Utilization of SCBA as a Supplementary Cementitious Material in Concrete and subjected to Elevated Temperature

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Abstract – The present study is aimed at utilizing sugarcane bagasse ash concrete, with partial replacement of cement in concrete and its behavior when subjected to elevated temperature. The concrete mix is designed for M 30 grade as per IS 10262:2009. The replacement is done at various percentages like 0%, 5%, 10%, 15% and 20% by weight and the concrete mix demands more amount of chemical admixture as the percentage replacement increases in order to attain the desired slump. At room temperature the compressive strength decreases with increase in percentage replacement and was found that at 10% replacement the desired strength of 30MPa is achieved.
The specimens were subjected to elevated temperatures of 200°C, 400°C and 600°C with a retention period of 1 hour. After 1 hour of exposure, specimens were allowed to cool under furnace cooling regimes to ambient temperature. At the elevated temperature the loss in strength at 10% replacement was more compared to 20% replacement.

***Key Words*: Sugarcane Bagasse Ash (SCBA), Blended concrete, Compressive strength, Elevated Temperature.**

1. INTRODUCTION

Ordinary Portland cement is a controlled blend of calcium silicates, aluminates and ferrate, which is ground to a fine powder with gypsum and other materials. Ordinary Portland cement is the conventional building material that actually is responsible for about 5% - 8% of global CO2 emissions. This is the environmental problem will most likely be increased due to exponential demand of ordinary Portland cement.

Concrete is most widely used and very necessary material which is used in all types of construction works. Concrete consists of cement, aggregates, water and admixtures. Concrete uses is over 10 billion tons per year, concrete can present good mechanical strength, and also acceptable durability performance. Out of concern for the environment, and in support of sustainable development, cement industries are improving their production through a range of alternatives such as the use of alternative fuels or increasing the production of blended cements. All these aspects have been contributing to reduce CO2 emissions, which can reach up to 30% of diminishing according to the Danish Centre for Green Concrete.

Researchers all over the world are focusing on ways of utilizing industrial or agricultural waste, as a source of raw materials for industry. Industrial wastes, such as blast furnace slag, fly ash and silica fumes are being used as supplementary cement replacement materials. Sugarcane cane 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 300 million tons/year that cause about 10 million tons of sugarcane bagasse ash as an un-utilized and waste material. After the extraction of all economical sugar from sugarcane of about 40-45% fibrous residue is obtained, which is reused in the same industry as fuel in boilers for heat generation leaving behind 8-10% ash as waste material, known as sugarcane bagasse ash (SCBA). Sugarcane bagasse ash contains high amounts of unburnt matter, silicon, aluminum and calcium oxides. The ash, therefore becomes an industrial waste and possess disposal problems. A few studies have been carried out in the past on the utilization of bagasse ash obtained directly from the industries to study the pozzolonic activity and their suitability as binders by partially replacing cement. The experimental study examines the workability properties of fresh concrete such as slump and compaction factor and also compressive strength and split tensile strength with 5%, 10%, 15% and 20% replacement of cement with bagasse ash by volume.

Concrete as the best fire resistance properties of any building material. This outstanding fire resistance is due to concrete component materials that are cement and aggregates that form a substantially inert the material with low thermal conductivity, elevated heat capacity and slower temperature degradation of strength when chemically mixed. In this work the bagasse ash is sieved using 90µm sieve and it is grinded in order to improve its physical and chemical properties. The concrete specimen was subjected to elevated temperature (200^0C, 400^0C and 600^0C).

2. OBJECTIVES

The main objectives of this study,

i. The present study aims at mix design of M30 grade of concrete and to find the required constitutes of it.

ii. To study the effect of replacement of cement in concrete by pozzolonic material that is bagasse ash.

iii. To ascertain the effect of Bagasse Ash as alternative cementitious material with variable percentages by weight of cement in fresh properties of bagasse ash based on concrete to be compared with controlled concrete.

iv. To ascertain the effect of Bagasse Ash as alternative cementitious material with variable percentages by weight of cement in hardened properties like compressive strength and tensile strength of bagasse ash based on concrete to be compared with controlled concrete.

v. To study the variation of compressive strength of concrete cubes subjected to sustained elevated temperature (200^0C, 400^0C and 600^0C).

3. MATERIALS AND METHODS

3.1 Cement

The Ordinary Portland cement is tested according to IS specification (IS:12269-2013) to determine its various properties. The grade of cement is 53 grade. The physical properties of cement are given below,

Table-1: Physical properties of Cement

Sl. No	Tests	Values obtained	Requirement as per IS 269:2015	IS Code
1	Specific Gravity	3.09	3 to 4	IS 4031
2	Normal Consistency	32%		IS 4031 (Part 4):1988
3	Setting Time Initial Setting Time Final Setting Time	227mins 335mins	>30mins < 600mins	IS 4031 (Part 5);1988
4	Fineness	5%		IS 4031

3.2 Fine Aggregate

M sand is the alternative for the river sand produced by crushing the hard granite stones. The size of the manufactured sand is less than 4.75mm. The physical properties of fine aggregate are given below,

Table-2: Physical properties of Fine Aggregate

Sl.No	Tests	Results	Requirementsas per IS 383:2016	IS Code
1	Specific Gravity	2.65	2.3 to 3	IS:2386 (Part 3)
2	Fineness modulus	2.34	2.2 to 3.2	IS:2386 (Part 1)
3	Water absorption	3%		
4	Passing 75 micron	1.5%	<15%	

3.3 Coarse Aggregate

Locally available crushed granular aggregates of size less than 20 mm were used throughout the study and it was tested as per IS 383:2016. The physical properties of coarse aggregate are given below,

Table-3 Physical properties of Coarse Aggregate

Sl.No	Tests	Results	Requirements as per IS 383:2016	Is Code
1	Specific gravity	2.7	2.5 to 3	IS 2386(Part 3)-1963
2	Water Absorption	0.50%	0.6%	IS 2386(Part 3)-1963
3	Fineness modulus	7.06	5 to 8	IS 2386(Part 1)-1963
4	Angularity Number	8.1	0 to 11	IS 2386(Part 1)-1963

3.4 Water

Potable water available in the college campus has been used in the concrete mix design. PH value of the water used for concrete as per IS 456-2000 less than 7.

3.5 Sugar Cane Bagasse Ash

Source: NSL Sugars Ltd, Koppa.

Bagasse ash is an industrial waste or farming waste. It is a consequence which is obtained in sugarcane milling industries. Productivity of bagasse ash contains silica, aluminum, iron and calcium oxide. The bagasse ash used in the current study is obtained by burning the bagasse ash at a temperature of about 750-8500C for the purpose of generation of electricity in the factory. The ash so obtained from the discharge is sieved to obtain particles which are finer than 90µm in order to remove the unburnt particles present in the raw bagasse ash. The physical and chemical properties of the bagasse ash is obtained are given below.

Table-4: Physical Properties of Bagasse Ash

Sl. No	Properties	Results
1	Specific Gravity	2.17
2	Color	Black
3	Bulk Density Loose Compacted	 520 648

Table-5: Chemical Properties of Bagasse Ash

Sl. No	Properties	Percentage
1	Silica as SiO_3	76.32
2	Aluminum as Al_2O_3	0.20
3	Iron as Fe_2O_3	4.02
4	Calcium as CaO	3.68
5	LOI	6.67

3.5.1 X-Ray Diffraction Analysis

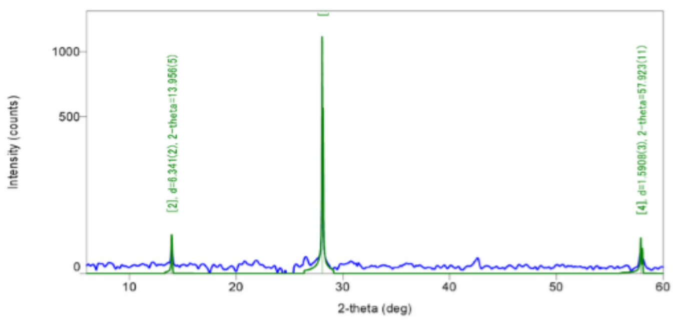

Fig 1: X – Ray Diffraction (XRD) Analysis of raw bagasse ash

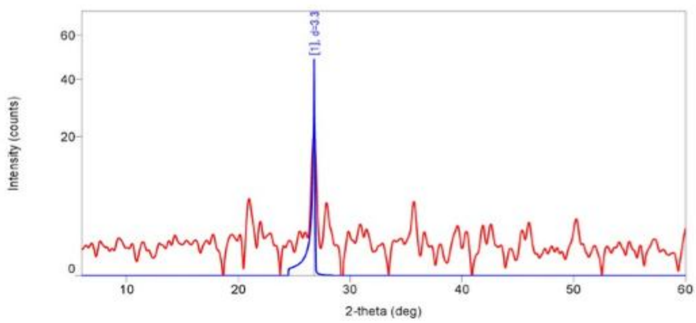

Fig 2: X – Ray Diffraction (XRD) Analysis of 90µm fine bagasse ash

The XRD pattern of raw bagasse ash and 90µm fine bagasse ash are shown in the fig 1 and fig 2 respectively. The XRD analysis was performed and the intensity was found for the angle of incidence 2 – theta varying from 0 to 60^0. It is found that the peak intensity is obtained at an angle of incidence 26.7811^0. in general, when the peaks are obtained between $15\text{-}40^0$, it indicates the presence of silica in form of quartz.

3.5.2 Scanning Electron Microscopic Analysis (SEM)

The SEM analysis is conducted in order to know the morphology of the bagasse ash sample.

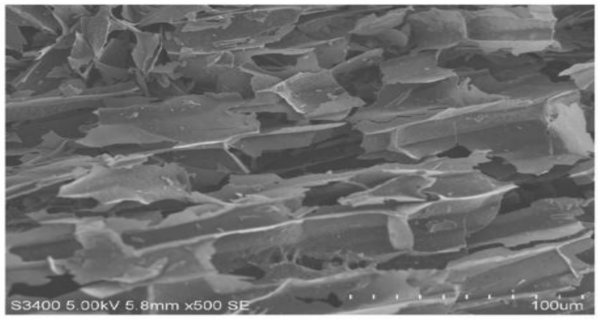

Fig 3: SEM analysis of raw bagasse ash at 100µm magnification

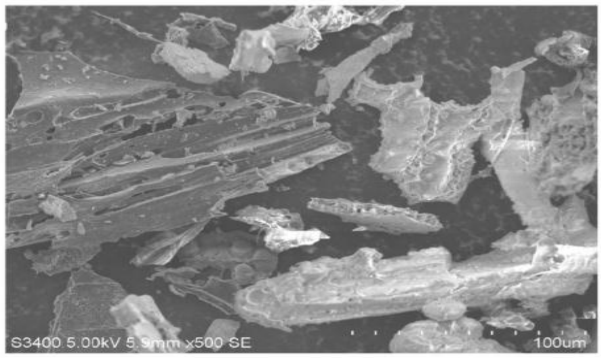

Fig 4: SEM analysis of 90µm fine bagasse ash at 100µm magnification

The microstructure of raw bagasse ash and 90 µm fine bagasse ash are as shown in fig 3 and 4 respectively. From the SEM analysis of SCBA sample it was found that they were composed of grains with different sizes and shapes. They contain prismatic particles consisting mainly of silica and oxides and spherical particles consisting of silica and oxides as well as some other minor compounds. Fiber particles contain only carbon at higher magnification small pores were observed on surface of the particles.

4. RESULTS AND DISCUSSIONS

4.1 Tests on Fresh Concrete

4.1.1 Slump Test

Workability of the concrete is spotted by the slump test. The slump test values are obtained for each mixes are given in the table 6. Control mix value of slump is 100mm for designed M30 grade.

Table-6: Slump for various mix constituents

Percentage Replacement	Slump(mm)	Chemical Admixture
0%	135	1%
5%	126	1%
10%	120	1%
15%	125	1.2%
20%	120	1.6%

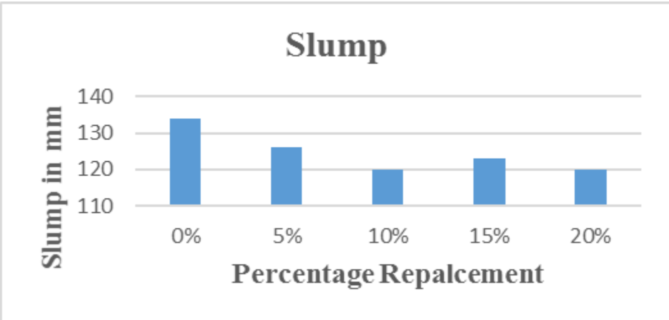

Fig 5: Variation of Slump with different percentage of SCBA

From the above graph indicates that the controlled concrete of M30 grade demands the chemical admixture of 1% to attain a slump of 100mm.Bagasse ash based concrete of M30 grade, as the bagasse ash is increased by 5%, 10%, 15% and 20% by the weight of cement demand of chemical admixture was also increased by 1%, 1%, 1.2% and 1.6% to attain a slump of 120-130 mm which is more than the desired slump of 100mm. Since the bagasse ash also have high loss on ignition (LOI) content which absorbs more water and demands more chemical admixture to attain desired slump value.

4.2 Tests on Hardened Concrete

4.2.1 Compressive Strength

The compressive strength of bagasse ash blended concrete decreased with the replacement of 5%, 10%, 15% and 20% sugar cane bagasse ash by the weight of cement at 28 days of curing as shown in fig 6. At 28 days of curing, when compared with controlled mix, the compressive strengths of 5%, 10%, 15% and 20% bagasse ash blended concrete mixes were reduced by 9.28%,6.59%, 27.74% and 37.23%. The decrease in strength for the bagasse ash blended concrete mix prepared with bagasse ash was attributed to the pozzolonic effects of bagasse ash at later ages. In conclusion, the replacement of 10% bagasse ash by weight of cement is suitable for inducing the good compressive strength in bagasse ash blended concrete.

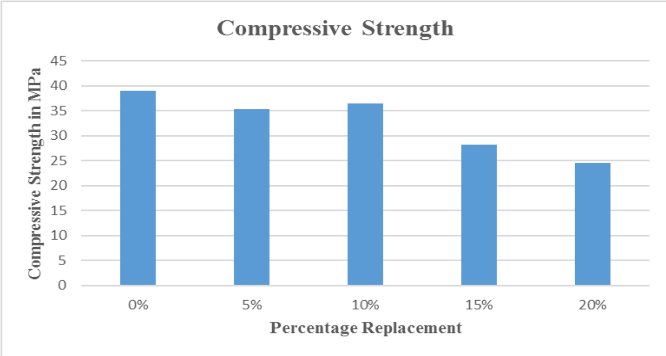

Fig 6: compressive strength at 28 days for different percentage replacements

4.2.2 Split Tensile Strength

The tensile strength of bagasse ash blended concrete varied with replacements of 5%, 10%, 15% and 20% bagasse ash by the weight of cement at 28 days as shown in the fig 7. At 28 days of curing, when compared with the controlled mix, the tensile strength of 5%, 10%, 15% and 20% bagasse ash blended concrete mixes were reduced by 5.64%, 10.53%, 18.42% and 87%. The decrease in tensile strength for the bagasse ash blended concrete mix prepared with bagasse ash was also attributed to the pozzolonic effects of bagasse ash at later stages. In conclusion, the replacement of 10% bagasse ash by weight of cement is suitable for inducing the good tensile strength in bagasse ash blended concrete.

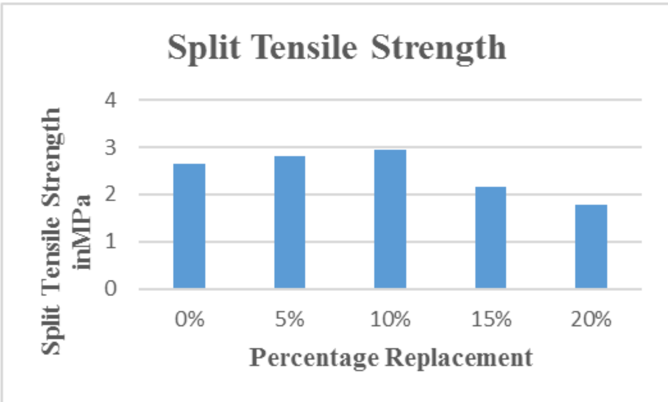

Fig 7: Split Tensile Strength for different percentage replacements

4.3 Exposure to Elevated Temperature

The concrete specimens when subjected to different temperatures showed variations with respect to their color, density and compressive strength.

The fig 8 shows the concrete specimen at room temperature and it can be seen that there is no change in color and development of cracks has not found at room temperature.

The fig 9 shows the specimen subjected to 200^{0}C and it can be seen that there is a slight change in its color and development of cracks has not been started at this temperature.

The fig 10 shows the specimen subjected to 400^{0}C and it can be seen that the micro cracks were developed at one or two faces of the specimen at this temperature.

The fig 11 shows the specimen subjected to 600^{0}C and it can be seen that the specimen as more cracks were developed than the previous temperature and powdered type formation were found on the surfaces and deterioration was seen on the edges at this temperature.

Fig 8 and 9: Concrete specimens at room temperature and subjected to 200°C

Fig 10 and 11: Concrete specimens subjected to 400°C and 600°C

4.4 Loss in Weight of Specimen

Table-7: Weight loss in specimen at various temperature

Percentage Replacement	Percentage loss in weight		
	200^{0}C	400^{0}C	600^{0}C
0%	4.24	5.21	6.78
5%	4.82	5.72	6.43
10%	5.95	6.53	5.67
15%	3.97	4.92	5.12
20%	3.21	4.32	4.24

The percentage losses in weight of specimen are shown in the tables 7. when subjected to temperatures 200^{0}C,400^{0}C and 600^{0}C respectively. The maximum losses in weight were seen at 10% replacement and with further increase in percentage of bagasse ash, the weight loss gradually decreased. The least amount of weight loss was seen at 20% replacement.

4.5 Compressive Strength of specimen subjected to elevated temperature

In this study an electric muffle furnace of 800^{0}C capacity is used. The specimens were subjected to temperatures (200^{0}C, 400^{0}C and 600^{0}C). Three sets of cube specimen of size 100mm x 100mm x 100mm were casted for each percentage replacements (0%, 5%, 10%, 15% and 20%).

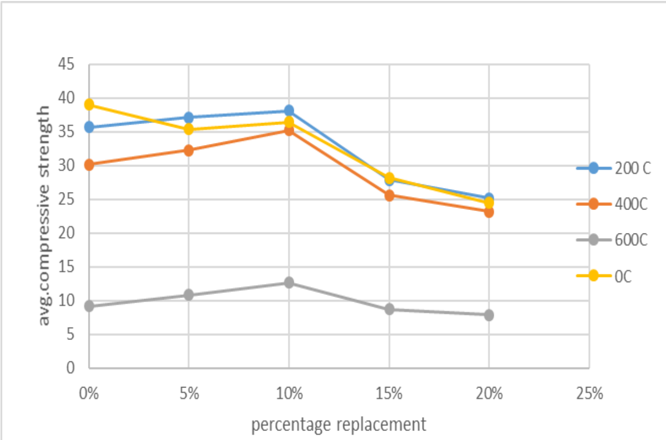

Fig 12: Variation of compressive strength for different percentage of replacement at different temperatures

From fig 12 it can be seen that the strength of concrete specimens decreases with the increase in temperature expect for 15% and 20% bagasse ash blended concrete at 200^{0}C.

At 200^{0}C, the strength reduced by a percentage of 3.85%, 6.80%, 22.01% and 28% for 5%, 10%, 15% and 20% replacements respectively when compared to conventional mix at the same temperature.

At 400^{0}C, the strength reduced by a percentage of 7.16%, 16.98%, 14.96% and 23.02% for 5%, 10%, 15% and 20% replacements respectively when compared to conventional mix at the same temperature.

At 600^{0}C, the strength reduced by a percentage of 17.62%, 37.54%, 5.55% and 14.15% for 5%, 10%, 15% and 20% replacements respectively when compared to conventional mix at the same temperature.

5. CONCLUSIONS

The following conclusion shown below.

1. The utilization of bagasse ash in concrete and mortar solves the problem of its disposal thus keeping the environment free from pollution.
2. The increase in percentage of replacement of cement by SCBA resulted in higher standard consistency.
3. The increase in percentage of replacement of cement by SCBA resulted in delayed setting time.
4. The improvement in compressive strength of concrete by partially replacing cement by SCBA is due to filler effect and pozzolonic reaction between reactive SiO2 from SCBA and Ca (OH)2 from cement hydration.
5. From the compressive strength results of cubes, it is found that on 10% of bagasse ash replacement with cement will yield better compressive strength as compared to controlled concrete.
6. From the split tensile strength results, it is found that on 10% of bagasse ash replacement with cement will yield better tensile strength as compared to controlled concrete.
7. From the compressive strength results of cubes subjected to elevated temperature, it was found that with the increase in temperature strength decreases for both conventional mix and 10% bagasse-based concrete.
8. The total percentage weight loss of the specimen increases as the exposure temperature increases; however, this is maximum for furnace cooling and minimum for sudden cooling.
9. The performance of 10% bagasse-based concrete was highly poor when subjected to elevated temperatures when compared to 15% and 20% bagasse-based concrete.
10. For all mixes it was seen that the there was a sudden decrease in strength at a temperature of 600°C.
11. The study in turn is useful for various resource persons involved in using SCBA material to develop sustainable construction material.

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