A Study on Usage of Potential Bagasse Ash as a Substitute Material for Cement Concrete

Prof. Priyadarshini H. P.
Assistant Professor,
Civil Engineering Department,
R. R. Institute of Technology,
Raja Reddy Layout, Chikkabanavara,
Bengaluru, India

Prof. Bhojegowd V.T.
Assistant Professor,
Civil Engineering Department,
R. R. Institute of Technology,
Raja Reddy Layout, Chikkabanavara,
Bengaluru, India

INTRODUCTION:

The use of industrial and agricultural waste by industrial processes has been the focus of waste reduction research for economic, environmental, and technical reasons. Sugar-cane bagasse is a fibrous waste-product of the sugar refining industry, along with ethanol vapor. This waste product (Sugar-cane Bagasse ash) is already causing, environmental pollution. Bagasse ash mainly contains aluminum ion and silica. In this project, Bagasse ash has been chemically and physically characterized, and partially replaced in the ratio of 0%, 5%, 15%, 20% and 25% by weight of sand in concrete.

OBJECTIVE OF STUDY:

The objectives of project are to make a synergic effect of Sugar cane bagasse ash (SCBA) incorporated in concrete in order to study the feasibility of using Bagasse Ash to partial replace of sand in concrete and usage of waste product for better performance.

1. To study and evaluate the physical and chemical properties of Cement, Aggregates and bagasse ash.
2. To study the effect of partial replacement of fine aggregate by bagasse ash on workability of concrete.
3. To study the mechanical properties of hardened concrete.

LITERATURE REVIEW:

Asokan Pappua et al., tests were carried out inclusion of industrial waste-based newer building materials, emphasizing their environmental significance in the curriculum at higher education level and practical applications of wastes in construction sector will give fill to such technology promotion. The new and alternative building construction materials developed using agro-industrial wastes have ample scope for introducing new building components that will reduce to an extent the costs of building materials

The study was carried out by Ganesan et al., The utilization of waste materials in concrete manufacture provides a satisfactory solution to some of the environmental concerns and problems associated with waste management. Agro wastes such as rice husk ash, wheat straw ash, hazel nutshell and sugarcane bagasse ash are used as pozzolanic materials for the development of blended cements.

According to Ajay Goyal and Hattori Kunio,2009 the ever increasing demand and consumption of cement and in the backdrop of waste management, scientists and researchers all over the world are always in quest for developing alternate binders that are environment friendly and contribute towards sustainable management. It is, however, generally used as a fuel to fire furnaces in the same sugar mill that yields about 8-10% ashes containing high amounts of un-burnt matter, silicon, aluminum, iron and calcium oxides

Osinubi and Stephen, 2015 evaluated Bagasse ash is the residue obtained from the incineration of bagasse in sugar producing factories. Research works have been carried out on the improvement of geotechnical characteristics of soils using bagasse ash.

According to Srinivasan and Sathiya 2010, the utilization of industrial and agricultural waste produced by industrial processes has been the focus of waste reduction research for economic, environmental, and technical reasons. Sugar-cane bagasse is a fibrous waste-product of the sugar refining industry, along with ethanol vapor.

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 (SiO_2). 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.

MATERIALS AND RESULT DISCUSSIONS:

1. Cement: Cement is binding material in the cement concrete. Cement is an extremely fine grounded material with adhesive and cohesive properties and act as a binding material in concrete. The properties of concrete are very much influenced with the properties of cement, hence if it of worth importance to know the cement properties. Following are the main tests conducted to know the cement properties.

Table 1.1: Test Results for Cement

Sl. No	Properties	Test Results	I. S. Permissible Limits
1	Specific gravity	3.05	-
2	Normal consistency	32%	-
3	Initial setting time	38 min	>30 min
4	Final setting time	180 min	<600 min

Table 1.2: Test Results for Compressive strength of cement

Sl. No	Age in days	Size of cube(mm)	Compressive strength(N/mm^2)
1	3	70x70x70	11.0
2	7	70x70x70	23.5
3	28	70x70x70	34.0

AGGREGATES:

Aggregates are important constituents of concrete and they constitute 75-80% total volume of concrete. They reduce shrinkage and effect economy to a great extent. As aggregates are main part of a body in concrete, its properties affect the economy to a great extent. The coarse aggregate are granular materials obtained from rocks and crushed stones. The sand obtained from river beds is used as fine aggregate. The fine aggregate along with the hydrated cement paste fill the space between the coarse aggregate.
Table 1.3 and 1.4 shows the properties and sieve analysis of sand.

Table 1.3: Properties of fine aggregate

Sl. No	Tests	Results
1	Specific gravity	2.62
2	Water absorption, %	1.0
3	Grading zone	II

Table 1.4 Sieve Analysis of Sand

IS sieve size	Percentage passing (%)	Grading requirement for zone II	Remarks
10 mm	100	100	Conforming zone II requirement as per IS383 (1970)
4.75 mm	100	90-100	
2.36 mm	98.7	85-100	

IS sieve size	Percentage passing (%)	Grading requirement for zone II	Remarks
1.18 mm	91.5	75-100	
600µm	66	60-79	
300µm	7.6	12-40	
150µm	1.4	0-10	

The properties of coarse are given in Table 1.5 to 1.6

Table 1.5: Properties of Coarse Aggregate

Sl. No	Test	Results	Specification
1	Specific Gravity	2.70	--------
2	Water absorption, %	0.39%	< 2

Table 1.6: Sieve Analysis of Coarse Aggregate (20mm down)

IS sieve size (mm)	Percentage passing (%)	Grading for Graded aggregates of nominal size 20mm
40	100	100
20	95	95-100
10	45	25-55
4.75	5	0-10

BAGASSE ASH:

Bagasse is a fibrous residue obtained from sugar cane during extraction of sugar juice at sugarcane mills. The average length of bagasse fibers is 80 mm and their average thickness is 0.2 mm. 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 (SiO_2). 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.

Tables 1 .7gives the properties of Bagasse ash

Table 1.7: Properties of Bagasse Ash

Sl. No	Test	Results
1	Specific Gravity	2.14
2	Water absorption, %	0.4%

Table 1.8: Sieve Analysis of SCBA

IS sieve size	Percentage passing (%)	Grading for zone II	Remarks
4.75 mm	93.1	90-100	Conforming zone III requirement as per IS383 (1970)
2.36 mm	88.3	85-100	
1.18 mm	80.2	75-100	
600µm	74.7	60-79	
300µm	43.1	12-40	
150µm	14.1	0-10	
75 µm	4.2	-	

Test on Fresh concrete results:

Table 2.1: Degree of Workability

Mix designation	Slump (mm)	Compaction Factor
Plain Concrete	75	0.976
SCBA 5%	40	0.86
SCBA 10%	35	0.87
SCBA 15%	25	0.88
SCBA 20%	18	0.86
SCBA 25%	14	0.81

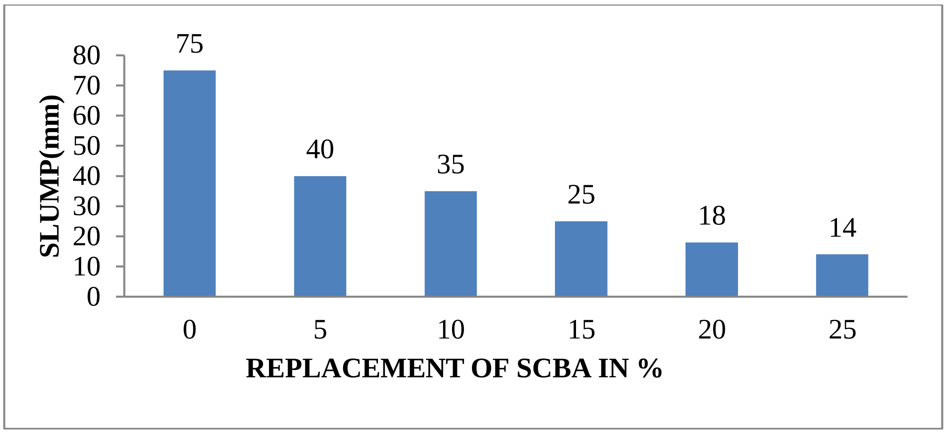

Fig 2.1: Results of Slump Cone Test

The fresh state the mixes containing Bagasse ash showed lower workability. The slump value decreases from 75mm to 14mm when ash content increased from zero to 25% as partial replacement of sand. This is due to the coarse grading angular nature of ash particle which increases the aggregate friction and interlock. This results in poor cohesion of fresh concrete. Also, a part of water found to be absorbed by the ash particles. The workability of which hardly improves even with further addition of water. Fig 5.2 shows the variation of compaction factor for the results with the percentage of ash content. The results show that there is a reduction in workability of concrete when ash is added.

 ISSN(Print) 2249-0302 ISSN (Online)2231-2528

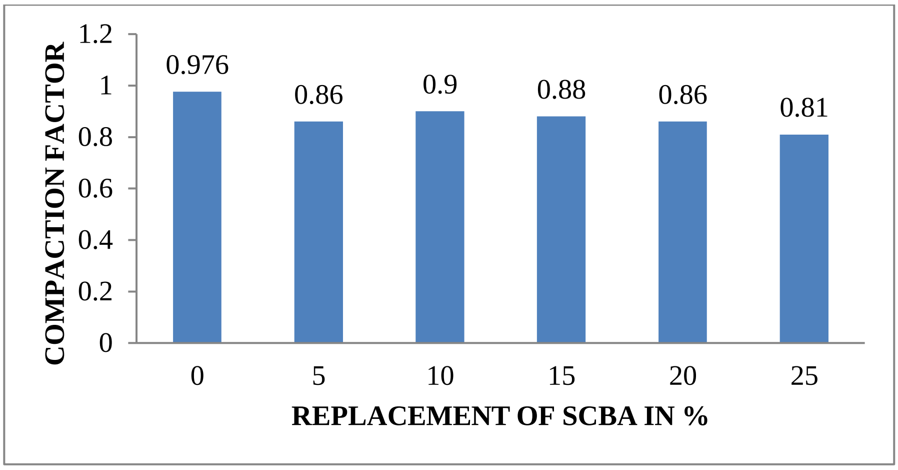

Fig 2.2: Result of Compaction Factor test

Test on Hardened Concrete:
COMPRESSIVE STRENGTH:

Table 3.1 to 3.3 represents compressive strength of a cube for 3, 7 and 28 days and Fig 5.3 to 5.5 shows the result of compressive strength. The compressive strength test result for various mixes of SCBA shows the optimum value at 20% replacement

Table 3.1: Mix proportions for the Cube Age of 3 days

Mix designation	Age of Cube (Days)	Test Load (kN)	Compressive Strength (N/mm^2)	Average Compressive Strength (N/mm^2)
Plain Concrete	3	145	14.5	13.86
		120	12.0	
		150	15.0	
SCBA 5%	3	150	15.0	14.5
		145	14.5	
		140	14.0	
SCBA 10%	3	180	18.0	18.16
		185	18.5	
		180	18.0	
SCBA 15%	3	195	19.5	19.17
		190	19.0	
		190	19.0	
SCBA 20%	3	200	20.0	20.16
		205	20.5	
		200	20.0	
SCBA 25%	3	170	17.0	16.83
		165	16.5	
		170	17.0	

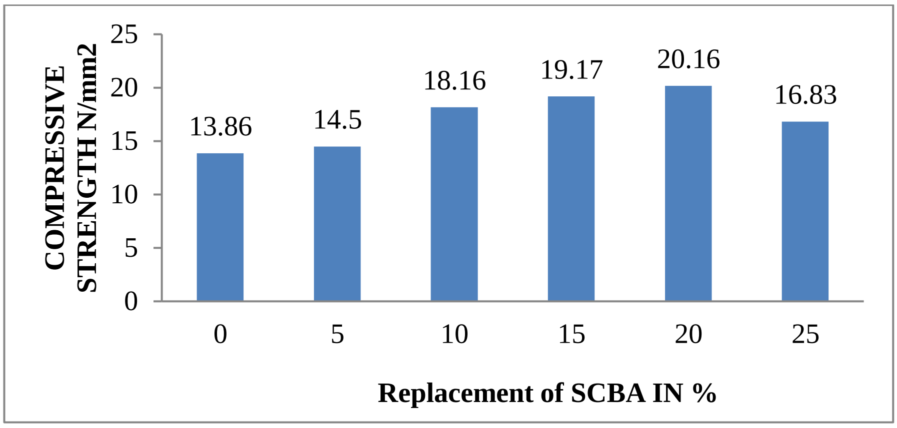

Figure 3.1: Compressive Strength of cubes for 3 days

Table 5.2: Mix proportions for the Cube Age of 7 days

Mix designation	Age of Cube (Days)	Test Load (kN)	Compressive Strength (N/mm²)	Average Compressive Strength (N/mm²)
Plain Concrete	7	175	17.5	18.16
		185	18.5	
		185	18.5	
SCBA 5%	7	280	28.0	26.00
		260	26.0	
		240	24.0	
SCBA 10%	7	245	24.5	24.67
		250	25.0	
		245	24.5	
SCBA 15%	7	280	28.0	28.33
		280	28.0	
		290	29.0	
SCBA 20%	7	310	31.0	30.50
		300	30.0	
		305	30.5	
SCBA 25%	7	220	22.0	21.66
		210	21.0	
		220	22.0	

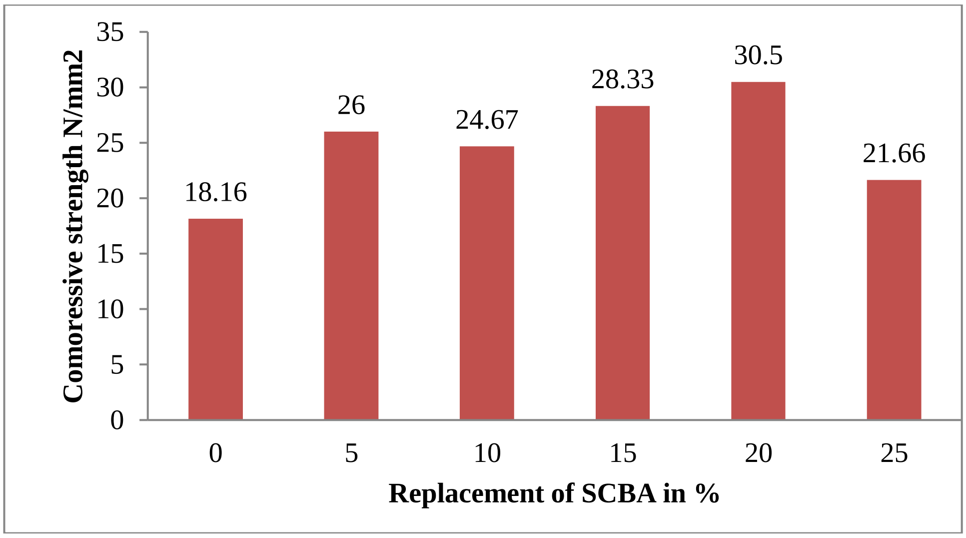

Figure 3.2: Compressive Strength of cubes for 7 days

Table 3.3: Mix proportions for the Cube Age of 28 days

Mix designation	Age Of Cube (Days)	Test Load (kN)	Compressive Strength (N/mm²)	Average Compressive Strength (N/mm²)
Plain Concrete	28	300	30.0	29.83
		295	29.5	
		300	30.0	
SCBA 5%	28	320	32.0	32.50
		340	34.0	
		350	35.0	
SCBA 10%	28	340	34.0	33.30
		320	32.0	
		340	34.0	
SCBA 15%	28	390	39.0	39.33
		400	40.0	
		390	39.0	
SCBA 20%	28	420	42.0	43.33
		445	44.5	
		435	43.5	
SCBA 25%	28	320	32.0	33.33
		350	35.0	
		330	33.0	

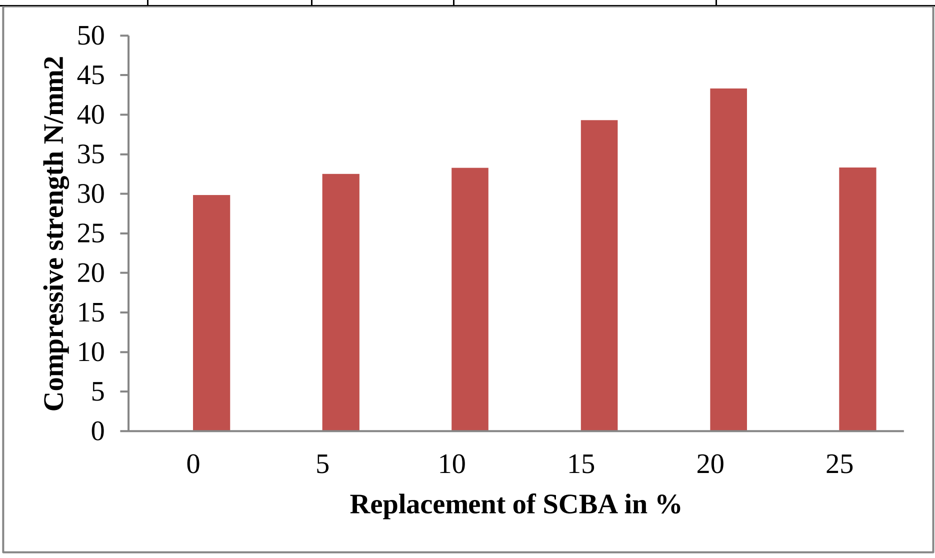

Figure 3.3: Compressive Strength of cubes for 28 days

This confirms the fact that concrete with SCBA up to 20% develops early compressive strength as compared to control concrete specimens. The reasons for early compressive strength development of SCBA concretes and increase in compressive strength up to 20% sand replacement of SCBA may be due to silica content, fineness, amorphous phase, specific surface area, degree of reactivity of SCBA and pozzolanic reaction between calcium hydroxide and reactive silica in SCBA. Therefore 20% SCBA seems to be the optimal limit. The compressive strength of concrete is found in the range of 20.16 N/mm² to 40.33N/mm² for 3 to 28days.

COMPARISON OF COMPRESSIVE STRENGTH FOR 3, 7 AND 28 DAYS:

Fig 3.4 clearly shows that the compressive strength varies as the cube aging process takes place for 3,7,28 days . Higher the aging process higher will be the compressive strength.

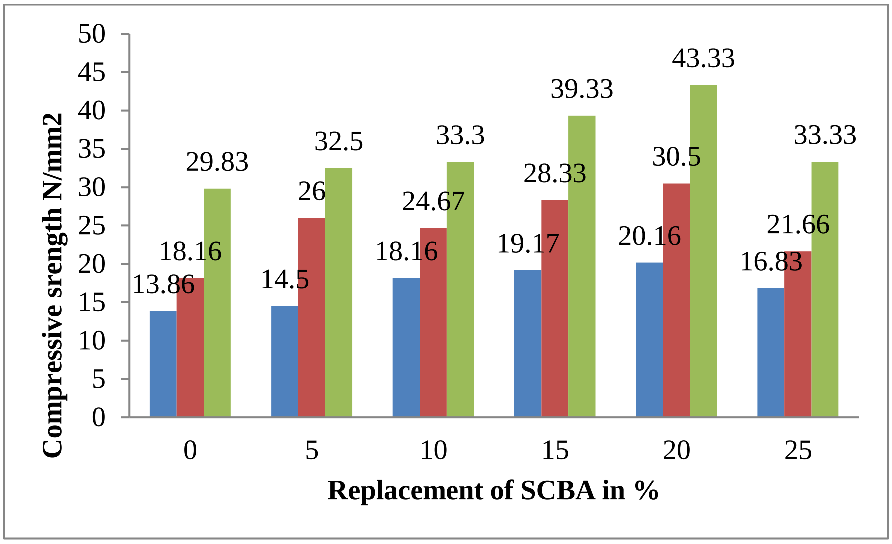

Fig 3.4 Variation in Compressive Strength

FLEXURAL STRENGTH:

Fig 3.5 and Table 3.6 shows the result of flexural strength for beams. The flexural strength of conventional concrete is 3.28N/mm² and for 20% replacement of SCBA in concrete gives the optimum value 3.87N/mm² for 28days.

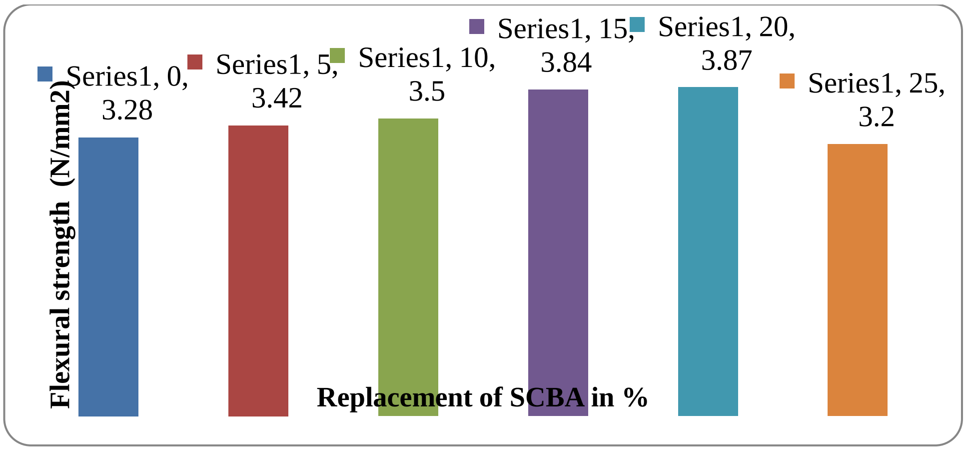

Fig 3.5: Flexural Strength for beams

Table 3.4: Flexural Strength of Beams

Mix designation	Test Load (kg)	Flexural strength (N/mm^2)	Average flexural strength(N/mm^2)
Plain Concrete	825	3.24	3.28
	750	2.94	
	930	3.65	
SCBA 5%	860	3.37	3.42
	960	3.77	
	795	3.12	
SCBA 10%	840	3.29	3.50
	860	3.37	
	980	3.85	
SCBA 15%	990	3.88	3.84
	990	3.88	
	960	3.77	
SCBA 20%	980	3.85	3.87

Mix designation	Test Load (kg)	Flexural strength (N/mm^2)	Average flexural strength(N/mm^2)
	1000	3.92	
	980	3.85	
SCBA 25%	750	2.94	3.20
	900	3.53	
	800	3.14	

The partial replacement of SCBA with sand gave a 28 days Flexural strength value of 3.87N/mm^2 at 20% replacement level. Increase in Flexural strength associated with partial replacement of sand with SCBA be attributed to frictional resistance's component's contribution to compressive strength arising from the rough and irregular nature of SCBA particles that fills the voids between the SCBA and sand particles while cement binds the components together.

SPLIT TENSILE STRENGTH :

The splitting tensile strength values of SCBA blended concretes after 28 days of curing are shown in Table 3.5 and Fig 3.6. It can be clearly seen that up to 20% of SCBA, the splitting tensile strength values increase and then at 25% of SCBA, the value decreases. Obviously from tensile strength point of view also, 20% of BA is the optimal limit, the split tensile strength of concrete is 4.09N/mm².

Table 3.5: Split tensile strength for Cylinders

Mix designation	Test Load (kN)	Split tensile strength(N/mm^2)	Average split tensile strength(N/mm^2)
Plain Concrete	100	3.18	3.23
	105	3.34	
	100	3.18	
SCBA 5%	110	3.5	3.55
	110	3.5	
	115	3.66	
SCBA 10%	110	3.50	3.39
	105	3.34	
	105	3.34	
SCBA 15%	115	3.66	3.71
	115	3.66	
	120	3.82	
SCBA 20%	125	3.98	4.09
	130	4.14	
	130	4.14	
SCBA 25%	115	3.66	3.61
	110	3.50	
	115	3.66	

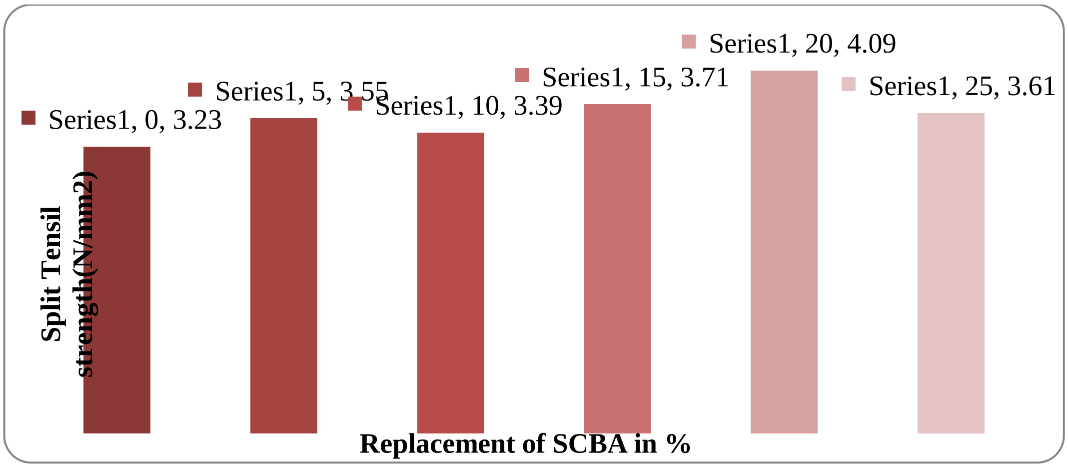

Fig 3.6: Split tensile Strength for cylinders

This confirms the fact that concrete with SCBA up to 20% develops early split tensile strength as compared to control concrete specimens. The reasons for early split tensile strength development of SCBA concretes and increase in split tensile strength up to 20% sand replacement of SCBA may be due to silica content, fineness, amorphous phase, specific surface area, degree of reactivity of SCBA and pozzolanic reaction between calcium hydroxide and reactive silica in SCBA. Therefore 20% SCBA seems to be the optimal limit.

CONCLUSIONS:

The results show that the SCBA in blended concrete had significantly higher compressive strength, tensile strength, and flexural strength compare to that of the concrete without SCBA. It is found that the SCBA could be advantageously replaced with sand up to maximum limit of 20%. The density of concrete decreases with increase in SCBA content, low weight concrete produced in the society with waste materials (SCBA). Based on results obtained from the casted specimens the following conclusions are drawn.

- Use of Bagasse ash reduces the workability.Use of Bagasse ash as sand replacement material, helps the concrete to attain higher strength at early ages (3 and 7 days), which may speed up the construction process.
- The compressive strength of the control mix concrete was 29.83 N/mm^2. The compressive strength was found to be maximum at 20% (43.33N/mm^2) replacement of fine aggregate by sugar cane bagasse ash which was greater than the conventional concrete.
- Split tensile strength and flexural strength was also found to be maximum at 20% (4.09 N/mm^2 and 3.87N/mm^2) replacement which was greater than the conventional concrete (3.23N/mm^2 and 3.28 N/mm^2).

REFERENCES:

. Feng X., Garboczi E.J., Bentz D.P., and Stutzman P.E. (2004): "Estimation of the degree of hydration of blended cement pastes by a scanning electron microscopy point-counting procedure". Building and Fire Research Laboratory, 20899 USA.

Aigbodion V.S, Hassan S.B, Ause T and Nyior G.B. (2010) 'Potential Utilization of Solid Waste (Bagasse Ash)', Journal of Minerals & Materials Characterization & Engineering, Vol. 9, No.1, pp.67-77

Ajay Goyal, Hattori Kunio, Ogata Hidehiko, Mandula "Properties and Reactivity of Sugarcane Bagasse Ash", Department of Environmental Engineering, Tottori University2009.

Akram T, Memon SA, Obaid H. Production of low cost self-compacting concrete using bagasse ash. Constr Build Mater 2009; 23:703–12.

Asokan Pappua, Mohini Saxenaa, Shyam R and Asolekarb (2007) 'Solid wastes generation in India and their recycling potential in building', Materials Building and Environment 42 pg. 2311–2320.

Berry E., Hemmings R.T., Zhang M., Cornelius, B.J., and Golden, D.M. (1994): "Hydration for Structural Engineering and Design, Cooperative Programme, p. 394.

Chusilp, N., Jaturapitakhul, C., and K., Kaittikomol. "Utilization of Bagasse ash as a Pozzolanic Material in Concrete", Construction Materials Journal, 2009: 23: 3352 3358.

Cordeiro G.C, Toledo Filho R.D, Fairbairn E.M.R (2010) 'Ultrafine sugar cane bagasse ash: high potential pozzolanic material for tropical countries ',Ibracon structures and material science (journal) Volume 3, Number 1 pg. 50 – 67.

Mehta P. K. (1997): "Properties Of Blended Cements Made From Rice Husk Ash", ACI Journal Vol.74, No. 9, Page 440 – 442.

Noor-Ul-Amin (2010) 'Chemical activation of Bagasse ash in cementitious system and its impact on strength development', J.Chem.Soc.Pak., vol 32, no 4, pg. 481-484.

Nuntachai Chusilp, Napongsatorn Likhitsripaiboon and Chai Jaturapitakkul, "Development of bagasse ash as a pozzolanic material in concrete", Asian Journal on Energy and Environment, 2009, 10(03), 149-159

Nuntachai Chusilp, Chai Jaturapitakkul, Kraiwood Kiattikomol (2009) 'Utilization of bagasse ash as a pozzolanic material in concrete', Construction and Building Materials Vol 23, Issue 11, pg. 3352-3358.

Osinubi K.J and Stephen Ayuba Thomas (2007) 'Influence of Compactive Efforts on Bagasse Ash Treated Black Cotton Soil', Nigerian Journal of Soil and Environmental Research Vol. 7: pg. 92-101.

Use of Brazilian sugarcane bagasse ash in concrete as sand replacement (2010), Department of Civil Engineering, UFSCar, Via Washington Luis, km 235, Monjolinho, 13565-905 São Carlos, SP, Brazil. almir@ufscar.br

----