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EXPERIMENTAL STUDY ON PARTIAL REPLACEMENT OF CEMENT BY SUGARCANE BAGASSE ASH (SCBA)

R. Vignesh*, V. Hemalatha*, S. Jeyanthi Saranya & J. K. Ronnietta Kennedy***
* Assistant Professor, Department of Civil Engineering, Kalasalingam Institute of Technology, Tamilnadu
** UG Students, Department of Civil Engineering, Kalasalingam Institute of Technology, Tamilnadu

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Abstract:

India is the second largest in major sugar producing countries after Brazil. Bagasse is the fibrous residue of sugar cane after crushing and extraction of juice. Sugar cane bagasse ash is the waste product of the combustion of bagasse for energy in sugar factories. Sugar cane bagasse ash is disposed of in landfills and is now becoming an environmental burden. In this experimental study concrete cubes, beams and cylinders of M20 grade were casted and tested to examine various properties of concrete like workability, compressive strength, split tensile strength, modulus of elasticity and flexural strength. Sugar cane bagasse ash was partially replaced with cement at 2, 4, 6, 8 and 10 % by weight of cement in concrete. After mixing, concrete specimens were casted and subsequently all test specimens were cured in water at 7, 14 and 28 Days. From the results we can conclude that optimum amount of sugar cane bagasse ash that can be replaced with cement is 6% by weight without any admixture.

Key Words: Sugar Cane Bagasse Ash, Cement, Concrete, Replacement & Properties

1. Introduction:

Concrete is the widely used first number of structural material in the world today. Concrete is manufacturing involves of ingredient like cement, aggregate, Water. Infrastructure developed across the world created demand for different construction materials. Cement are important constituent in concrete. Concrete has been used for many amazing things throughout history, including architecture, infrastructure and more. Concrete is formed when Portland cement creates a paste with water that binds with sand and rock to harden. Cement is manufactured through a closely controlled chemical combination of calcium, silicon, aluminium, iron and other ingredients. Common materials used to manufacture cement include limestone, shells, and chalk or marl combined with shale, clay, slate, blast furnace slag, silica sand, and iron ore. These ingredients, when heated at high temperatures form a rock-like substance that is ground into the fine powder that we commonly think of as cement. Sugarcane is a member of the grass family. Sugarcane is a tree-free renewable resource and one of the most important agricultural plants that grown in hot regions. Sugarcane is "carbon neutral" (i.e. emissions are equal to energy generated) and is the product of choice in the manufacture of bio-fuels due to its high energy conversion rate. Bagasse is lateral production of sugarcane that after treatment of sugarcane in the form of light yellow particles is produced. The chemical composition of this product are cellulous fibers, water and some soil soluble material such as cube sugar, by passing time cube sugary converted alcohol also the evaporation of bagasse fibre produce the methane gas which can cause fire in some circumstance. Bagasse is a major by-product of sugar industry which finds a very useful utilization in the same industry as an energy source. Sugarcane consists of 25-30% bagasse whereas sugar recovered by the industry is about 10%. Bagasse is also used as a raw material for paper making due to its fibrous content and about 0.3 tons of paper can be made from one ton of bagasse. Bagasse is a by-product during the manufacture of sugar and it has high calorific value. It is utilized as a fuel in boilers in the sugar mills to generate steam and electricity. The bagasse is used in the energy production (steam/electricity), fuel, hydrolysis, paper pulp, cellulose and wood veneer. 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 bagasse ash is the remains of fibrous waste after the extraction of the sugar juice from cane. In many tropical countries there are substantial quantities of bagasse and husks from rice both are rich in amorphous silica, which react with lime. The bagasse ash is a pozzolanic material that would otherwise require disposal.

Figure 1: Wet Sugarcane

Figure 2: Dry Sugarcane

Table 1: Top ten Sugarcane producers

Country	Production (Million tons)
Brazil	672.16
India	285.03
People's republic of China	116.25
Thailand	66.82
Pakistan	50.04
Mexico	49.49
Colombia	38.50
Philippines	32.50
Australia	30.28
Argentina	29.00

Figure 3: Statistical Division)

2. Objective of the Study:

The main objective of this research was to determine the effectiveness of sugar cane bagasse ash (SCBA) as a cement replacement material in concrete.

3. Materials and Methods: The materials used in this investigation are:

Cement: The most commonly used cement in concrete is Ordinary Portland Cement Out of the total production, ordinary Portland cement accounts for about 80-90 percent. Many tests were conducted to cement of 53 Grade conforming to IS12269 (p.g.no.13).

Table 2: Physical Properties of Cement

Physical properties	Result obtained	
Fineness (retained on 90-m sieve) cm^2/gm	2940	
Normal Consistency	29.5%	
Vicat initial setting time (minutes)	75	
Vicat final setting time (minutes)	370	
Compressive strength (MPa)	7 days	39.58
	14 days	43.20
	28 days	56.10
Specific gravity	3.15	

Fine Aggregate: Locally available free of debris and nearly riverbed sand is used as fine aggregate. The sand particles should also pack to give minimum void ratio, higher voids content leads to requirement of more mixing water. In the present study the sand confirms to zone I as per Indian standards. (IS: 10262, IS: 383). The specific gravity of sand is 2.75. Moisture content of sand is 12.5%. Fineness modulus of sand is 4.45.

Coarse Aggregates: The crushed aggregates used were 20mm nominal maximum size and are tested as per Indian standards and results are within the permissible limit. (IS: 10262, IS: 383). The specific gravity is 2.74. Fineness modulus is 6.75. Water absorption is 2%. Impact load test on coarse aggregate is 0.36.

Water: Water available in the college campus conforming to the requirements of water for concreting and curing as per IS: 456-2009.

Sugarcane Bagasse Ash: 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). In spite of being a material of hard degradation and that presents few nutrients, the ash is used on the farms as a fertilizer in the sugarcane harvests. In this experimental study sugarcane bagasse ash was collected from Tharani Sugar Factory, Tharani Nagar, Vasudevanallur

Chemical Analysis of Sugar Cane Bagasse Ash: Sugar cane bagasse ash collected for experimental work was tested for the Chemical Compound. The result is as follows:

Table 3

Chemical Compound	Abbreviation	%
Silica	SiO_2	68.42
Aluminium Oxide	Al_2O_3	5.812
Ferric Oxide	Fe_2O_3	0.218
Calcium Oxide	CaO	2.56
Phosphorous oxide	P_2O_5	1.28
Magnesium oxide	MgO	0.572
Sulphide Oxide	SO_3	4.33
Loss of Ignition	LOI	15.90

Table 4

Chemical Compound	Abbreviation	Mg/kg
Sodium Oxide	Na_2O	1621

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Potassium Oxide	K_2O	9406
Manganese Oxide	MnO	244
Titanium Oxide	TiO_2	240
Barium Oxide	BaO	23.73

Sugar Cane Bagasse Ash Preparation: Before the use of bagasse ash, it was oven dried at 1200C to remove the moisture in the ash. After oven dry ash was sieve in the mechanical shivers to separate unburned particles from ash. Sugar cane bagasse ash passing from 150 micron was used in this experiment work. Specific gravity for SCBA is 2.68.

Chemical Characterization of Concretes with SCBA: Corrosion is one of the most serious causes that reduce service life of Reinforced Concrete Structures .Binary Concretes were made and evaluated in the impact of Sugar Cane Bagasse Ash (SCBA) as a partial substitute for Portland cement, with the aim of reducing the rate of corrosion induced by chloride ions and sulphate. The behaviour of corrosion was monitored for 14 months in two aqueous solutions of NaCl and Na2SO4 both at 3.5%, using electrochemical techniques of corrosion potential (Ecorr) and linear polarization resistance (Rp). Under the conditions of study, the binary mixture that showed a better corrosion protection was the one that contained 80% from sugar Cane bagasse ash and 20% Portland cement. The CSH is responsible for the hardness and compactness of the concrete, the SiO2 of the SCBA the pozzolan reacts as follows:

First reaction of hydration (First production of CSH):

$$2(3CaO \cdot SiO_2) + 6H2O \rightarrow 3CaO \cdot 2SiO_2 \cdot 3H_2O + 3Ca\,(OH)_2$$

Second reaction of hydration after 14 days of conventional curing (second production CSH)

$$3Ca(OH)_2 + 2SiO_2 + H_2O \rightarrow 3CaO \cdot 2SiO_2 \cdot 3H_2O$$

The good corrosion resistance of concrete modified with SCBA, can also be due to the appropriate particle size (lower than 75µm) that the pozzolana in the study presented, because it makes denser concrete inhibiting the ingress of oxygen and moisture, which are essential for the cathodic reaction, and it results that corrosion rate is reduced. The excessive amount of silica in SCBA will reduce the workability. It combines with calcium in cement to form leaching.

4. Mix design:

The mix was designed as per IS 10262:2009 for M20 grade concrete with 0.5 water cement ratio. Concrete mixes are prepared by partial replacement of cement by sugarcane bagasse ash with different percentages (0%, 2%, 4%, 6%, 8%, 10%) respectively.

Table 5: Mix Design

Mix	Cement	SCBA	Fine Aggregate	Coarse Aggregate
Conventional	100%	0%	100%	100%
Trail 1	98%	2%	100%	100%
Trail 2	96%	4%	100%	100%
Trail 3	94%	6%	100%	100%
Trail 4	92%	8%	100%	100%
Trail 5	90%	10%	100%	100%

Casting of Samples: Preparation of the Specimens: For the experiment work concrete cubes of size 150x150x150mm, Cylinder of diameter 150mm and height 300mm, Beam of size 500mmx100mmx100mm, were prepared. The 53 grade OPC was replaced with 0%, 2%, 4%, 6%, 8% and 10% SCBA. In the present investigation a total of 135 concrete specimens were casted and tested. M20 Grade of concrete is adopted throughout the study with w/c ratio of 0.5.

Experimental Work: Based upon the quantities of ingredient of the mixes, the quantities of SCBA for 0, 2, 4, 6, 8 and 10% replacement by weight were estimated. The ingredients of concrete were thoroughly mixed in mixer machine till uniform thoroughly consistency was achieved. Before casting, machine oil was smeared on the inner surfaces of the cast iron mould. Concrete was poured into the mould and compacted thoroughly using table vibrator. The top surface was finished by means of a trowel. The specimens were removed from the mould after 24h and then cured under water for a period of 7, 14 and 28 days. The specimens were taken out from the curing tank just prior to the test. The tests for compressive, split tensile strength were conducted using a 2000kN compression testing machine, the modulus of elasticity the test conducted using a compression testing machine and compress meter (strain measurements). For modulus of rupture was conducted using 1000kN universal testing machine. These tests were conducted as per the relevant Indian Standard specifications.

5. Experimental Result:

The strength results obtained from the experimental investigations are showed in tables. All the values are the average of the three trails in each case in the testing program of this study. The results are discussed as follows.

Workability: A high-quality concrete is one which has acceptable workability (around 6.5 cm slump height) in the fresh condition and develops sufficient strength. Basically, the bigger the measured height of slump, the better workability will be, indicating that the concrete flows easily but at the same time is free from segregation. Maximum strength of concrete is related to the workability and can only be obtained if the concrete has adequate degree of workability because of self-compacting ability. The results show that unlike the C0 series, all investigated SCBA mixtures had high slump values and acceptable workability. This may be due to the increasing in the surface area of sugarcane ash after adding SCBA that needs less water to wetting the cement particles.

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Slump Test: Slump test is done before casting of each mix, Slump of concrete is increase respectively increase of PCA in concrete. Reason of slump increase was less water absorption of plastic aggregates and plastic fibres. The slump test results are shown in table – 6

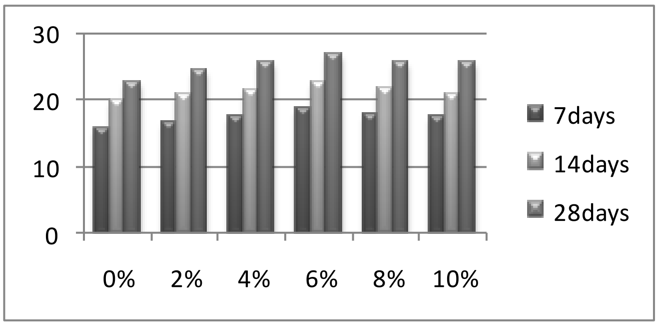
Table 6: Slump value

S.No	%SCBA	w/c ratio	Slump value
1	0%	0.5	20mm
2	2%	0.5	40mm
3	4%	0.5	40mm
4	6%	0.5	40mm
5	8%	0.5	40mm
6	10%	0.5	40mm

Compressive Strength: The compressive strength results of different mixes are given by table7 and fig4. In the present investigation compressive strength of concrete produced by partial replacement of cement by sugarcane bagasse ash is goes on increasing up to 6% replacement of SCBA. The percentage in the compressive strength at this 0% to 10% replacement of SCBA found to be seen in table 7 and fig4.

Table 7: Compressive strength in 7days, 14days, 28days

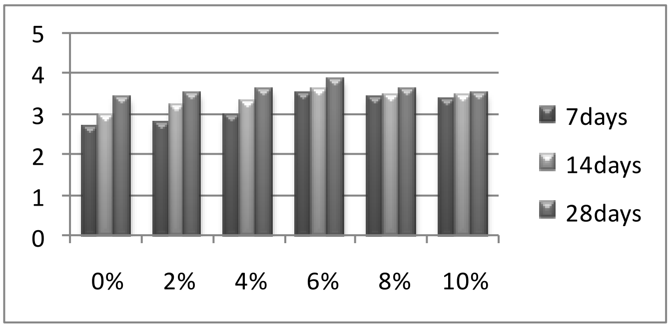
	7days	14days	28days
0%	15.69	19.98	22.59
2%	16.58	20.91	24.68
4%	17.67	21.68	25.71
6%	18.89	22.71	26.89
8%	17.80	21.75	25.68
10%	17.60	20.81	25.60



Split Tensile Strength: The tensile strength results of different mixes are given by table8 and fig5. In the present investigation tensile strength of concrete produced by partial replacement of cement by sugarcane bagasse ash is goes on increasing up to 6% replacement of SCBA. The percentage in the tensile strength at this 0% to 10% replacement of SCBA found to be seen in table 8 and fig5.

Table 8: Split tensile strength in 7days, 14days, 28days

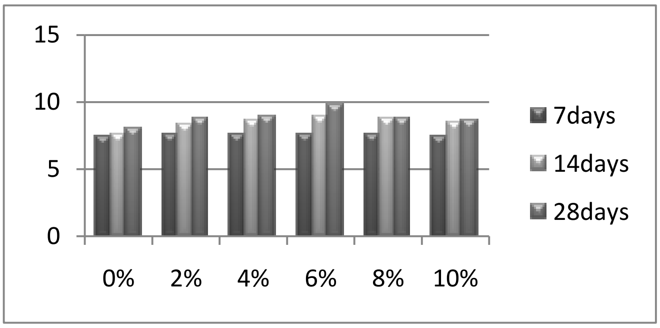
%SCBA	7days	14days	28days
0%	2.66	2.96	3.41
2%	2.76	3.23	3.51
4%	2.98	3.33	3.60
6%	3.51	3.60	3.87
8%	3.40	3.45	3.64
10%	3.38	3.49	3.50



Flexural Strength: The flexural strength results of different mixes are given by table9 and fig6. In the present investigation flexural strength of concrete produced by partial replacement of cement by sugarcane bagasse ash is goes on increasing up to 6% replacement of SCBA. The percentage in the flexural strength at this 0% to 10% replacement of SCBA found to be seen in table9 and fig6

Table 9: Flexural strength in 7days, 14days, 28days

	7days	14days	28days
0%	7.38	7.59	7.98
2%	7.49	8.34	8.76
4%	7.58	8.61	8.85
6%	7.61	8.85	9.81
8%	7.56	8.66	8.71
10%	7.41	8.48	8.60



6. Result Comparison:

Comparison of the results from the 7, 14 and 28 days samples shows that the compressive strength, spilt tensile strength and flexural strength increases with SCBA up to 6% replacement and then it decreases, although the results of 10% replacement is still higher than those of the plain cement concrete. It was shown that the use of 10% SCBA decreases the compressive strength to

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a value which is near to the control concrete. This may be due to the fact that the quantity of SCBA (pozzolan) 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 a deficiency in strength as it replaces part of the cementitious material but does not contribute to strength. Also, it may be due to the defects generated in dispersion of SCBA that causes weak zones. In Modulus of Elasticity decreases with increase in SCBA and also the density of concrete with SCBA were decreases.

7. Conclusion:

The results show that the SCBA in blended concrete had significantly higher compressive strength compare to that of the concrete without SCBA. It is found that the cement could be advantageously replaced with SCBA up to maximum limit of 10%. Although, the optimal level of SCBA content was achieved with 6% replacement. Partial replacement of cement by SCBA has optimum workability of fresh concrete; therefore use of super plasticizer is not essential. The density of concrete decreases with increase in SCBA content, low weight concrete produced in the society with waste materials (SCBA). This is because of increase in SCBA decrease in workability occurs due to the formation of improper mixing and leaching of cement. Therefore, with the use of sugar cane bagasse ash in partially replacement of cement in concrete, we can increase the strength of concrete with reducing the consumption of cement. Also it is best use of sugar cane bagasse ash instead of land filling and make environment clean.

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