse aggregate. Both fine aggregate and coarse aggregate confirmed to Indian Standard Specifications IS: 383-1970 [6].

Table2. Physical properties of Coarse and Fine Aggregates

Physical tests	Coarse aggregate	Fine aggregate	
		River sand	Bagasse ash
Specific gravity	2.83	2.64	1.25
Fineness modulus	6.86	3.08	2.12
Bulk density (kg/m^3)	1363	1428	837

2.3 *Sugarcane bagasse ash*

The bagasse ash used in the investigation is obtained from a Corporate Sugar Factory in the nearby vicinity. The sugarcane bagasse consists of approximately 50% of cellulose, 25% of hemicellulose 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). Table3. gives the chemical composition of bagasse ash.

Table3. The Chemical Composition of Bagasse Ash

Component	Mass (%)
SiO_2	62.43
Al_2O_3	4.28
Fe_2O_3	6.98
CaO	11.8
K_2O	3.53

MgO	2.51
SO_3	1.48
Loss of Ignition	4.73

3. Experimental Work

The experimental work consists of performing the sieve analysis of bagasse ash as per the Indian standard procedure and using the results for the mix design to achieve the concrete of required strength and quality. Thereafter the concrete is tested for workability parameters by performing the slump cone and compaction factor test on it, followed by casting the cubes of concrete for further investigations. For carrying out the strength investigations a total 45 number of concrete cubes and 15 cylindrical specimens were casted. Based upon the quantities of ingredient of the mixes, the quantities of sugar cane bagasse ash for 0, 10, 20, 30 and 40% replacement by volume of sand were estimated. The water cement ratio was kept 0.40 and the dose of superplasticizer was kept constant at 0.8%. The casted concrete specimens were cured under standard condition in the laboratory and tested for 7 days and 28 days compressive strength, 28 days split tensile strength and sorptivity test.

Table 4. Properties of Fresh Concrete

Mix No.	Mix Proportion				%SCBA by volume of RS	W/C Ratio	Dose of SP, %	Slump mm	CF
	Cement, Kg/m^3	CA, Kg/m^3	FA, Kg/m^3						
			RS	BA					
M0	430	1260	650	00	0	0.40	0.8	110	0.92
M10	430	1260	585	33	10	0.40	0.8	78	0.84
M20	430	1260	520	65	20	0.40	0.8	65	0.81
M30	430	1260	455	99	30	0.40	0.8	32	0.75
M40	430	1260	390	130	40	0.40	0.8	7	0.64

4. Test Methods

At the end of each curing period, a total of 3 specimens were tested for each concrete property. The compressive strength test was carried out on the 150mm cube specimens, whilst the split tensile strength test was carried out on the 150mm diameter and 300mm height cylindrical specimens as per Indian standard. Water absorption test were carried out to determine the sorptivity coefficient of concrete specimens, which were preconditioned in oven at 105ºC for 24 hr and then cooled down in desiccators for 24 hr to achieve a constant moisture level. Then, four sides of the concrete specimens were sealed by electrician tape to avoid evaporative effect as well as to maintain uniaxial water flow during the test and the opposite faces were left open. Before specimens were kept in water, their initial weights were recorded. One face of the specimen was in contact with water whilst the water absorption at predefined intervals was measured with a balance of 0.1gm readability. The sorptivity coefficient can be calculated by the following expression:

$$S = (Q/A) / t^{1/2} \quad (1)$$

5. Results and Discussion

The table 5 gives the results of various tests performed on the samples.

Table 5. Test Results of Various Tests

Sample	Average Compressive Strength, N/mm^2		Average split TensileStrength, N/mm^2	Sorptivity $cm/s^{1/2}$
	7 days	28 days		
M0	13.91	22.36	4.31	1.53
M10	12.16	23.85	3.99	1.72
M20	10.37	21.9	3.87	2.01
M30	10.05	19.17	3.35	2.71
M40	6.19	14.7	3.12	3.78

5.1 Compressive Strength

The results obtained from compressive strength test for all the mixes are given in fig 1. It can be seen from the figure that the compressive strength results of specimens at 10% replacement of SCBA were higher than those at 0% SCBA. Further increase in SCBA percentage results in decreasing compressive strength along with significant fall in properties of fresh concrete. It is also indicated that the rate of increase of strength of mixes with SCBA is higher at later days that may be due to pozzolanic properties of SCBA.

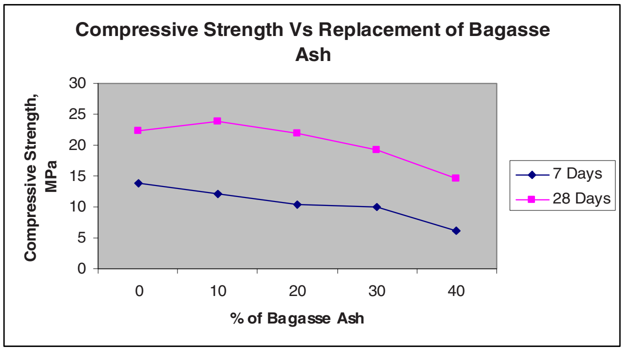

Fig. 1. 7 & 28 Days Compressive Strength for All Mixes

5.2 *Tensile Strength*

The tensile strength results for all the mixes for 28 days curing are shown in fig.2. When the influence of SCBA on the tensile strength of concrete was examined, it was observed that the development of tensile strength of mixes decreases as the replacement of SCBA increases.

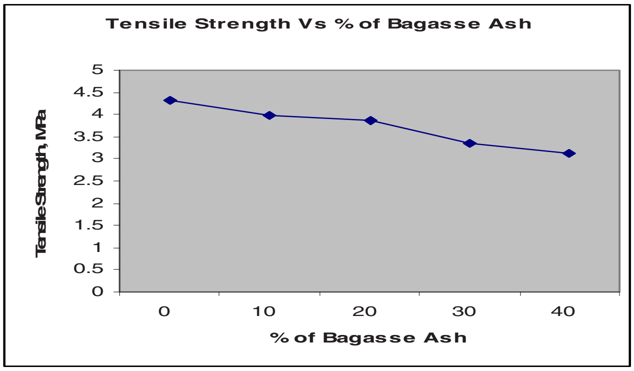

Figure5.2 28 Days Split tensile Strength Results for All Mixes

5.3 Sorptivity

The results of sorptivity tests are given in table 5 and fig.3. It can be seen that the Sorptivity coefficient increases with increase in percentage of SCBA and decreases with increase in compressive strength of concrete. The raw SCBA contains coarser, unburnt and halfburnt particles which are porous hence absorb more water. It is reflected in the increase in the sorptivity with increase in the percentage of baggase ash.

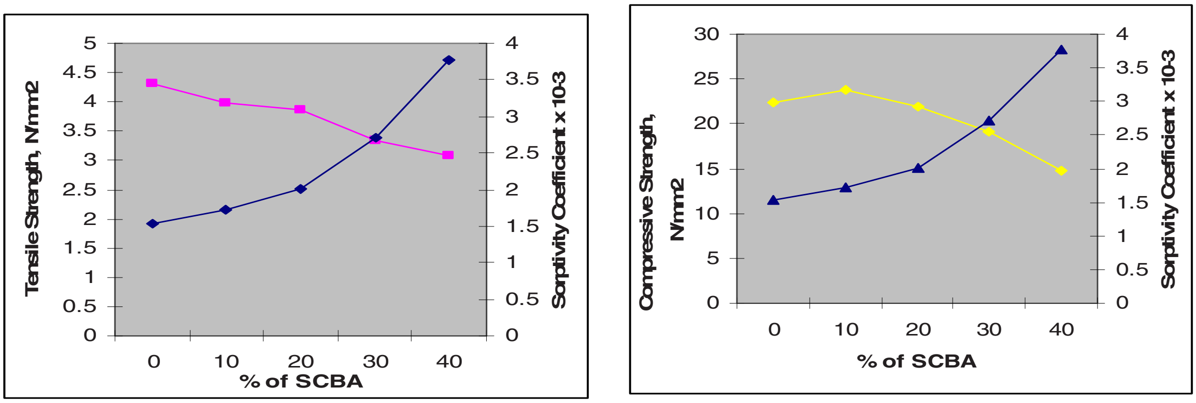

Figure 3. Variation of Compressive Strength, Tensile Strength and Sorptivity Coefficeints

6.0 Conclusion

On the basis of experimental investigation carried out, the following conclusions can be drawn.

i) The fraction of fine aggregates i.e. 10% to 20% can be effectively replaced with a bagasse ash (untreated) without a considerable loss of workability and strength properties.

ii) The compressive strength results represent that, the strength of the mixes with 10% and 20% bagasse ash increases at later days (28 days) as compared to7 days that may be due to pozzolanic properties of bagasse ash.

iii) The Sorptivity test result shows that the sorptivity coefficient increases with increase in percentage of bagasse ash which indicate more permeable concrete that is due to porous nature of SCBA and the impurities in it.

iv) In its purest form the bagasse ash can prove to be a potential ingredient of concrete since it can be an effective replacement to cement and fine aggregate.

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