International Journal of Innovative Research in Engineering & Management (IJIREM)
ISSN: 2350-0557, Volume-3, Special Issue-1, April-2015
Fifth National Conference on Innovative Practice in Construction Waste Management (IPCWM'15) On 8th & 9th April, 2015
Organized by Department of CIVIL Engineering, Sri Ramakrishna Institute of Technology, Coimbatore, India

An Article on Usage of Sugarcane Bagasse Ash as Partial Replacement of Cement

P.Sivasankari,
PG Student Sri Ramakrishna Institute Of Technology,
Coimbatore-10,India

ABSRACT

Concrete is one of the most commonly used construction material in the world. It is basically composed of three components: cement, water and aggregates. Cement plays a great role in the production of concrete and is the most expensive of all other concrete making materials. In addition, there is environmental concern in the production of cement.
Due to this, requirements for more economical and environmental-friendly cementing materials have extended interest in partial cement replacement materials. Ground granulated blast furnace slag, pulverized fly ash and silica fume, have been successfully used for this purpose.This paper deals with the study of implementing sugarcane bagasse ash as a partial replacement of cement.

1. INTRODUCTION

Bagasse is a by-product from sugar industries which is burnt to generate power required for different activities in the factory. 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.
The present study was carried out on SCBA obtained by controlled combustion ofsugarcane bagasse, which was procured from the Tamilnadu province in India. Sugarcane production in India is over 300 million tons/year leaving about 10 million tons of as unutilized and, hence, wastes material. This paper analyzes the effect of SCBA in concrete by partial replacement of cement at the ratio of 0%, 5%, 10%, 15% by weight. The experimental study examines the compressive strength, split tensile strength, flexural strength. 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 seven and 28 Days.
The sugarcane bagasse consists of approximately 50% of cellulose, 25% of hemicellulose 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 the sugarcane harvests. In this sugarcane bagasse ash was collected during the cleaning operation of a boiler operating in the Sugarcane Breeding Institute, located in Veerakeralam of Coimbatore,Tamilnadu.

CHEMICAL COMPOSITION :

COMPONENT	MASS%
SiO_2	78.34
Al_2	8.55
Fe_2O	3.61
CaO	2.15
Na_2O	0.12
K_2O	3.46
MnO	0.13
TiO_2	0.50
LOSS OF IGNITION	0.42

PHYSICAL PROPERTIES

The test results indicated that the sugarcane bagasse ash had a low density (2.16g/cm^3) and higher specific surface area (4716cm^2/g) when compared with that of the Messebo OPC. Particle size analysis of ash samples (Fig. 1) indicates that 50% of the ash particles passed through 40.1μm and 90% were of size less than 76.1μm, whereas the analysis for the cement indicated that 50% of the particles passed through 43.4μm which is slightly greater than the bagasse ash and 90% of the particles were less than 72μm which is less than the ash. The fineness was determined using blain air permeability method.The chemical composition shown in Table 2, revealed that the bagasse ash can be assigned as a class N pozzolan, as per ASTM C618 classification since the sum of SiO_2, Al_2O_3, and Fe_2O_3 content is greater than 70%. The loss on ignition (LOI) value was found to be 10.48% which is slightly higher than that specified by the same standard, which is 10%. Normal Consistency and Setting Time .The results of setting time tests shown in Table 6 indicate that the addition of bagasse ash retarded the setting time of the paste; however this retardation was within limits as specified by the Ethiopian standard which is not less than 45 minutes for initial setting time and not greater than 10 hours for final setting time. It could have been caused by the adsorption of water at the surface of bagasse ash.

2. SCOPE AND METHODOLOGY

2.1 Scope of the study

1) This study concentrated on the performance of a Sugarcane bagasse ash. Sugarcane bagasse is collected from Sugarcane Breeding Institute.
2) The influence of different gradations of the sugarcane bagasse ash on concrete properties was not evaluated in this study but it should be considered in future researches.

3) All the SCB waste collected were chosen from those manufactured by standard Sugarcane breeding institute to avoid any inconsistent properties that may arise by mixing materials from different sources. The properties of waste from other institutes were not included in this study.
4) The study was done on M25 grade of concrete. The percentage replacements were limited to three categories i.e. 05%, 7.5%,10%,12.5%,15% replacement of the cement. The different effects, which can be observed in different percentages of replacements, were not included in the present study.

2.2 Methodology of the study

The different methods utilized in this research include the following:

i) Background study

Literature survey was carried out to review previous studies related to this thesis.

ii) Collection of raw Materials

All the required materials were collected and delivered to the laboratory. These are; Cement, fine aggregate, coarse aggregate,Sugaracane Bagasse ash.

iii) Material Tests

Tests were conducted on the raw materials to determine their properties and suitability for the experiment.

iv)Mix Proportioning (Mix Design)

Concrete mix designs were prepared using the Indian Standard Code method. M25 mix design is prepared with code. They were prepared with Cement replacements by 05%, 7.5%,10%,12.5%,15% of the bagasse ash. A control mix with no SCB ash was produced to make a comparative analysis.

v) Specimen preparation

The concrete specimens were prepared in the C.M.S. Civil Engineering Department Testing laboratory. The prepared samples consist of concrete cubes, cylinders and beams.

vi) Testing of Specimens

Laboratory tests were carried out on the prepared concrete samples. The tests conducted were slump, unit weight, compressive strength, splitting tensile strength, and flexural strength tests.

vii) Data collection

The data collection was mainly based on the tests conducted on the prepared specimens in the laboratory.

viii) Data Analysis and Evaluation

The test results of the samples were compared with the respective control concrete properties and the results were presented using tables, pictures and graphs. Conclusions and recommendations were finally forwarded based on the findings and observations.

3.MATERIAL USED AND PROPERTIES

3.1 Cement

Cement is a binding material used in the preparation of concrete. It bends the coarse aggregates and fine aggregates with help of water, to a monolithic matter and also it fills the voids in the concrete.
There are two requirements for any cement in the concrete mix design. That is compressive strength development with time attainment of appropriate rheological characteristic, type and production of cement.

OPC 53 Grade sample was tested to obtain the following characteristic as per IS 12269-1987:
1) Specific gravity
2) Standard consistency
3) Initial setting time
4) Fineness
The results of the tests on cement sample are listed in Table.

Table 1. Properties Of Cement (Opc 53 Grade)

PROPERTIES	STANDARD VALUES	OPC USED IN PRESENT STUDY
Specific gravity	3.10 - 3.20	3.15
Standard consistency	30 – 35	29%
Initial setting time	>30 min	35 min
Fineness	25% - 35%	28.50%

3.2 Fine Aggregate

The fine aggregate used in the manufacturing of concrete should be free from debris, fungi and chemical attack. It plays a vital role in concrete, so it should durable, angular and sharp edges then only it gives a rich mix concrete and workability.
In this present investigation, the river sand which was available near Karur , was used as fine aggregate and the following tests, carried out on sand as per IS:2386-1963 PART (1),(111)&(1v)
1) Specific gravity
2) Sieve analysis and fineness modulus
3) Bulk density
4) Percentage of voids

The results of the tests on sand sample are listed in Table

Table 2. Grading Of Fine Aggregate (Sand)

PROPERTIES	RESULTS	STANDARD VALUES
Specific gravity	2.56	2.30 - 2.60
Fineness modulus	2.74	2.20 – 3.20
Bulk density	17kN/m3	-
Percentage of voids	38.00%	<40%

Table 3. Properties Of Fine Aggregates (Sand)

CUMULATIVE PERCENTAGE OF PASSING		
IS SIEVE DESIGNATION	GRADING LIMITS ZONE-11	GRADING LIMITS OF SAND
10mm	100	100
4.75mm	90-100	100
2.36mm	75-100	94.45
1.18mm	60-90	82.39
600micron	39-59	60.96
300micron	8-30	11.23
150micron	0-10	1.47

3.3 Coarse Aggregate

Aggregate are the important constituents in concrete. They give body to the concrete, reduces shrinkage and effect economy. Earlier, aggregates were considered as chemically insert materials but now it has been recognized that some of aggregates are chemically active and also that certain aggregate exhibit chemical bon at the interface of aggregate and paste. The more aggregates occupy 70 – 80 percentage of concrete; their impact on various characteristics and properties of concrete is undoubtedly considerable.

In this present investigation ,locally available crushed blue stone aggregate of size 20mm and down was used and the various tests carried out on the aggregates are given below as per IS: 2386-1963(1V)

1) Specific gravity
2) Sieve analysis and fineness modulus
3) Bulk density
4) Crushing strength
5) Impact strength

Table 4. Grading Of Coarse Aggregate

IS SIEVE DESIGNATION	CUMULATIVE PERCENTAGE OF PASSING
80mm	100
40mm	100
20mm	60
10mm	26.7
4.75 mm	10

Table 5. Properties Of Coarse Aggregate

PROPERTIES	RESULTS	STANDARD VALUES
Specific gravity	2.78	2.6 - 2.9
Fineness modulus	6.80	6.0 – 7.0
Bulk density	16.50kN/m3	———
Water absorption	12.0%(By mass)	0.2% - 4%
Crushing strength	13.80%	<45%

3.4 Properties Of Sugarcane Bagasse Ash

1. Specific Surface Area Is 4716 Cm2/Gm
2. Sugarcane Bagasse ash is finer in nature.
3. The density is 2.16 g/cm3.
4. Average size(μm)(where 50% of the particle passes) is 40.1

WATER:

Portable water free from organic and other impurities confirming to IS: 3025(17), (18), (24)
& (32)

4. PREPARATION OF SPECIMENS

4.1 Casting

The ingredients cement, fine aggregate, coarse aggregate and crumb rubber were hand mixed in the laboratory. It was always ensured that proper and uniform mixing of the concrete was obtained. The required percentage of Sugarcane Bagasse ash was replaced with that of coarse aggregate. Then the water was added to the mix. The mix was mixed through by trowel.

4.2 Compacting

Steel moulds were used for casting the specimens. The mould sizes are as follows.

- Size of cube = 150mm×150mm×150mm
- Size of cylinder = 150mm diameter and 300mm long
- Size of beam = 500mm×100mm×100mm

Tamping rod was used for compacting in the mould. After cleaning the mould, oil was applied in the side of inner surfaces. The concrete was placed by layers into the mould and each layer was compacted before the next layer was placed.

5. TESTING TECHNIQUES AND RESULTS

5.1 Compressive Strength

After the period required period of curing, the cubes were taken out and allowed to dry for about four hours. Then the cubes were kept in the Uniaxial compression testing machine (UTM) of capacity 2000 KN. Before starting the test, the machine was completely checked and proper working was ensured.

At the time of breaking, the cube failure load was noted and the average compressive strength was calculated.

Ultimate Compressive Strength = {Ultimate Compressive load (Pu)/
Area of the specimen (A)}

5.2 Split Tensile Strength

This is also referred as "Brazilian Test". This test was developed in Brazil in 1943. At about the same time, this was also independently developed in Japan.

The test is carried out by placing a cylinder specimen horizontally between the loading surface of a compression testing machine and the load is applied until failure of the cylinder, along the vertical diameter. The load at failure is divided by the area of the specimen

Ultimate Split Tensile Strength = $2P / \pi LD$

6.RESULTS

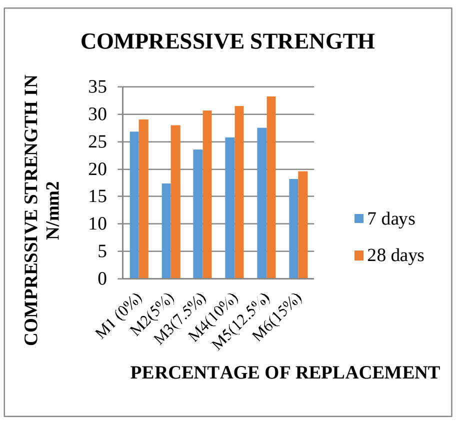
6.1 Compression Test For Cubes

Size of the specimen = 150mm ×150mm× 150mm
Area of the specimen = 22500mm^2

Table 6

S.NO	PERCENTAGE REPLACEMENT	ULTIMATE COMPRESSIVE STRENGTH IN N/mm^2	
		7 days	28 days
1	0%	25.68	34.26
2	5%	17.33	28
3	7.5%	23.55	30.67
4	10%	25.78	31.56
5	12.5%	27.56	33.33
6	15%	18.22	19.56

COMPARISON OF COMPRESSIVE STRENGTH OF CUBES :



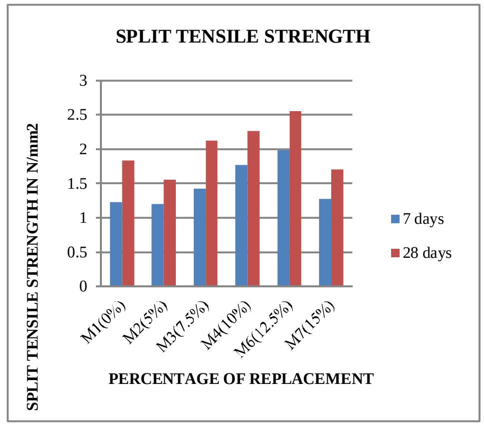
6.2 Split Tensile Strength For Cylinders

Size of the specimen = 150mm diameter and 300mm long.

Table 7

S.NO	PERCENTAGE REPLACEMENT	ULTIMATE SPLIT TENSILE STRENGTH IN N/mm^2	
		7 days	28 days
1	0%	1.25	3.14
2	5%	1.202	1.56
3	7.5%	1.42	2.12
4	10%	1.77	2.26
5	12.5%	1.98	2.55
6	15%	1.27	1.70

COMPARISON OF SPLIT TENSILE STRENGTH OF CYLINDERS :

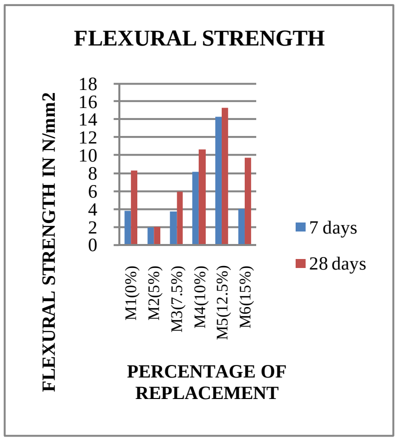


6.3 Flexural Strength

Table 8

S.NO	PERCENTAGE REPLACEMENT	ULTIMATE FLEXURAL STRENGTH IN N/mm^2	
		7 days	28 days
1	0%	3.26	8.32
2	5%	1.91	2.01
3	7.5%	3.72	5.94
4	10%	8.12	10.65
5	12.5%	14.32	15.26
6	15%	3.98	9.75

COMPARISON OF FLEXURAL STRENGTH :



7. CONCLUSION

1. The oxide composition test indicates that, the bagasse ash from Wonji sugar factory can be classified as class N pozzolana as prescribed by ASTM C 618.
2. The replacement of OPC by bagasse ash up to 10% resulted in a better compressive strength than the control mortar with 100% OPC. However, the replacement of PPC with bagasse ash resulted in a lower compressive strength than the control mortar even at lower replacement.Moreover, all of the mortars containing OPC and bagasse ash satisfy the ASTM C 618 minimum pozzolanic activity index requirement i.e. 75%.
3.Higher replacements of cement by bagasse ash resulted in higher normal consistency and longer setting time. The workability of the concrete has also shown a slight reduction as the bagasse ash content increases.
4.The difference in the trend of strength development of OPC-BA mortars (increasing with age for most of the mixes and having improvement up to 10% replacement) and PPC-BA mortars (decreasing with age for most of the mixes and having a lower compressive strength than the control for all blended mixes) proved the presence of pozzolanic reaction.
5. The compressive strength results of the concrete with 5% ordinary Portland cement replacement by bagasse ash have shown a 5% compressive strength improvement at 28 days over the control concrete mix, whereas the 15% and 25% replacements have shown 3.4% and 12.6% reduction, respectively. 6. The water penetration depth increases as the bagasse ash content of the concrete increases and all the concretes with bagasse ash have a maximum penetration depth greater than the control specimen.
7. Since bagasse ash is a by-product material, its use as a cement replacing material reduces the levels of CO2 emission by the cement industry and also saves a great deal of virgin materials.

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