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## UTILIZATION OF SUGARCANE BAGASSE ASH AS A SUPPLEMENTARY CEMENTITIOUS MATERIAL IN CONCRETE AND MORTAR - A REVIEW

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### ABSTRACT

In developing countries, accumulation of unmanaged agricultural waste has resulted in an increased environmental concern. Recycling of such agricultural wastes is the viable solution not only to pollution problem, but also the problem of land filling. In view of utilization of agricultural waste in concrete and mortar, the present paper reviews, utilization of sugarcane bagasse ash (SCBA) in different compositions that were added to the raw material at different levels to develop sustainable concrete and mortar. Various physico-mechanical properties of the concrete and mortar incorporating sugarcane bagasse ash are reviewed and recommendations are suggested as the outcome of the study.

The study in turn is useful for various resource persons involved in using SCBA material to develop sustainable construction material.

**Keywords:** Agro Waste, Cementitious Material, Concrete, Mortar, Sugarcane Bagasse Ash.

### 1. INTRODUCTION

Agro wastes are used in construction material. 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 concrete and mortar [1]. Sugarcane is major crop grown in over 110 countries and its total production is over 1500 million tons. Sugarcane production in India is over 300 million tonnes per year. The processing of it in sugar-mill generates about 10 million tonnes of SCBA as a waste material. One tonne of sugarcane can generate approximate 26% of bagasse and 0.62% of residual

ash. The residue after combustion presents a chemical composition dominated by silicon dioxide [2-3]. In 2009, the total production of sugarcane in the world was estimated to be approximately 1661 million tons. The largest producer of sugarcane is Brazil and India is the second largest [4-7]. After the extraction of all economical sugar from sugarcane, about 40-45% fibrous residue was 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). The SCBA contains high amounts of un-burnt matter, silicon, aluminium and calcium oxides [8, 9]. Bagasse is often used as a primary fuel source for sugar mills; when burned in quantity, it produces sufficient heat energy to supply all the needs of a typical sugar mill. The dumping of these industrial wastes in open land poses a serious threat to the society by polluting the air and waste bodies. This also adds the non-availability of land for public use [10-14]. In the present study the utilization of SCBA (Sugarcane bagasse ash) in concrete and mortar by various researchers were reviewed.

## **2. DEVELOPMENT OF CONCRETE BY SUGARCANE BAGASSE ASH**

Ganesan et al. [1] studied the effects of SCBA content as partial replacement of cement (0-30%) on physical and mechanical properties of hardened concrete. The properties of concrete were investigated include compressive strength, splitting tensile strength, water absorption, permeability characteristics, chloride diffusion and resistance to chloride ion penetration. All tests carried out in accordance with Indian Standards. The test results indicated that SCBA is an effective mineral admixture up to 20% replacement was advantageous. The increase in strength may be due partially to the pozzolanic reaction. [15–20].

Nunta chai et al. [2] examined the importance of bagasse ash for development as pozzolanic materials in concrete. The physical properties of concrete containing ground bagasse ash (BA) including compressive strength, water permeability, and heat evolution were investigated and all tests were done in accordance with American Standards. When bagasse ash is ground up into small particles, the compressive strength of concrete containing this ground bagasse ash improves significantly [21]. The low water permeability values of concretes containing ground bagasse ash at 90 days were mostly caused by the pozzolanic reaction [22]. The higher the replacement fraction of Portland cement by ground bagasse ash, the longer the delay time to obtain the highest temperature rise. [23,24]. Concrete containing up to 30% ground bagasse ash had a higher compressive strength and a lower water permeability than the control concrete, both at ages of 28 and 90 days.

Kawade et al. [3] studied the effect of use of SCBA on strength of concrete by partial replacement of cement at the ratio of 0%, 10%, 15%, 20%, 25% and 30% by weight for compressive strength. If some of raw material having similar composition can be replaced by weight of cement in concrete then cost could be reduced without affecting its quality [25]. It was found that the cement could be advantageously replaced with SCBA up to maximum limit of 15%. Partial replacement of cement by SCBA increases workability of fresh concrete; therefore use of super plasticizer is not essential. All tests were done in accordance with American Standards.

Abbasi et al. [4] studied the moisture percent and the method of burning bagasse, physical characteristics, chemical composition by XRF (X-ray fluorescence), crystal fixtures by XRD (X-ray diffraction) test and specific area of bagasse ash and compared with cement. The burning of bagasse will produce very viscous smoke that causes difficulties for producers and near residential [26]. Replacing cement by 10% of bagasse ash, their compressive strength at 28 days was increased by 25% in comparison with normal concrete specimens. Use of bagasse ash in concrete as 10% cement replacement causes slump increase and compressive strength and delayed in initial and final setting time. As per American Standards the above mentioned tests were conducted.

Modani et al. [5] optimized the workability and flow ability. Bagasse ash was partially replaced in the ratio of 0%, 10%, 20%, 30% and 40% by volume of fine aggregate in concrete. Fresh

concrete tests like the compaction factor test and the slump cone test were undertaken along with hardened concrete tests like compressive strength, split tensile strength and sorptivity in accordance with Indian Standards. The result showed that bagasse ash can be a suitable replacement to fine aggregate.

Srinivasan et al. [6] studied chemical and physical characterization of SCBA, and partially replaced in the ratio of 0%, 5%, 15% and 25% by weight of cement in concrete. Compressive strength, split tensile strength, flexural strength and modulus of elasticity at the age of 7 and 28 days was obtained as per Indian Standards. It was found that the cement could be advantageously replaced with SCBA up to a maximum limit of 10%. Therefore it is possible to use sugarcane bagasse ash (SCBA) as cement replacement material to improve quality and reduce the cost of construction materials such as concrete [27].

Horsakulthai et al. [7] studied the compressive strength, the durability to chloride penetration and the corrosion of concrete containing bagasse-rice husk-wood ash (BRWA) in accordance with American Standards. The Portland cement was partially replaced with BRWA at the dosage of 10% and 20% by weight of binder. The chloride penetration resistance of the concretes was evaluated using the measurement of non-steady state chloride diffusion coefficient by accelerated salt ponding.

Somna et al. [8] studied the utilization of a pozzolanic material to improve the mechanical properties and durability of recycled aggregate concrete. Ground bagasse ash (GBA) was used to replace Portland cement at the percentages of 20, 35, and 50 by weight of binder. SCBA used to replace natural coarse aggregate not more than 25% by weight [28]. When GBA was used to partially replace cement in recycled aggregate concrete, the chloride penetration decreased and was lower than those of control concrete at the same immersed time [29]. Compressive strength, modulus of elasticity, water permeability, and chloride penetration depth of the concretes were determined as per American Standards. Recycled aggregate concrete by incorporating SCBA has the modulus of elasticity, lower than that of the conventional concrete by approximately 25–26% [30,31].

Montakarntiwong et al. [9] studied two different sources of bagasse ash with low and high loss on ignition (LOI). Ordinary Portland cement was replaced by bagasse ash at the levels of 20%, 30%, and 40% by weight of binder. The effects of LOI, fineness, and cement replacement of bagasse ash on the compressive strength of concrete were investigated as per American Standards. The value of LOI was not only the weight of unburned carbon in the ash and there was a possibility of a small amount of contribution from some slow mineral phase decomposition reactions [32]. The results revealed that the compressive strength of concrete containing ground bagasse ash was much lower than that of control concrete.

Sivakumar et al. [10] conducted the various tests on bagasse ash for the physical and chemical properties such as fineness, specific gravity, initial & final setting time in accordance with Indian Standards. Various moulds were cast 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 the 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 of the waste materials.

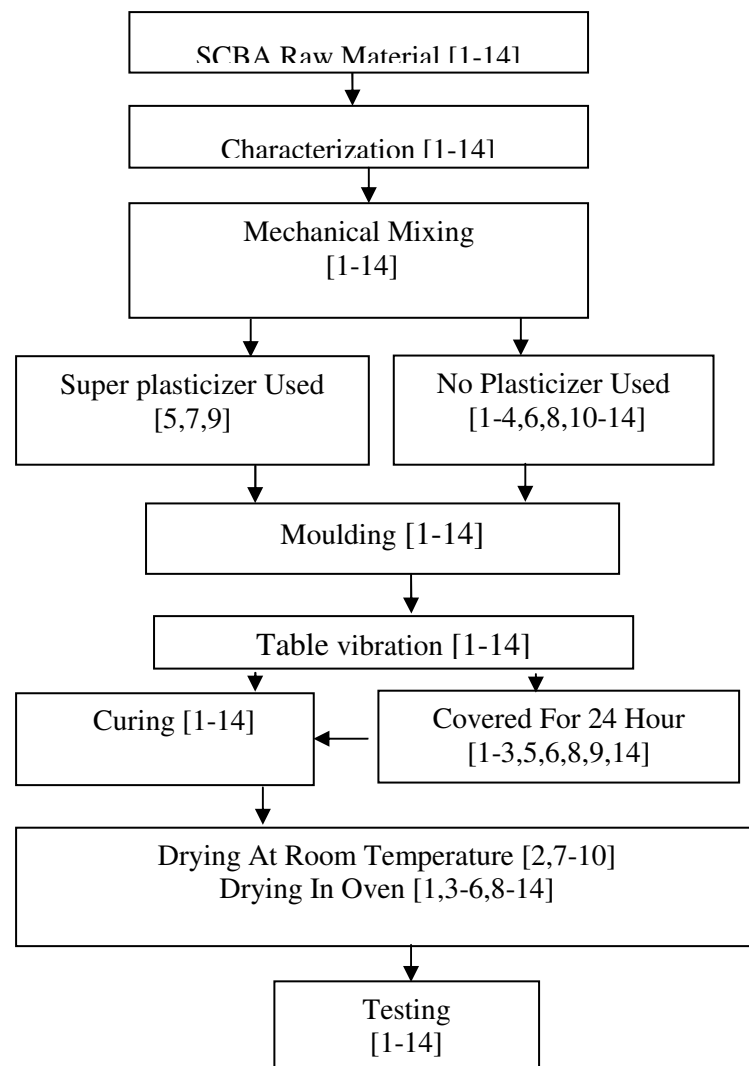
Otuoze et al. [11] concluded that SCBA was a good pozzolana for concrete cementation and partial blends of it with OPC could give good strength development and other engineering properties in concrete. An optimum of 10% SCBA with OPC could be used for reinforced concrete with dense aggregate. The replacement of cement by SCBA was 0-30% and in accordance with American and Brazilian Standards all tests were carried out.

Brittany [12] studied the chemical and physical characteristics of sugarcane bagasse ash and compressive strength test, tensile strength were investigated in accordance with American Standards

by the replacement of 0-30%. Bagasse ash can increase the overall strength of the concrete when used up to 20% cement replacement level.

Vyavhare et al. [13] optimized the workability and flowability. Bagasse ash was partially replaced in the ratio of 0%, 10%, 20%, 30% and 40% by volume of fine aggregate in concrete. Fresh concrete tests like the compaction factor test and the slump cone test were undertaken along with hardened concrete tests like compressive strength, split tensile strength and sorptivity in accordance with Indian Standards. The result shows that bagasse ash can be a suitable replacement to fine aggregate.

Lavanya et al. [14] examined the partial replacement for cement in conventional concrete. The tests were conducted as per Bureau of Indian Standards (BIS), IS 516-1959 codes to evaluate the suitability of SCBA for partial replacements up to 30% of cement with varying water cement (w/c) ratio. The physical properties of SCBA were studied. Compressive strengths (7, 14 and 28 days) were determined in accordance with Indian Standards. The results showed that the addition of sugarcane bagasse ash improves the strengths in all cases. The maximum strength increase happens at 15% with 0.35w/c ratio.



**Fig. 1.** Methodology followed for manufacturing of SCBA concrete specimen

**Table 1.** Detailing of Each References (1-14)

Ref. No.	SCBA Replacement %	Superplasticizer %	W/C ratio	Various test conducted	Curing days	Size of cube mould(mm)	Size of cylinder mould(mm)
1	0-30	----	0.53	Particle size distribution, Compressive strength, Split tensile strength, water absorption, sorptivity, chloride penetration, chloride diffusion	7,28	100×100×100	150×300
2	0-30	----	0.50	Compressive strength, Water permeability, heat evolution	28,90	-----	100×200
3	0-30	-----	-----	Compressive strength	7,28,56,90	150×150×150	-----
4	0-10	-----	-----	XRF test, XRD test, Compressive strength	7,28	-----	200×100
5	0-40	0.8	0.40	Compressive strength, split tensile strength, sorptivity	7,28	150×150×150	150×300
6	0-25	-----	0.48	Compressive strength, split tensile strength, flexural strength, modulus of elasticity, bulk density	7,28	150×150×150	150×300
7	0-40	0.8	0.45	Particle size distribution, Compressive strength,	7,28,91,180	-----	-----
8	0-50	-----	0.45	Compressive strength, modulus of elasticity, chloride penetration, water permeability.	7,28,60,90,180	-----	100×200
9	0-40	0.8	0.50	Compressive strength, heat evolution, LOI	7,28,90	-----	100×200
10	0-40	-----	0.50	Compressive strength	7,14,28	150×150×150	-----
11	0-40	-----	-----	Compressive strength	7,14,21,28	100×100×100	-----
12	0-30	-----	-----	Compressive strength	3,7,28	-----	-----
13	0-40	-----	0.40	Compressive strength, split tensile strength, sorptivity	7,28	-----	150×300
14	0-30	-----	0.35	Compressive strength	7,14,28	150×150×150	-----

### 3. DEVELOPMENT OF MORTAR BY SUGARCANE BAGASSE ASH

Hailu et al. [33] investigated the compressive strength of different mortar with 5% to 30% replacement of cement with bagasse ash in mortar as per ASTM Standards. From the research it was found that the bagasse ash improves some properties of mortar [42-45]. The replacement of OPC by bagasse ash in 10% results in better compressive strength than control mortar. Higher replacement of cement by bagasse ash results in higher normal consistency and longer setting time. The control

mortar cubes with no cement replacement, a mortar with 15% replacement were prepared and tested for 3, 7, and 28 days.

pozzolana Piyanut et al. [34] analysed the compressive strength, flow ability and chemical composition of cement mortar. The replacement of SCBA was varying from 0% to 40%. For compressive strength test water/ cement ratio was 0.485:1 and specimen was tested as per ASTM Standards for curing period of 3, 7, and 28 days. The First reaction was the hydration reaction which takes place after addition of water in cement to form calcium hydroxide (CH) and calcium silicate hydrate (C-S-H). And the second reaction is pozzolanic reaction which takes place between CH from hydration reaction and SiO<sub>2</sub> a pozzolan from SCBA and produced second phase of CSH which increase the compressive strength [46-50]. Amount of SCBA influence the compressive strength of cement mortar by replacing with 20% SCBA as the most appropriate ratio.

Marcos et al. [35] studied that the addition of 10%, 20% and 30% of SCBA had a delay of 10 min in the time period between set time due to reduction of cement in combination prepared. The mortar samples were mixed in proportion 1:3 and having replacement variation of SCBA 0% to 30%. Initial and final setting time, compressive strength, pozzolanic activity, specific mass, water absorption by immersion, and an index of porous tests were conducted according to Brazilian Standards.

Chusilp et al. [36] studied that the development of compressive strengths of mortars containing ground bagasse ash with high LOI was slower than low LOI. At the later age, both types of ground ash mortars displayed similar compressive strengths. Bagasse ash contains amorphous silica and display good pozzolanic properties [51-55]. For compressive strength test binder to sand ratio used was 1:2.75 by weight and Standards flow was 110 according to ASTM Standards. SCBA was replaced at 10%, 20%, 30% and 40%.

Goyal et al. [37] studied the amorphousness and morphology of SCBA particle by XRD and SEM (Scanning electron microscopy). The blended mortar was prepared as per Japanese Standards, and replaced OPC with 10, 15, 20 and 25% SCBA (by weight). And used mix ratio of 1:3. Mortar with 15% replacement gave better strength than control mortar cubes. Observed hydration and strength development of SCBA blended specimen by ultrasonic pulse velocity test as per ASTM Standards.

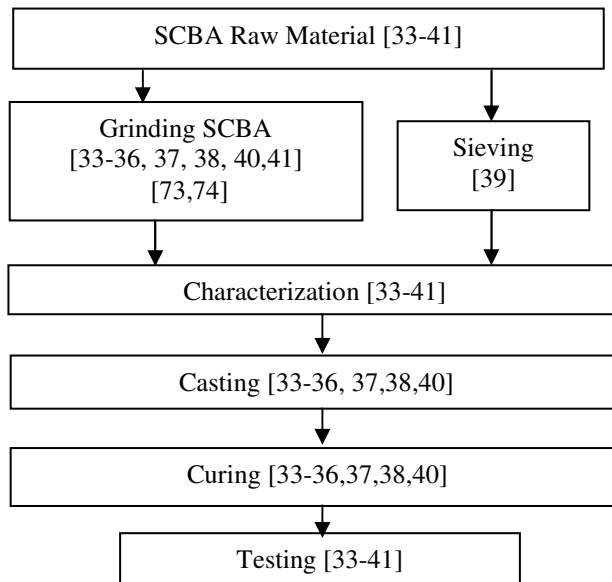
Castaldelli et al. [38] studied various mortar mixtures by replacing part of the SCBA from 0 to 40% by weight. After 270 days of curing at 20 °C, compressive strength of SCBA systems found to be 60 MPa. Also, microstructural properties were calculated by means of SEM (Scanning electron microscope), TGA (Thermo gravitometric analysis), XRD (X-ray Diffraction), pH, electrical conductivity.

Jimenez et al. [39] studied the effects of a sieved sugar cane bagasse ash (SCBA) and fly ash (FA) on the rheological properties of pastes and mortars. mini-slump cone and the flow/spread table tests were carried out to determine the feasibility of evaluating the rheological properties of pastes and mortars. Shape and size of the particles of the used SCBA produced more viscous and plastic pastes and mortars than mixes without the SCBA.

Guilherme et al. [40] presented the influence mechanical grinding to improve the pozzolanic activity of the sugarcane bagasse ash reactivity. The influence of grinding time on the sugarcane bagasse residual ash reactivity was also presented. Results of particle size, specific surface (Blaine), scanning electronic microscopy, pozzolanic activity index, and energy consumption during grinding were presented and analyzed as per Brazilian Standards. Mortar specimens were prepared using mix proportion of 1:3 by mass and SCBA were replace at level of 35% by volume. The specific grinding energy was calculated by Bond's law.

Cordeiro et al. [41]. Studied processing and characterization of highly reactive SCBA and determined the pozzolanic activity, structural state of silica and loss on ignition of the ashes. The use of SCBA as a partial replacement can improve the mechanical and durability properties of

cementitious materials [56-60]. The quality of the ash can be improved by the controlling parameters such as temperature, rate of heating, soaking time [61-64]. SCBA was characterised by chemical analysis, Scanning electron microscopy, density, specific surface area. Particle sizes were measured using laser diffraction analyzer and loss on ignition (LOI) was determined according to ASTM Standards and Brazilian Standards. The Standards mortar with mix proportion 1:3 and w/c ratio 0.52 was compared with mortar containing 35% of SCBA replacement.

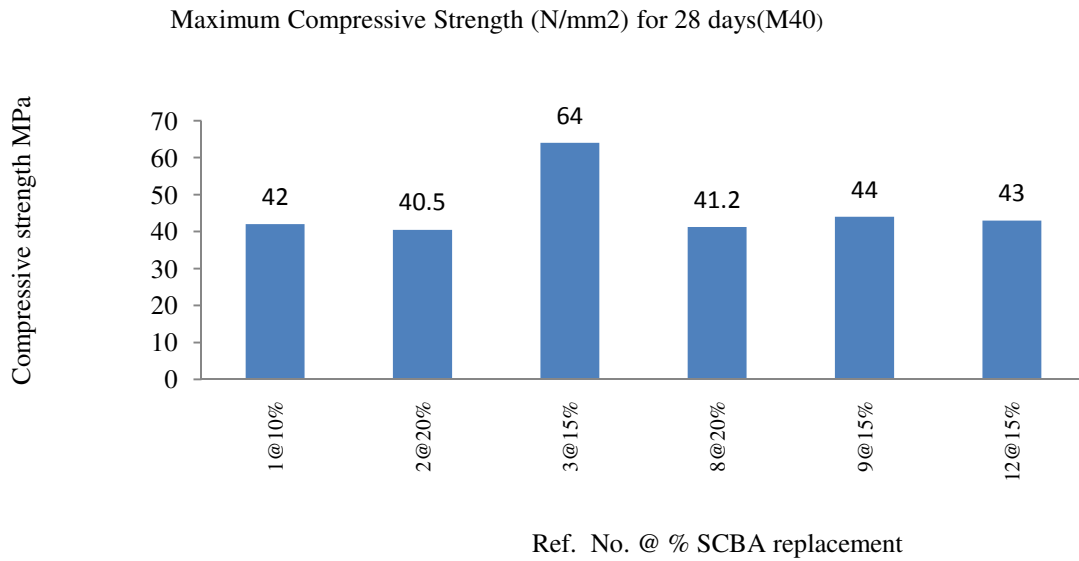


**Fig.2** Methodology for making of SCBA mortar specimens

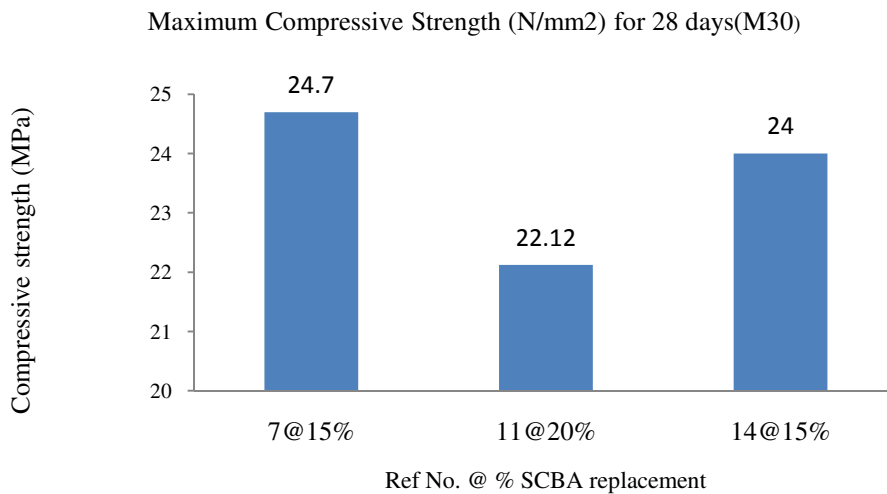
**Table. 2** Development of SCBA mortar specimens

Ref. No.	Curing days	SCBA Replacement %	Various test conducted	W/C ratio
15	3,7,28	0-30	Compressive strength	0.45
16	3,7,28	0-40	Comp.strength, flowability	0.485
17	7,28	0-30	Compressive strength Water absorption test	0.5
18	3,7,28,90	0-40	Compressive strength XRF, XRD, Partical size distribution	0.71-1.03
19	3,7,14, 28,56,90	0-20	Compressive strength Flexural strength XRD	0.35
20	3,7,28, 270	0-40	XRD, Compressive strength Flexural strength	0.45
21	-----	0-30	Slump cone Flow ability Shear stress	0.5
22	-----	----	XRF, SEM, Partical size distribution Flow index	0.52
23	16 hours	0-30	Loss on ignition, Partical size distribution XRD	0.52

#### 4. DISCUSSION



**Fig.3** Compressive Strength of M40 concrete

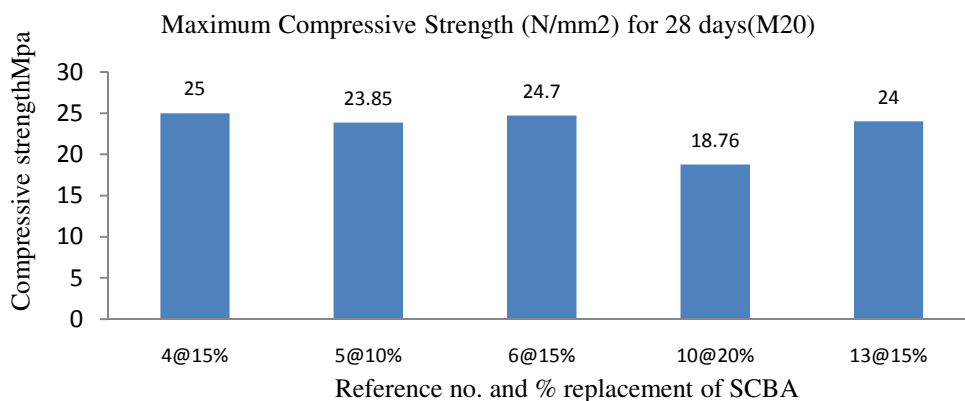


**Fig.4** Compressive Strength of M30 concrete

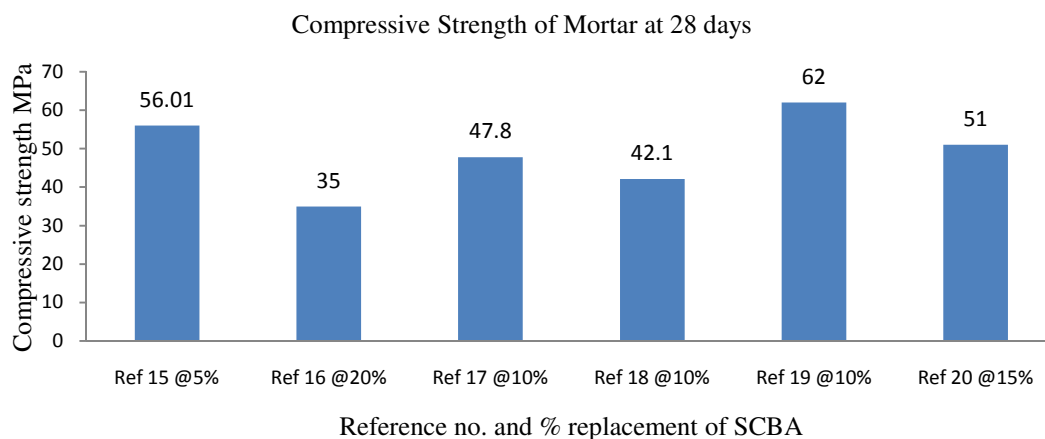
From Figure 3 it is observed that maximum compressive strength shown in reference 3. M40 grade of concrete got compressive strength ranges from 40-64 N/mm<sup>2</sup>. The maximum compressive strength was obtained at 15% replacement of SCBA for cement. At 20% replacement also researchers got compressive strength greater than that of control concrete or some results found similar to that of control concrete when compared to 20% replacement level.

From figure 4 it was noted that m30 grade of concrete shows maximum compressive strength at 15% replacement level of SCBA. The value of compressive strength was 24.7 N/mm<sup>2</sup> at 15% replacement of SCBA. In other reference when 20% SCBA was added the result shows that over 20% replacement the strength goes downward.





**Fig.5** Maximum Compressive Strength of concrete (M20)



**Fig.6** Compressive strength of mortar at 28 days

When a graph is plotted for M20 grade of concrete it is observed that when SCBA is added in 10% amount it had given good result but when 15% SCBA was added it shows maximum compressive strength. For M30 grade of concrete the maximum compressive strength noted was N/mm<sup>2</sup>.

From Figure 6 is seen that the compressive strength is increasing upto 10% replacement of SCBA, this mainly happens because of pozzolanic reaction between reactive SiO<sub>2</sub> from SCBA and Ca(OH)<sub>2</sub> from cement hydration. For replacement of SCBA by 20% give less compressive strength as compared to other replacement percentage, 15% replacement of SCBA by cement in mortar also gives better results of compressive strength.

The maximum compressive strength has shown in figure 1,2,3 for curing age 28 days. From reference no. 1, 2, 8,9,12, it is observed that in that papers M40 grade of concrete was used. By comparing these results for 15% replacement of SCBA, it got maximum compressive strength. In figure2 From reference 7, 11, 14 it is observed that in this paper M30 grade of concrete. The maximum strength was obtained at 15% replacement of SCBA. In Figure 3 from reference no.4, 5, 6, 10, 13. It is observed that M20 grade of concrete were used. Maximum strength one time again at the 15% replacement level was noted.

From Figure 4 upto 15% replacement of SCBA by cement is beneficial beyond that the strength gets decreases. 10% replacement is found to be getting more compressive strength. Replacement of SCBA in higher percentage causes decrease in compressive strength of concrete and

mortar as well as a slight reduction in the workability. Since baggasse ash is a waste material and it is used in development of cement mortar and concrete reduces the level of CO<sub>2</sub> emission and could reduce the environmental problems and minimize the requirement of landfill area to dispose SCBA. Use of SCBA in concrete and mortar reduces the heat of cement hydration and are also cost reduction in concrete and mortar production.

## **5. CONCLUSION**

The various methodologies for design and development of SCBA mortar and concrete have been reviewed. Various physico-mechanical and chemical properties of the SCBA are studied in accordance with the revived literature and the Standards. SCBA was a good replacement for cement in concrete as well as mortar. It can be easily replaced up to 20%. The maximum compressive strength was found at 15% replacement level, though 15% replacement gave higher strength 20% could be used because the result from 20% replacement is near about control concrete. In case of split tensile strength 10% replacement gave higher strength.

The utilization of baggasse ash in concrete and mortar solves the problem of its disposal thus keeping the environment free from pollution. The improvement in compressive strength of mortar by partially replacing cement by SCBA is due to filler effect and pozzolanic reaction between reactive SiO<sub>2</sub> from SCBA and Ca (OH)<sub>2</sub> from cement hydration. The study in turn is useful for various resource persons involved in using SCBA material to develop sustainable construction material.

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