STUDIES ON GREENER CONCRETE WITH PARTIAL REPLACEMENT OF BAGGASE ASH

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ABSTRACT

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. 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. M30 concrete mixes with bagasse ash replacements of 0%, 5%, 10%, 15%, 20% and 25% of the Ordinary Portland cement were prepared with water cement ratio of 0.42 and cement content of 378 kg/m3 for the control mix. 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 and hence environmental and economic advantages can be exploited by using bagasse ash as a partial cement replacement material.

Keywords: *Concrete, agro-waste, partial replacement, compressive strength.*

INTRODUCTION

The industrial and economic growth witnessed in recent decades has brought with it an increase in the generation of different types of waste (urban, industrial, construction etc.) despite the waste management policies which have been adopted nationally and internationally the practice of dumping and/or the inadequate management of waste from the various manufacturing sectors have had a notable impact on the receiving environment. At the same time, these practices represent an economic cost. However if waste is managed correctly it can be converted into a resource which contributes to savings in raw materials, conservation of natural resources and the climate, and promotes sustainable development.

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. Despite variety use of bagasse, for production of wood, papers, animal food, compost and thermal insulation, statistics show that about one million tone extra of bagasse ash remains in the country.

Sugarcane bagasse ash has recently been tested in some parts of the world for its use as a cement replacement material. 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.

LITERAURE REVIEW

R.Srinivasn, Vol. 5, 2010, International Journal for service learning in Engineering, examine a review on **"Experimental study on use of bagasse ash in concrete"**. Bagasse ash mainly contains aluminum ion and silica. In this paper, Bagasse ash has been chemically and physically characterized, and partially replaced in the ratio of 0%, 5%, 15% and 25% by weight of cement in concrete. Fresh concrete tests like compaction factor test and slump cone test were undertaken was well as hardened concrete tests like compressive strength, split tensile strength, flexural strength and modulus of elasticity at the age of seven and 28 days was obtained. The result shows that the strength of concrete increased as percentage of bagasse ash replacement increased. This paper reviews the use of bagasse ash as replacement of cement material in concrete.

Yashwanth M.K, Maharaja, Institute of Technology, Mysore, Vol.3 January 2014, International Journal of Latest Trends in Engineering and Technology (IJLTET). He examined that **"An Experimental study on bagasse ash as replacement for cement in light weight concrete"**. The present study is to investigate experimentally the fresh and hardened properties of lightweight concrete using sugarcane bagasse ash(SCBA) as replacement for cement by weight at 0%, 5%, 10%, 15% and 20% and expanded polystyrene (EPS) beads as 100% replacement for coarse aggregate respectively. From the result it was found that there is marginal increase in workability with bagasse ash content up to 10% beyond that there is possibility of reduction in slump value. The compressive strength of lightweight concrete increases with bagasse content up to 15% and beyond this there is possibility of drastic reduction in strength and this 15% bagasse ash replacement strength is slightly less than OPC based lightweight concrete at 28 days but this value is comparable.

Prashant O Modania, M.R Vyawahareb, Vol.4 2013 Procedia Engineering. He examined "**Utilization of bagasse ash as a partial replacement of fine aggregate in concrete**". 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 at the age of 7 days and 28 days. The result shows that bagasse ash can be a suitable replacement to fine aggregate up to 20%.

AbdolkarimAbbasi and Amin Zargar, Middle-East Journal of Scientific Research 2013. He examined a review on **"Using bagasse ash in concrete as pozzolanic".** The aim of this research is to use bagasse ash as pozzolan. In this research the moisture percent and the method of burning bagasse, physical characteristics, chemical combination (XRF test), crystal fixtures (XRD test) and specific area of bagasse ash were investigated and compared with cement and micro silica. Replacing cement by 10% of bagasse ash by fine grade (specific area of 9000cm /gr), the workability and flow ability is optimized and their compressive strength 7 at 28 days is increased by 25% in comparison with normal concrete specimens. Using bagasse ash has no effect on the setting time and absorbing water. Due to wastage nature of bagasse the producing cost is predicted to be low and can be replaced as cement.

M. Siva kumar and N. Mahendran, Vol.2 2013, International Journal of Engineering Research & Technology. He examined "**Experimental studies of strength and cost analysis of concrete using bagasse ash"**. The Bagasse ash mixture provides strength equal to the nominal strength of the concrete and reduces the cost at a large & scale. Various moulds were casted for the different properties of bagasse ash and Cement concrete i.e. replacement of cement with various percentage of Bagasse ash. The various specimens were tested for the compressive strength and the most optimum value was found out. Cost analysis was done on the account of optimum replacement of the account of optimum replacement of the cement. The tests reveal the cost to be lesser than the initial cost. Use of Bagasse ash also contributes to the reduction of waste disposal by the industries which reveal that the environmental hazards from the waste materials.

SumrerngRukzon, PrinyaChindaprasirt Vol-34, 45-50 (2012).**"Utilization of bagasse ash in high-strength concrete"**. This paper presents the use of bagasse ash (BA) as a pozzolanic material for producing high-strength concrete. Portland cement type I (PC) is partially replaced with finely ground bagasse ash. The concrete mixtures, in part, are replaced with 10%, 20% and 30% of BA respectively. In addition, the compressive strength, the porosity, the coefficient of water absorption, the rapid chloride penetration and the chloride diffusion of concretes are determined. The test results indicate that the incorporation of BA up to 30% replacement level increases the resistance to chloride penetration. Besides, the use of 10% of BA produced concretes with good strength and low porosity. Reasonably, the substitution of 30% BA is acceptable for producing high-strength concrete.

Mao Chieh Chi, examined Volume 19, Issue 3, 2012, Pages 279–285, **"Effects of sugar cane bagasse ash as a cement replacement on properties of mortars".** In this study, SCBA with particle sizes <45 μm was used to replace type I ordinary Portland cement with various dosages (10%, 20%, and 30%) by weight of binder. The water/cementitious material (w/cm) and sand/binder ratios were kept at constants of 0.55 and 2.75, respectively. Experimental results show that the flow spread of fresh mortars would decrease with an increase of SCBA replacement. The specimens with 10% SCBA have the superior performance on compressive strength, drying shrinkage, water absorption, initial surface absorption, and chloride ion penetration, TGA, and SEM at the age of 56 days. It indicates that 10% cement replacement of SCBA may be considered as the optimum limit.

MATERIAL USED

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.

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. Since quality of the water effects strength, it is necessary for us to go in to the purity and quality of water. The water, which is used for making solution, should be clean and free from harmful impurities such as oil, alkali, acid, etc. in general, the distilled water should be used for making solution in laboratories. 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 Physical properties of water

S. No	Property	Value
1	pH	7.1
2	Taste	Agreeable
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 (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 sugarcane harvests. In this sugarcane bagasse ash was collected during the operation of boiler operating in the Nava Bharat Ventures Sugar Factory, located in the Samalkot, East Godavari District, Andhra Pradesh.

Fig.Sugarcane Bagasse

Physical properties of bagasse ash

Table-Physical Properties of Bagasse Ash

Properties	Values

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

Chemical properties of bagasse ash

Table-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 Nava Bharat sugar industry located at samalkot

Fig. Bagasse Ash

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.

EXPERIMENTAL WORK

Process of manufacturing of concrete:

Aggregates: The coarse aggregate was kept completely immersed in clean water for 24 hours for water absorption. After 24 hours, the aggregate was gently surface dried. It was then spread out and exposed to the atmosphere until it appears to be completely surface dry. For fine aggregate, considering the huge time to be taken to become surface dry from wet condition, it was not immersed in water. Instead the water was sprinkled then it was spread out and exposed to the atmosphere until it appears to be completely surface dry.

Batching: Batching means measuring the quantities of constituents of concrete required for the preparation of concrete mix. Weight batch method is adopted to measure the quantities. The quantities of fine aggregate, coarse aggregate, cement, water and bagasse ash for each batch were measured by a weighing balance according to the mix proportions obtained by the mix design.

Mixing: The object of mixing is to coat the surface of all aggregate particles with Cement paste and to blend all the ingredients of concrete into a uniform mass. Though mixing of the materials is essential for the production of uniform concrete. The mixing should ensure that the mass becomes homogeneous, uniform in colour and consistency. In this study the process of machine mixing was adopted.

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.

Curing: The cast moulds are dried then the moulds are un moulded, then cubes, cylinders and beams were kept for curing in potable water.

Workability: Workability is a property of fresh concrete. It is, however, also a vital property as far as the finished product is concerned because concrete must have workability such that compaction to maximum density is possible with a reasonable amount of work or with the amount that we prepared to put in under given conditions.

According to ACI, workability is that property of the freshly mixed concrete or mortar which determines the ease and homogeneity with which it can be mixed, placed, consolidated and finished.

Workability of the concrete can be measured in many ways. Here, workability in terms of slump and compaction factor was considered for the present study.

Slump cone test: This test is used extensively in site all over the world. The slump test does not measure the workability of concrete, but the test is very useful in detecting variations in the uniformity of a mix of given nominal proportions.

The slump test is done as prescribed by IS: 516.The apparatus for conducting the slump test essential consists of a metallic mould in the form of a cone having the internal dimensions as under

Bottom diameter : 200 mm

Top diameter : 100 mm

The mould for slump is a frustum of a cone, 300 mm high. It is placed on a smooth surface with the smaller opening at the top, and filled with concrete in three layers. Each layer is tamped twenty five times with a standard 16 mm diameter steel rod, rounded at the end, and the top surface is strucked off by means of sawing and rolling motion of the tamping rod. The mould must be firmly fixed against its base during the entire operation; this is facilitated by handles or foot-rests brazed to the mould. Immediately after filling, the cone is slowly lifted vertically up, and the unsupported concrete will now slump – hence the name of the test. The difference in level between the height of the mould and that of highest point of subsided concrete is measured. This difference in height in mm is taken as slump of concrete.

Compaction factor test:

There is no generally accepted method of directly measuring the amount of work necessary to achieve full compaction, which is a definition of workability. Probably the best test yet available uses the inverse approach: the degree of compaction achieved by a standard amount of work is determined. The work applied includes perforce the work done against the surface friction but this is reduced to a minimum, although probably the actual friction varies with the workability of the mix.

The degree of compaction, called compacting factor, is measured by the density ratio, i.e. the ratio of the density actually achieved in the test to the density of the same concrete fully compacted.

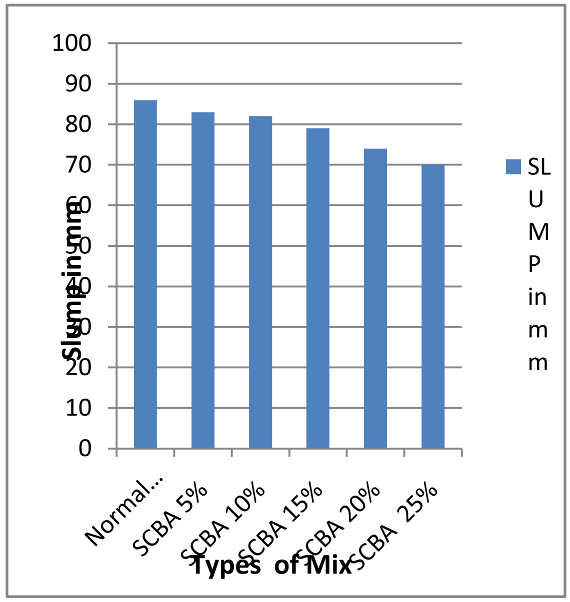
The test known as the compacting factor is described in IS: 516 and is appropriate for concrete with a maximum size of aggregate up to 40 mm. the apparatus consists essentially of two hoppers, each in the shape of the frustum of a cone, and one cylinder of 15cm and 30cm internal height and internal diameter respectively, the three being above one another. The hoppers have hinged doors at the bottom. All inside surfaces are polished to reduce friction.

The upper hopper is filled with concrete, this being placed gently so that at this stage no work is done on the concrete to produce compaction. The bottom door of the hopper is then released and the concrete falls into the lower hopper, this is smaller than the upper hopper one and is, therefore, filled to overflowing, and thus always contains approximately the same amount of concrete in a standard state; this reduces the influence of the personal factor in filling the top hopper. The bottom door of the lower hopper is then released and the concrete falls into the cylinder. Excess concrete is cut by two floats slid across the top of the mould, and the net mass of concrete in the known volume of the cylinder is determined.

The weight of the concrete in the cylinder is now, calculated, and this weight is divided by the weight of the fully compacted concrete is defined as the compacting factor. The latter weight is obtained by filling the cylinder with concrete in four layers, each tamped 25 times with 16 mm diameter tamping rod with rounded end or vibrated.

TEST RESULTS

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



Graph Slump test vs mixes

Compressive strength:

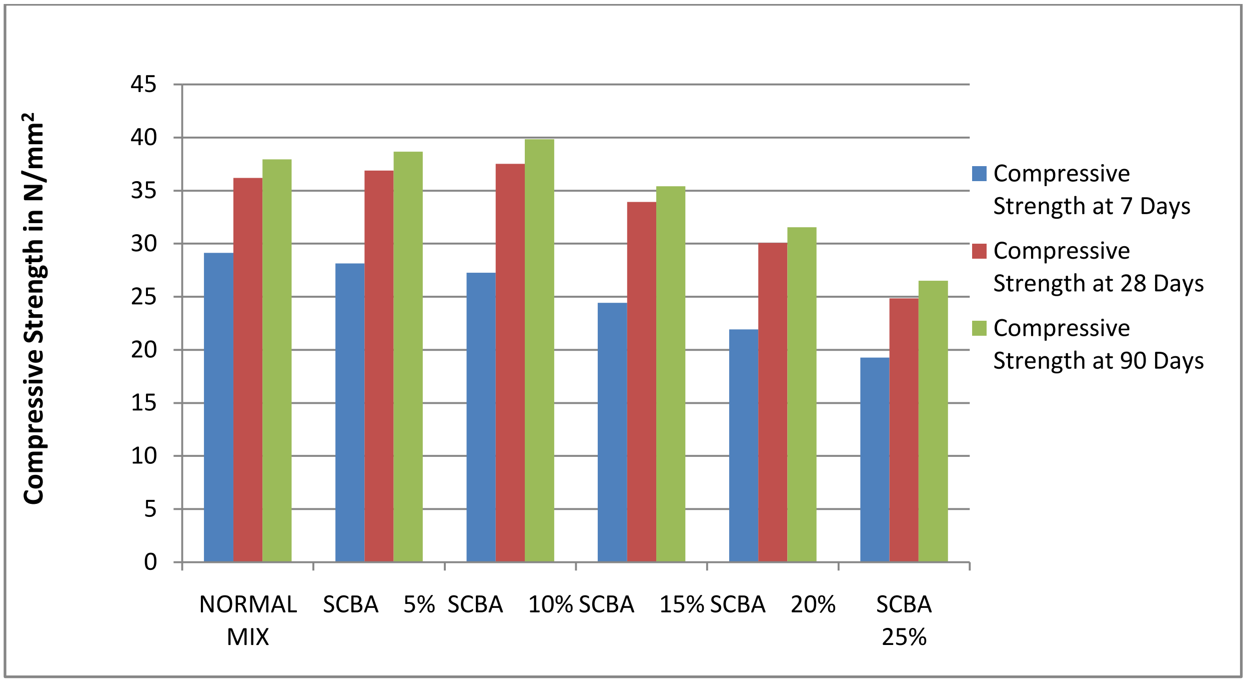
The compressive strength of the concrete was done on 150 x 150 x 150 mm cubes. A total of 54 cubes were cast for the five mixes. i.e., for each mix 9 cubes were prepared. Testing of the specimens was done at 7 days, 28 days and 90 days, at the rate of three cubes for each mix on that particular day. 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 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



Graph: Compressive Strength vs age

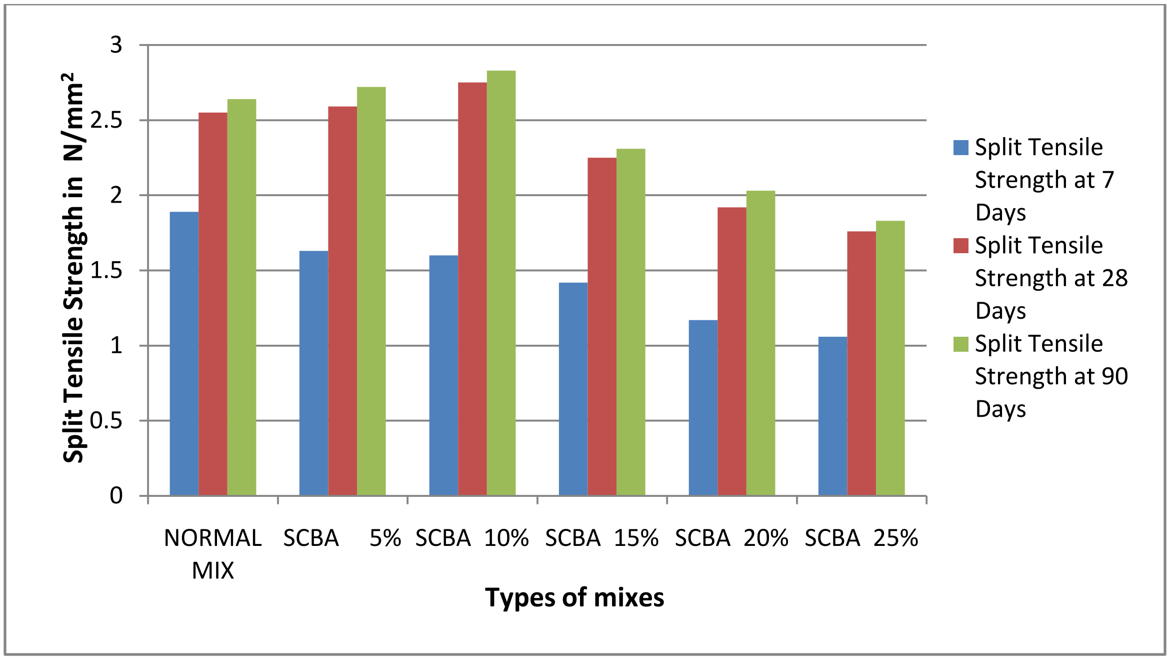
Split tensile strength:

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: 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



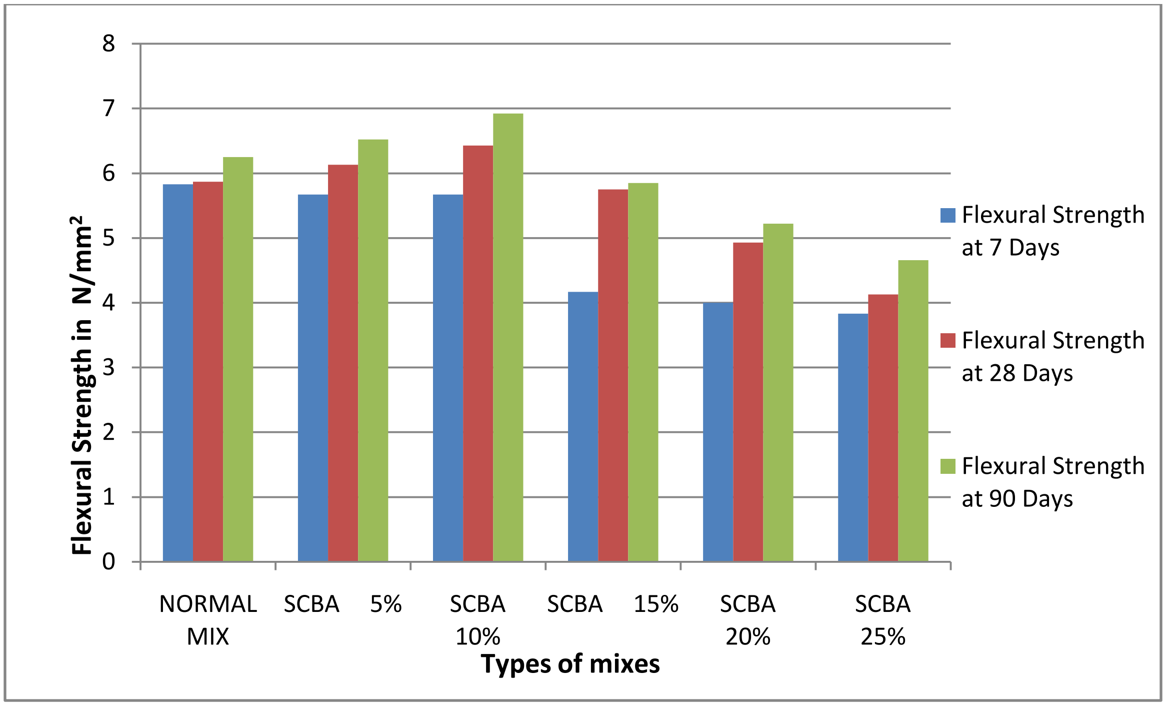
Graph Split Tensile Strength graph vs age

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: 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



Graph: Flexural Strength graphvs Age

Conclusions: Based on the study, following conclusions can draw.

i. There is a change in slump for SCBA 5% has decreased 3.5% when compared with normal mix.

ii. 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.

iii. The compressive strengths of SCBA mixes at the age of 7 days was gradually decreases its strength when compared with normal mix.

iv. 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.

v. 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.

vi. 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.

vii. 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.

viii. 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.

ix. Cement can be replaced with bagasse ash up to 10% without much loss in compressive strength.

x. Considerable decrease in compressive strength was observed from 15% cement replacement.

xi. 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. Concerned stakeholder, such as sugar industries, cement industries and relevant government institutions, should be made aware about this potential cement replacement material and promote its standardized production and usage.

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