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Study on Utilization of Bagasse Ash as Partial Replacement for Cement in Concrete

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Abstract -*With increasing demand and consumption of cement, researchers and scientist are in search of developing alternate binders that are eco-friendly and contribute towards waste management. The utilization of industrial and agricultural waste produced by industrial processes has been the focus of waste reduction research for economical, environmental and technical reasons. There are lots of environmental impacts of cement on our ecology. Cement industry creating environmental problem by emission of CO2 during manufacturing of cement. Sugar-cane bagasse is a fibrous waste-product of the sugar refining industry, along with ethanol vapour. This waste product (Sugar-cane Bagasse ash) is already causing serious environmental pollution, which calls for urgent ways of handling the waste.*

Sugar-cane bagasse is one such fibrous waste product of the sugar mills and sugar refining industry. The bagasse ash with alumina and silica creates disposaland environmental problems around the factories. The use of such ash in concrete by partial replacement of cement, not only reduces the cost of making concrete, but also improves the properties of concrete and reduces environmental pollution. This paper presents the attempt made in making concrete with partially replacing cement by 2.5, 5.0, 7.5,10 and 12.5 % of bagasse ash. Mix design is made for conventional M20 grade, conventional and ash based concrete prepared, the workability, strength and durability characteristics are determined through proper testing and the results are compared.

Key Words: Sugarcane bagasse ash, Pozzolanic property, compressive strength, workability.

1. INTRODUCTION

In any industry the difference between the products and the wastages is the way of using them and with a small investment, most of the wastages can be used and can be treated as by-products. In this line the industrial and agricultural wastages are recycled and reused in construction industries. One such potential usage is often recognized by many researchers from the agricultural waste called sugarcane Bagasse of sugar industries which by burning results in sugarcane Bagasse ash (SCBA). Sugarcane is one of the most important agricultural plants that grown in hot regions. Brazil and India are the world's major sugarcane producing countries with Brazil having over of 719 million tons and recorded one-third of the world's total sugarcane production. Nigeria produces over 15 million tons of sugarcane. The total sugar production capacity of India is over 30 million tons per annum. Despite the variety use of bagasse, for production of wood, papers, animal food and thermal insulation materials, a large quantity of bagasse are remained unused and hence the ash. If utilized properly, use of SCBA can promote for the green technology. The main composition of SCBA is siliceous oxide that reacts with free lime from cement hydration but only crystal silica oxide has reactive properties that can be obtained by burning bagasse in 700oC for 90 minutes and also 800oC at time of 15 minutes. It is observed that one ton of sugarcane to generate 26% of bagasse and 0.62% of residual ash (SnehithDevasani and Kaushik, 2015). Mostly when a quantity of bagasse is burnt, only 7-10% of ash is got. In India, SCBA is commonly obtained by bagasse carbonation, in which bagasse is packed in graphite crucible air tight, placed in electrically controlled furnace and burnt at 1200oC for five hours. The carbonated bagasse is collected and burnt at 600oC for 6 hours and a further burning for three hours at 700oC. The cooled ash is used as SCBA in concrete. There is only limited research available on the utilization of SCBA as cement replacement material in concrete as compared to other popular pozzolans. Having a good quantum of availability of bagasse, SCBA being high in silica content can be easily produced and used as an alternative cement replacement material in concrete products. The prime aim of this study is to realize the use of SCBA from waste and experimental investigations performed for studying the effect of partial replacement of cement with SCBA.

Fig -1: Sample SCBA

2. LITERATURE REVIEW

Many researchers from various countries have made experimentation in utilizing the SCBA as replacement materials in concrete mostly replacing cement and few on fine aggregate.

George Rowland Otoko (2014) reported thatup to 2% of cement only can be replaced by the SCBA without adverse effect.Hailu and AbebeDinku (2012**)** reported that up to 10% replacement of cement by bagasse ash results in better concrete properties.

Srinivasan and Sathiya (2010) by partially replacing with SCBA up to 25% by weight of cement reported that the strength of concrete increased as percentage of replacement increased.

Abdolkarim Abbasi and Amin Zargar (2013) reported that Replacing cement by 10% of bagasse ash, the workability and flowability are optimized and the compressive strength at 28 days is increased by 25% compared with normal concrete.

Abdulkadir, et al (2014) concluded that 10% replacementof SCBA has the highest PAI and also, based on the compressive strength results 10% and 20% replacement of SCBA with compressive strengths of 22.3N/mm2 and 20.1N/mm2 are recommended for concrete. Kawade et al (2013) characterized SCBA and partially replaced cement with bagasse and observed that the strength of concrete increased up to 15% SCBA replacement.

Asma El hameed Hussein et al (2014) and Sagar Dhengare et al (2015) examining on workability, strength of concrete reported to have optimum of 15% replacement level. Núñez-Jaquez et al (2012) studied the corrosion rate of steel by polarization resistance method, embedded in concrete having cement replaced with bagasse ash by 20% and found some beneficial effect on protection of steel rebar from corrosion.

Amin, N (2011) reported that with the optimal replacement ratio of 20% cement reduced the chloride diffusion by more than 50% without any adverse effects on other properties of the concrete. Almir Sales and Sofia Araújo Lima (2010), Prashant Modani and Vyawahare (2013), Subramani and Prabhakaran (2015) and Vinícius et al (2013) tried to replace sand partially with SCBA and concluded that SCBA can be a suitable replacement to fine aggregate.

Sadiqul Hasan et al. (2014) investigated the properties of recycled aggregate concrete and SCBA as the partial replacement of cement observed that the strength is enhanced up to 10%. As the chemical composition varies, the characterization of bagasse ash is to be done before makingdecision on using it in concrete. It is observed that SCBA has been tried up to 40% and the optimum level is a variant.

Mr. H.S. Otuoze et al. had investigated on characterization of Sugar Cane Bagasse Ash (SCBA) and Ordinary Portland Cement (OPC) blends in concrete. The SCBA was obtained by burning Sugar Cane Bagasse (SCB) between 600-700 degrees Celsius. The sum of percentages of SiO_2, Al_2O_3 and Fe_2O_3 is 74.44%.For strength test , mix ratio of 1:2:4 was used and OPC was partially replaced with 0% ,5%, 10%, 15%, 20%, 25%, 30%, 35% and 40% by weight in concrete. Compressive strength values of hardened concrete were obtained at the ages of 7, 14, 21 and 28 days. Based on the tests conducted, it can be concluded that SCBA is a good pozzolanic material 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 blends with OPC could be used for reinforced concrete with dense aggregate. Higher blends of 15% and up to 35% of SCBA with OPC are not acceptable. The values fell short of meeting requirements.

M.Vijaya Sekhar Reddy and I.V.Ramana Reddy studied the behaviour of High Performance Concrete (HPC) which is being the most used type of concrete in the construction industry. They replaced cement with Supplementary Cementing Materials (SCM) like fly ash, silica fume and SCBA. The mix design adopted was M60, cubes were casted and cured for 90 days in 5% HCl (PH=2), NaOH, $MgSO_4$ and Na_2SO_4 solutions. They concluded that there was a considerable increase in service life of the concrete structures and reduction in heat of hydration by using the supplementary cementing materials in concrete. They observed that the maximum and minimum percentage of reduction in strength of concrete when concrete was replaced with fly ash were 12.64% and 1.92%.

3. PROPERTIES OF MATERIALS AND METHODOLOGY

3.1 Process to Obtain SCBA

- Bagasse was packed in graphite crucible air tight and Place inside electric furnace.
- Burnt an temperature of 1200°C for 5 hour to obtain black ash.
- This carbonated bagasse was collected and burned For 6 hours at 600°C.
- After burn a layer of light coloured ash was observed on the surface and then an ash of black colour and Heterogeneous composition of observed.
- This bagasse ash is used in the research.
- Before the use of bagasse ash, it is oven dried at 1200°C.
- To remove the moisture in the ash.
- After oven dry ash was sieved in the mechanical shivers to separate unburned particles from ash.
- Sugarcane bagasse ash passing through 300µ was used.

Sr. No.	Component	Mass %
1	Silica (SiO2)	66.89
2	Alumina (Al2O3)	29.18
	Ferric oxide (Fe2O3)	
3	Calcium Oxide (CaO)	1.92
4	Magnesium Oxide (MgO)	0.83
5	Sulphur Tri Oxide (SO3)	0.56
6	Loss of Ignition	0.72
7	Chlorode	-

Table-1 Composition of SCBA

Fig-2 Bagasse Ash

3.2 Cement

The cement used in all mixtures was Ordinary Portland cement (43Grade) with a specific gravity of 3.15. Initial and final setting times of the cement were 69 min and 195 min, respectively. Some of the important required experiments conducted on the cement as specific gravity of cement, normal consistency of cement, initial and final setting time of cement, results are shown below table.

Sl. No.	Properties	Values
1	Specific Gravity	3.15
2.	Standard consistency	34%
3.	Initial setting time in min.	30
4.	Final setting time in min	480

Table-2 Properties of Cement

3.3 Fine aggregates (sand)

Manufactured sand was used as fine aggregate for the experiments. Various tests were conducted to determine the properties of sand. Grading is the particle-size distribution of an aggregate as determined by a sieve analysis. Some of the importance tests will be conducted on fine aggregates which is required in mix design of concrete as shown in below table. The test was done according to IS: 2386 (Part 1) – 1963

Sl. No.	Properties	Values
1	Specific Gravity	2.65
2.	Fineness modulus	2.963
3.	Water absorption	11%
4.	Zone	II

Table-3 Properties of Fine Aggregate

3.4 Coarse aggregate

Aggregate is commonly considered inert filler, which accounts for 60 to 80 percent of the volume and 70 to 85 percent of the weight of concrete .Maximum size of aggregate affects the workability and strength of concrete. It also influences the water demand for getting a certain workability and fine aggregate content required for achieving a cohesive mix. In this study the natural coarse aggregates are used, which was bought from the nearby quarry. Aggregates of 20 mm and 12.5 mm size were chosen for the experiment which is clean and free from deleterious materials. The importance tests are to be conducted on the coarse aggregates as per IS 10262:2009. Which the experimental results are required in mix design as shown in below table

Sl. No.	Properties	Values
1	Specific Gravity	2.90
2.	Fineness modulus	2.596
3.	Water absorption	0.5%

Table-4 Properties of Coarse Aggregate

3.5 Methodology

Collection of material: for SCBA for concrete and materials are collected like normal grade of cement, aggregates, water. Weighing and mixing process: material are weighed in proper ratio as per design and after then mixed in proper way.

Moulding process: concrete mixer is moulded in cube sized 150*150*150 mm^3 and beam size of 500*100*100 mm^3.

Removing of mould. After 24 hours the moulds are removed. Curing process: concrete cubes and beams are cured in fresh water for 7 days to 28 days.

Testing process: after removing the moulds, concrete cubes and beams are tested in campus concrete laboratory.

Analysis and test result: after various test on cube and beams, result are calculated.

In this research paper, M20, mix proportion is designed as per guidelines of Indian Standard recommended method IS 10262:2009. We used 53-grade cement; also zone 2 is taken into consideration from IS 383(1970) for fine aggregate. The coarse aggregate is selected passing through 20mm and retained on 10mm Sieve.

MIX PROPORTION OF M20

Water	Cement	Sand	Aggregate
0.55	1	1.94	2.62
197.16	297	698.13	945.45

Table-5 M20 Grade Concrete Mix Proportions

Mix Designation	Cement	FA	CA	SCBA as Replacement of Cement
M-0%	100%	100%	100%	0%
M-10%	90%	100%	100%	10%
M-20%	80%	100%	100%	20%
M-25%	750%	100%	100%	25%
M-30%	70%	100%	100%	30%

Table-6 Details of Replacement by SCBA

4. RESULTS AND DISCUSSIONS

All the tests have been performed in standard procedures and the results and load values obtained were tabulated and calculated in following sections.

4.1 Workability

Slump of Concrete Mixes

The slump test was performed for the concrete with and without SCBA to check the consistency of NMC and the observed result are reported. After the execution of slump test for concrete grade M20, the continuous fall in the slump value were recorded, when cement replaced by SCBA. The range for slump test was targeted in between 75 mm to 54mm (as recommended by ACI). It is prominent that slump value represent the workability of fresh mix concrete and the observed values fall in the category of low and medium degree of workability. Therefore, the usage of super plasticizer (SP) is not essential in this case

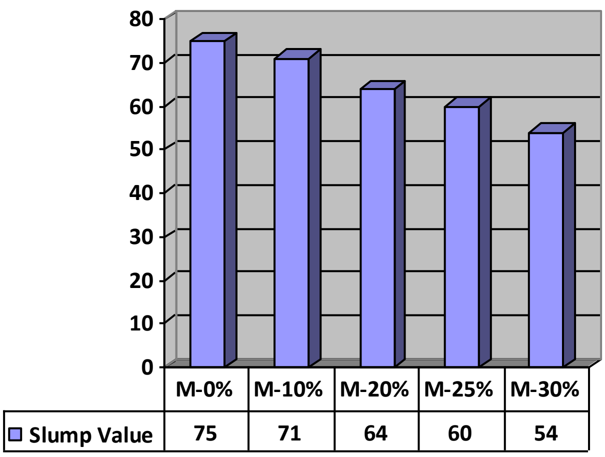

Chart-1 Slump values

4.2 Compressive Strength

Compressive strength tests were conducted on cured cube specimen at 7 days and 28 days age using a compression testing machine of 200 kN capacity. The cubes were fitted at center in compression testing machine and fixed to keep the cube in position. The load was then slowly applied to the tested cube until failure.

Concrete cubes of size 150mm x150mm x 150mm were casted for 0%, 10%, 20%, 25%, 30%, SCBA replacement. The compressive strength for M20 grade of concrete is tested for 7, 28 days of curing and the results are tabulated and plotted.

Sl.no	Mix (days)	SCBA as replace ment%	Cube Compressive strength (N/mm^2)
1	7	0%	21
		10%	17.6
		20%	18.21
		25%	19.44
		30%	17.22
2	28	0%	21.6
		10%	23
		20%	23.89
		25%	26.33
		30%	21.51

Table -7 Compressive Strength values

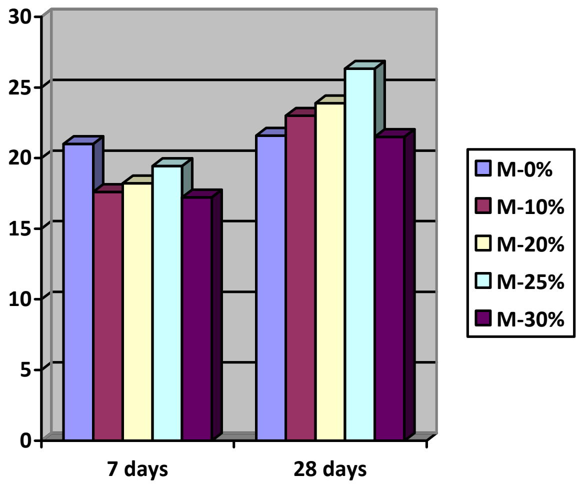

Chart -2 Compressive Strength

4.3 Split Tensile Strength

The split tensile test were conducted as per IS 5816:1999. Concrete cylinders of size 150mmx300mm were casted for 0%, 10%, 20%, 25%, 30% replacement of SCBA. The split tensile strength for M20 grade of concrete is tested for 28 days of curing and the results are tabulated and plotted below

Sl.no	Mix (days)	SCBA as replacement%	Cylinder
			Split Tensile strength (N/mm^2)
1	28	0%	2.18
		10%	2.01
		20%	2.93
		25%	3.11
		30%	3.01

Table -8 Split Tensile Strength values

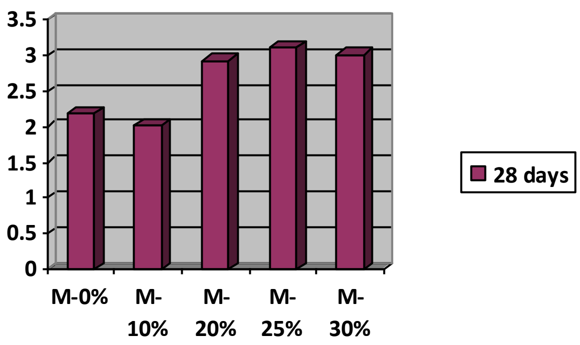

Chart -3 Split Tensile Strength

5. SUMMARY AND CONCLUSIONS

This research was successfully carried out, to the establishment of SCBA as an alternative cement replacement material in concrete. After the detailed investigation the following conclusions have been drawn:

Use of high volume SCBA as a replacement of cement, in any construction work provides lower impact on environment (reduced CO emission) and economical use of resources (energy conservation, use of by-product etc).

Use of SCBA in the concrete generates less heat while mixing with the water as against cement .It also helps to reduce the heat of hydration resulting less shrinkage and temperature cracks in the concrete.

The use of SCBA as a replacement of cement helps to reduce the Energy consumption in the manufacturing of cement.

It is observed that there is an increase in the compressive strength and split tensile strength at 25 % of SCBA and after thatit gets decreased slightly .The increase in strength is due to high reactivity of SCBA with Cement.

From the above experimental results, it is proved that SCBA can be used as an alternative material for cement, reducing cement consumption and reducing the cost of construction.

Use of industrial waste products saves the environment and conserves natural resources, achieves economy. Heat of hydration is slower in case of SCBA cement which lowers the risk of thermal cracking

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