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SUSTAINABLE CONCRETE USING AGRICULTURAL WASTE

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ABSTRACT: Today researchers 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 a fibrous waste-product of the sugar refining industry, along with ethanol vapor. This waste product (Sugar-cane Bagasse Ash) is already causing serious environmental pollution, which calls for urgent ways of handling the waste. Bagasse Ash has mainly contains silica and aluminum ion. In this project, the Bagasse ash has been chemically and physically characterized, and partially replaced in the ratio of 0%, 5%, 10%, 15% and 25% by the weight of cement in concrete. Ordinary Portland cement was replaced by ground bagasse ash at different percentage ratios. The compressive strengths of different mortars with bagasse ash addition were also investigated. Wet concrete tests like slump cone test, as well as hardened concrete test like compressive strength, split tensile strength and flexural strength at the age of 7days, 28 days and 90 days were carried out. The test results indicated that up to 10% replacement of cement by bagasse ash results in better or similar concrete properties.
Keywords: Concrete, agro-waste, partial replacement, compressive strength

I. INTRODUCTION

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 is one of the most important agricultural plants that grown in India. Bagasse is a byproduct of the sugarcane industry. The burning of bagasse leaves bagasse ash as a waste, which has a pozzolanic property that would potentially be used as a cement replacement material. It has been known that the worldwide total production of sugarcane is over 1500 million tons. Sugarcane consists about 30% bagasse whereas the sugar recovered is about 10%, and the bagasse leaves about 8% bagasse ash (this figure depend on the quality and type of the boiler, modern boiler release lower amount of bagasse ash) as a waste. The bagasse ash was found to improve some properties of the paste, mortar and concrete including compressive strength and water tightness in certain replacement percentages and fineness. The higher silica content in the bagasse ash was suggested to be the main cause for these improvements. Although the silicate content may vary from ash to ash depending on the burning conditions and other properties of the raw materials including the soil on which the sugarcane is grown, it has been reported that the silicate undergoes a pozzolanic reaction with the hydration products of the cement and results in a reduction of the free lime in the concrete. Bagasse is commonly used as a substitute for wood in many tropical and subtropical countries for the production of pulp, paper and board, such as India, China, Columbia, Iran, Thailand and Argentina. The present study was carried out on sugar cane bagasse ash (SCBA) obtained by controlled combustion of sugarcane bagasse, which was procured from the Samalkot in East Godavari district. This study analyzes the effect of SCBA in concrete by partially replacement of cement at the ratio of 0%, 5%, 10%, 15%, 20%, and 25% by weight. The experimental study examines the compressive strength, spilt tensile strength and flexural strength of concrete. The main ingredients consist of Portland cement, SCBA, river sand, coarse aggregate and water. After mixing, concrete specimens were casted and subsequently all test specimens were cured in water at 7 days, 28 days and 90 days.

The main objective of the work is to study the effect of partial replacement of cement with bagasse ash on the strength. In this work, we study the comparison between strength variation on normal cement concrete (NCC) and bagasse ash replaced concrete. From the study we can find out how much economy can be attained on using bagasse ash as partial replacement for cement. The objectives of using SCBA in concrete.

II. SCOPE OF THE WORK

The scope of present study includes the following aspects: Laboratory tests on cement, fine aggregate, coarse aggregate, bagasse ash, water.Whatever may be the type of concrete being used, it is important to mix design of the concrete. The same is the case with the industrial waste based concrete or bagasse ash replacement. The major work involved is getting the appropriate mix proportions. In the present work, the concrete mixes with partial replacement of cement with bagasse ash were developed using OPC 53 grade cement. A simple mix design procedure is adopted to arrive at the mix proportions. After getting some trail mix, cubes of dimensions 150 mm *150 mm *150 mm, cylinder of dimensions 150mm*300 mm and beams of dimensions 100mm*100mm*150mm was casted and cured in the curing tank. Compressive strength, Split tensile strength and Flexural strength of concrete were conducted to know the strength properties of the mixes. Initially, a sample mix design was followed and modifications were made accordingly while arriving at the trail mixes to get optimized mix which satisfies both fresh, hardened properties and the economy. Finally, a simple mix design is proposed. From previous experimental works, it was found that an optimal amount of 10%-15% of cement can be replaced with bagasse ash. So, to carry out further experimental studies, the cement was replaced by bagasse ash as 5%, 10%, 15%, 20%, and 25% by weight of cement. The changes in properties of concrete mix are studied.

III. MATERIALS

In this section, materials properties and concrete mix design calculations for M30 grade concrete in detail was presented. Raw materials required for the concrete use in the present work are Cement, Coarse Aggregates, Bagasse ash, Fine aggregate, Water.

Ordinary Portland cement:

Ordinary Portland cement is used for general constructions. The raw materials required for manufacture of Portland cement are calcareous materials, such as limestone or chalk and argillaceous materials such as shale or clay.

Testing on Cement:

The following tests as per IS: 4031-1988 is done to ascertain the physical properties of the cement. The results of the tests are compared to the specified values of IS: 4031-1988.

Consistency

The standard consistency of cement paste is defined as consistency, which will permit the Vicat plunger to penetrate to a point 5-7 mm from the bottom of the mould, this test is done to determine the quantity of water required to produce cement paste of standard consistency.

Initial and final setting time:

Lower the needle gently and bring it in contact with the surface of the test block and quickly release. Allow it to penetrate into the test block. In the beginning, the needle will completely pierce through the test block. But after some time when the paste starts losing its plasticity, the needle may penetrate only to a depth of 33-35mm from the top. The period elapsing between the times when water is added to the cement at the time of which the needle penetrates the test block to a depth equal to 33-35mm from the top is taken as initial setting time.

Table 1. Physical properties of cement

S. No	Property	Test results
1	Normal consistency	29%
2	Specific gravity	3.10
3	Initial setting time	42 minutes
4	Final setting time	295 minutes

Aggregates:

Aggregates are the important constituents in concrete. They give body to the concrete, reduce shrinkage and effect economy. Aggregates occupy 70 to 80 percent of volume of concrete.

Fine aggregate (sand):

The size of the fine aggregate is below 4.75mm.Fine aggregates can be natural or manufactured. The grade must be throughout the work. The moisture content or absorption characteristics must be closely monitored. The fine aggregate used is natural sand obtained from the river Godavari conforming to grading zone-II of IS: 10262-2009.

Sieve analysis (fineness modulus):

The process of dividing a sample of aggregates into fractions of same particle size is known as a sieve analysis and its purpose is to find fineness. The sieve analysis was carried out using locally available river sand and found Fineness Modulus =3.48

Specific gravity:

Specific Gravity is defined as the ratio of mass of material to the mass of the same volume of water at the stated temperature. The experiment was conducted as per IS: 2386-1963 and the values are tabulated in table.2

Table 2. Physical properties of fine aggregate

S. No	Property	Value
1	Specific gravity	3.08
2	Fineness modulus	2.82
3	Bulk density: Loose Compacted	$14kN/m^3$ $15kN/m^3$
4	Grading	Zone-II

Coarse aggregate:

The material whose particles are of size are retained on IS sieve of size 4.75mm is termed as coarse aggregate and containing only so much finer material as is permitted for the various types described in IS: 383-1970 is considered as coarse aggregate. Aggregates are the major ingredients of concrete. They constitute 70-80% of the total volume, provide a rigid skeleton structure for concrete, and act as economical space fillers. The properties of aggregate greatly affect the durability and structural performance of concrete. Aggregate was originally viewed as an inert material dispersed throughout the cement paste largely for economic reasons.

The properties of coarse aggregates are given in table 3.

Table 3. Physical properties of coarse aggregate

S. No	Property	Value
1	Specific gravity	2.69
2	Fineness modulus	7.01
3	Bulk density Loose Compacted	$14\ kN/m^3$ $16\ kN/m^3$
4	Nominal maximum size	20 mm

Water

This is the least expensive but most important ingredient of concrete. The quantity and quality of water is required to be looked in to very carefully. In practice very often great control on the properties of all other ingredients is exercised, but the control on the quality of the water is often neglected. Water containing less than 2000 milligrams per litre of total dissolved solids can generally be used satisfactorily for making concrete. Although higher concentration is not always harmful they may affect certain cements adversely and should be avoided where possible. A good thumb rule to follow is, if water is pure enough for drinking it is suitable for mixing concrete.

Table 4. Physical properties of water

S. No	Property	Value
1	$_{P}H$	7.1
2	Colour	Nil
3	Appearance	Clear
4	Turbidity(NT units)	1.75

Sugarcane Bagasse ash

The sugarcane bagasse ash consists of approximately 50% of cellulose, 25% of hemicelluloses 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 sugarcane harvests. In this work sugarcane bagasse ash was collected during the operation of boiler operating in the KCP sugar industry located at Vuyyuru, KrisnaDisrict, A.P District, Andhra Pradesh.

Table 5. Physical Properties of Bagasse Ash

Properties	Values
Specific Gravity	2.20
Colour	Black
Density (gm/cm^3)	1.20
Moisture content	6.28%

Table 6. Chemical composition of Bagasse Ash

Components	Mass %
Silica as SiO_2	70.5
Calcium as CaO	4.7
Potassium as k_2O	12.16
Iron as Fe_2O_3	1.89
Sodium as Na_2O	3.82
Aluminum as Al_2O_3	1.36
Magnesium as MgO	4.68
Titanium as TiO_2	< 0.06

These values are taken from the KCP sugar industry located at Vuyyuru, KrisnaDisrict, A.P. 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 400 million tons/year that cause about 10 million tons of sugarcane bagasse ash as an un-utilized and waste material. According to the world, Brazil leads the world in sugarcane production in 2011 with a 734 TMT tons harvest. India was the second largest producer with 342 TMT tons, and China the third largest producer with 115 125 TMT tons harvest. The average worldwide yield of sugarcane crops in 2011 was 70.54 tons per hectare. The most productive farms in the world were in Ethiopia with a nationwide average sugarcane crop yield of 126.93 tons per hectare.

IV. MIX PROPORTIONS

The process of selecting suitable ingredients of concrete and determining their relative amounts with the objective of producing a concrete of the required, strength, durability, and workability as economically as possible, is termed the concrete mix design. The proportioning of ingredients of concrete is governed by the required performance of concrete in two states, namely the plastic and the hardened states. If the plastic concrete is not workable, it cannot be properly placed and compacted. The property of workability, therefore, becomes of vital importance. The compressive strength of hardened concrete which is generally considered to be an index of its other properties, depending upon many factors, e.g. w/c ratio quality and quantity of cement, water, aggregate, batching, placing, compaction and curing. The cost of concrete is made up of the cost of material, plant and labour. The variation in the cost of material arise from the fact that the cement is several times costly than the aggregates, thus the aim is to produce as lean a mix as possible. The actual cost of concrete is related to the cost of materials required for producing a minimum mean strength called characteristic strength that is specified by the designer of the structure. This depends on the quality control measures, but there is no doubt that the quality control adds to the cost of concrete. The cost of labour depends on the workability of mix.

Factors to be considered for mix design:

The grade designation, (the characteristic strength requirement of concrete).The type of cement influences the rate of development of compressive strength of concrete. Maximum nominal size of aggregates to be used in concrete may be as large as possible within the limits prescribed by IS: 456-2000.The cement content is to be limited from shrinkage, cracking and creep.The workability of concrete for satisfactory placing and compaction is related to the size, shape, quantity and spacing of reinforcement and technique used for transportation, placing and compaction.

Design of M30 grade concrete:

Mix proportions obtained for trail are given below:

Cement = 378 kg/ m³
Water = 159litre
Fine aggregate = 797kg
Coarse aggregate = 1238kg
Water Cement ratio = 0.42

V. EXPERIMENTAL WORK

It was proposed to investigate the properties of concrete, cast with partial replacement of cement with bagasse ash in the ratio of 0%, 5%, 10%, 15%, 20% and 25% proportions and cured in water.

Table 7. No. of specimens prepared for determining hardened properties.

Specimens	**No. of specimen cured in water**					
Ingredients	NORMAL MIX	SC BA 5%	SC BA 10 %	SC BA 15 %	SC BA 20 %	SC BA 25 %
Cubes	9	9	9	9	9	9
Cylinders	9	9	9	9	9	9
Beams	9	9	9	9	9	9

Casting of concrete cubes, cylinders and beams:

The test moulds were kept ready before preparing the mix. Moulds were cleaned and oiled on all contacts surfaces then fixed on vibrating table firmly. The concrete is filled into moulds in three layers and then vibrated. The top surface of concrete is strucked off to level with a trowel. The number and date of casting were put on the top surface of the cubes, cylinders and beams. The test results of the cubes added with CI were compared to the test results of the controlled specimen. All the materials used in this investigation i.e. cement, fine aggregate, coarse aggregate, cast iron turnings. The cement, sand, coarse aggregate, cast iron turnings were mixed thoroughly manually. Approximately 25% of water required is added and mixed thoroughly with a view to obtain uniform mix. After that, the balance of 75% of water was added and mixed thoroughly with a view to obtain uniform mix. Care has to be taken in mixing to avoid balling effect.

VI. RESULTS & DISCUSSION

In this section, the experimental observations discussed are presented. Observations of slump and compaction factor in respect of fresh concrete are noted. The test results such as compressive strength, split tensile strength and flexural strength of hardened concrete of M30 grade replacement of cement with bagasse ash in the ratio of 0%, 5%, 10%, 15%, 20% and 25% proportions mixes at the ages of 7 days , 28 days and 90 days are detailed.

Compressive strength of concrete tested on cubes at different partial replacement of bagasse ash was tested in water curing tank and the test results were shown in below.

Slump cone test:

The slump cone test was conducted for all the six mixes. Slump for different mixes are shown below:

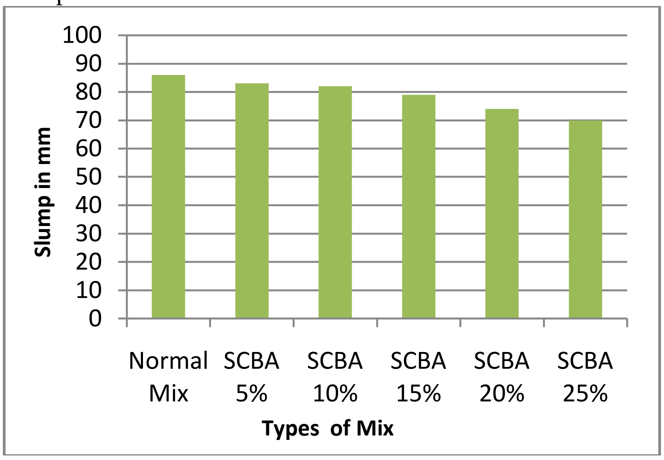

Figure 1. Slump tests mixes

The slump for SCBA 5% has decreased 4.7% when compared with the Normal Mix. The slump for SCBA 10%, SCBA 15%, SCBA 20% and SCBA 25% has reduced by 6.9 %, 10.5%, 16.3% and 21% when compared with Normal mix. The slump value was gradually decreases when compared with normal mix. To improve the slumps we can use the chemical admixture like super plasticizer.

Compressive strength:

The compressive strength of the concrete was done on 150 x 150 x 150 mm cubes. A total of 54 cubes were cast for the five mixes. i.e., for each mix 9 cubes were prepared. Testing of the specimens was done at 7 days, 28 days and 90 days, at the rate of three cubes for each mix on that particular day. The average value of the 3 specimens is reported as the strength at that particular age. The compressive strength test was conducted for all the mixes and the results are shown in the table below.

Table 8. Compressive strength test results

S.No	Mix ID	Compressive Strength (N/mm^2)		
		7 Days	28 Days	90 Days
1	NORMAL MIX	29.13	36.18	37.93
2	SCBA 5%	28.15	36.89	38.67
3	SCBA 10%	27.26	37.52	39.85
4	SCBA 15%	24.44	33.93	35.41
5	SCBA 20%	21.93	30.07	31.56
6	SCBA 25%	19.26	24.85	26.52

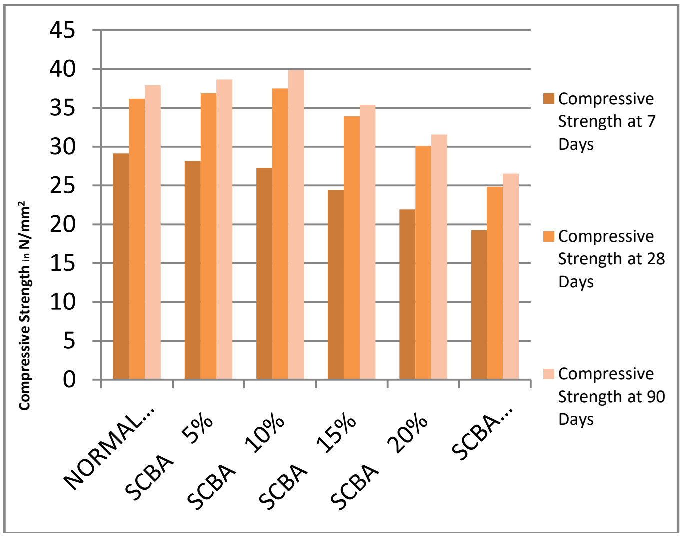

Figure 2. Compressive Strength vs age

The compressive strength values obtained by testing standard cubes made with different proportions of SCBA 0%-25%. From the study of all the above percentages of replacements, it was observed that the SCBA 10% gives the optimum compressive strength.

Split tensile strength:

The indirect tensile strength was measured on 150 x 300 mm cylinders and the results were shown below. A total of 54 cylinders were cast for the five mixes. Three specimens were tested each time and the average value at the particular age was reported as the tensile strength of the concrete.

Table 9. Split tensile strength test results

S.No	Mix ID	Split Tensile Strength (N/mm^2)		
		7 Days	28 Days	90 Days
1	NORMAL MIX	1.89	2.55	2.64
2	SCBA 5%	1.63	2.59	2.72
3	SCBA 10%	1.60	2.75	2.83
4	SCBA 15%	1.42	2.25	2.31
5	SCBA 20%	1.17	1.92	2.03
6	SCBA 25%	1.06	1.76	1.83

The tensile strength values obtained by testing standard cylinders made with different mixes with different bagasse ash proportions of 0-25%.

Finally it was observed that the SCBA 10% replacement gives the highest value compared with the other replacements.

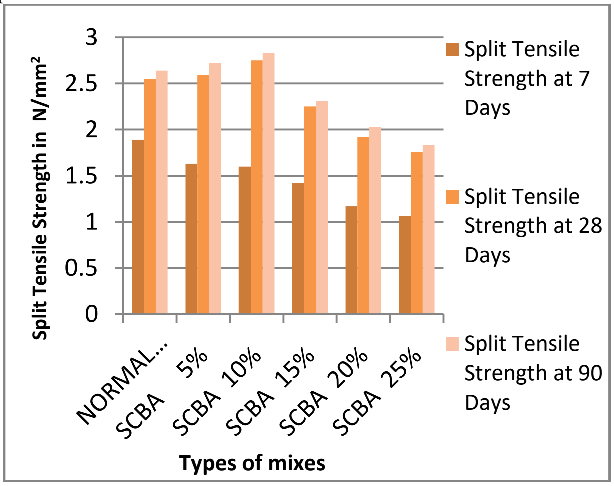

Figure 3. Split Tensile Strength graph vs age

Flexural strength:

Flexural strength of the concrete was determined from modulus of rupture test on beam specimens of 100 x 100 x 500 mm size. Here also, a total of 54 specimens were cast out of which three specimens were tested for each mix at 7days, 28 days and 90 days.

Table 10. Flexural strength test results

S.No	Mix ID	Flexural Strength (N/mm^2)		
		7 Days	28 Days	90 Days
1	NORMAL MIX	4.67	5.87	6.25
2	SCBA 5%	4.53	6.13	6.52
3	SCBA 10%	4.53	6.43	6.92
4	SCBA 15%	3.33	5.75	5.85
5	SCBA 20%	3.20	4.93	5.22
6	SCBA 25%	3.07	4.13	4.66

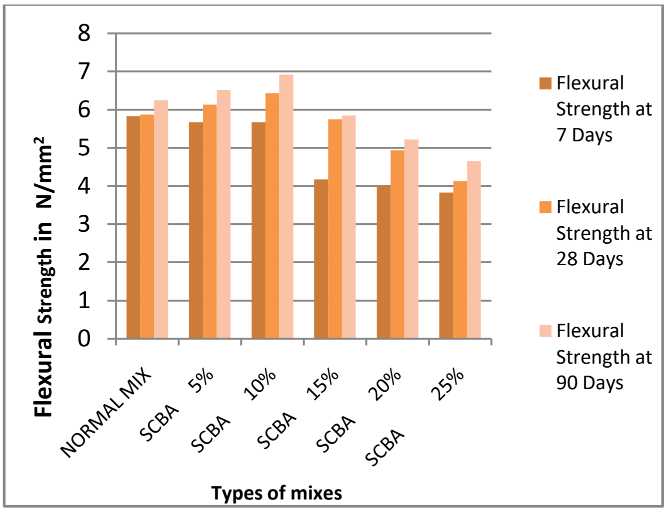

Figure 4. Flexural Strength graph vs Age

The flexural strength values obtained by testing standard cubes made with different SCBA mixes of 0-25%.

Finally it was observed that the SCBA 10% replacement gives the highest value compared with the other replacements

VII. CONCLUSIONS

Following conclusions can be drawn from the experimental investigation carried out.

1. There is a change in slump for SCBA 5% has decreased 3.5% when compared with normal mix.
2. The slump for SCBA 10%, SCBA 15%, SCBA 20% and SCBA 25% has reduced by 4.7%, 8.2%, 14% and 18.7% respectively when compared with the normal mix.
3. The compressive strengths of SCBA mixes at the age of 7 days was gradually decreases its strength when compared with normal mix.
4. It was observed that the compressive strength of SCBA 5% and SCBA 10% at the age of 28 days has reached its target mean strength; however the compressive strength was increased by 2.04% and 6.55% when compared with normal mix.
5. It was observed that the compressive strength of SCBA 15%, SCBA 20% and SCBA 25% at the age of 28 days has decreases its compressive strength by 6.15%, 16.92% and34.13% respectively when compared with the normal mix.
6. The split tensile strength of mixes SCBA 5% and SCBA 10% at the age of 28 days has increases its strengths by 4.42% and 9.5% respectively when compared with the normal mix.
7. The split tensile strength of mix SCBA 15%, SCBA 20%, SCBA 25% at the age of 28 days has decreases it strengths by 11.8%, 24.8% and 32.7% when compared with the normal mix.
8. The flexural strength of SCBA 5%, SCBA 10% at the age of 28 days has increases its strength by 4.42%, 9.5% when compared with the normal mix.
9. As a final conclusion, cement can be replaced with bagasse ash up to 10% without much loss in compressive strength. Similar kind of trend was observed with split tensile strength, and flexural strength also.
10. Considerable decrease in compressive strength was observed from 15% onwards cement replacement. It has been shown in this study that 10% sugarcane bagasse ash can be used as a partial cement replacement material with technical and environmental benefits.

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