THE EFFECT OF PARTIAL REPLACEMENT OF CEMENT WITH GROUND AND UNGROUND SUGARCANE BAGASSE ASH (SCBA) ON MECHANICAL PROPERTIES OF CONCRETE

KUMAR GAURAV
STUDENT
RAMA UNIVERSITY

Abstract— There has been an increase in infrastructural works in this century, especially in developing countries in line with realization of the Millennium goals. This has led to an increase in demand and consumption of cement since it is the major constituent of concrete. In the early 20th century, the composition of concrete was primarily cement, water and aggregates [02]. With time and use of technology, the scientists discovered the benefits that came with use of admixtures in the concrete production. This research paper focuses on how sugarcane bagasse ash (SCBA) can be used to replace cement partially in order to improve the performance of concrete.

In this paper, SCBA was ground in a ball mill for 60 minutes and 30 minutes and its physical and chemical properties determined to establish if it was pozzolanic. 0%, 10%, and 20% by weight of cement was then replaced by the ash in concrete and the workability and physical properties of concrete determined.

The grinding was very effective as illustrated by the particle distribution curve in this report. The specific gravity values increased with the grinding and the SCBA was found to be highly pozzolanic. The workability is improved with grinding as well as with increase in the amount of SCBA up to 10% replacement. Density was increased with grinding and increase in number of days of curing. The compressive strength and tensile strength also increased as the amount of SCBA was increased, as days of curing increased, with 10% replacement giving concrete with the highest strength. Lastly, water absorption reduced with grinding and increase in number of days of curing. 60 minutes ground SCBA with 10% replacement of cement gave concrete with the best performance in terms of workability and physical properties.

Key words: Density, Workability, Compressive strength, Tensile splitting Strength, Water Absorption, Sugar Cane Bagasse Ash (SCBA).

1.0 INTRODUCTION

Concrete is an artificial material in which aggregates both fine and coarse are bonded together by the cement when mixed with water. The selection of the relative proportions of cement, water and aggregate is called mix design. The requirements in mix design can be summarized into; strength, workability, durability and economy. Cement being the most expensive and main active constituent of the ingredients of concrete, needs a thorough study to find out the optimum requirements. On the odd occasion when things go wrong and strength does not develop as expected, rightly or wrongly the cement usually gets the blame. In most cases, cement contributes directly to the problem maybe one time in three, although it's mostly one of several contributing factors [08]. These distinctions can be summarized as either intrinsic or extrinsic:

a)Intrinsic: the cement has some inherent characteristic or defect that gives rise to the problem.

b)Extrinsic: the cement itself is not the cause of the problem; the low strength is in some way related to how the cement was used, or to the effect on the cement of other materials in the mix.

Extrinsic problems are, broadly, within the control of the concrete producer or contractor while intrinsic problems are generally for the cement manufacturer to identify and resolve. [08]

It is also important to note that the main constituent of cement is limestone (Calcium Carbonate). During manufacture of cement, this limestone is heated in the process of calcination and plenty of Calcium Oxide is produced, which is necessary for production of both hydraulic and non-hydraulic cement [05]. However, the other product of this combustion is Carbon (IV) Oxide, which is part of the green gases, responsible for pollution of the environment and the global warming, with its many negatives. Unfortunately, cement's huge contribution to air pollution is overlooked by the general public.

2.0 Materials and Methodology

2.1 Obtaining and preparation of the bagasse ash

The SCBA was obtained from Bharat sugar factory, in Bihar, where the bagasse had been burnt at about 10000C to produce electricity. The SCBA was then dried in the oven at 1000C for 24 hours before it was ground in a ball mill for 60 minutes and 30 minutes. A sample of the SCBA was then taken for determination of the chemical properties. Specific gravity and hydrometer analysis were then done on the SCBA.

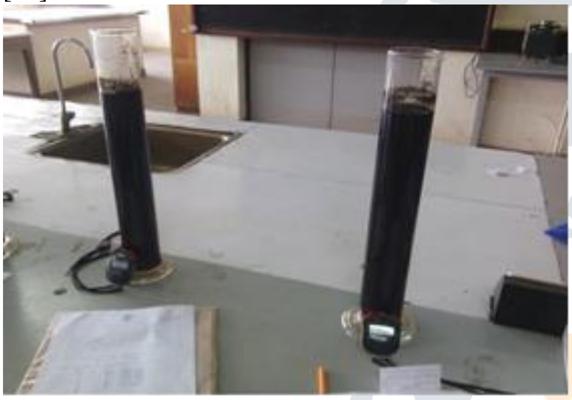
2.2 Specific gravity

The specific gravity was done on the unground and ground SCBA. An oven dried density bottle was weighed (W1) and about 15gms of the SCBA placed in it. The bottle with the ash was then weighed in gms, (W2). Air-free distilled water was then added to cover the SCBA and the bottle placed in the water bath to evacuate the air. It was then removed, air-free water added and stopper inserted. The bottle was then weighed in gms (W3). The bottle was then completely cleaned, filled with air-free liquid and stopper inserted. The bottle was wiped and weighed in gms (W4). The specific gravity, Gs was then determined according to the tabulation below. This test was done according to BS 1377-part 2-1990, [13].

Specific gravity determination in progress.

2.3 Hydrometer Analysis

This was done on the 60 minutes ground, 30 minutes ground and the unground SCBA, according to BS 1377-pt2-1990 [14].



Hydrometer Analysis in progress

2.4 The Mix Design

i) Maximum aggregate size=20mm (Uncrushed)
ii) Specific gravity of the aggregate=2.7.
iii) Specific gravity of OPC used=3.15
iv) Specific gravity of sand=2.65
v) Fineness modulus of sand=2.7
vi) Unit weight of water=1000kg/m3
vii) Cement used was ordinary Portland cement (OPC).

2.4.1Procedure

Required characteristic strength at 28 days, fcu=25N/mm2
Where,
M=margin strength,
=1.64S (In this case, for 5% defectives), where S=Standard deviation depending on the number of tests done and the characteristic strength. For the case of 25N/mm2 and less than 40 tests, S=8.
Therefore, M=1.64x8=13.12N/mm2
Target mean strength fm =25+13.12=38.12N/mm2 for mass concrete, slump required is 20-80mm.

2.4.2 Water/cement ratio

Estimated compressive strength, fcu=42N/mm2
Target mean strength fm=25+13.12=38.12N/mm2
w/c ratio=0.512(This is an approximate value. Exact value will be obtained by trial and error)

2.4.3 Water content

For uncrushed aggregate of maximum diameter 20mm, slump of 20-80mm, water needed is180kg/m3

2.4.4 Cement content

= water content/ (w/c ratio.)
= 180/0.512
= 378.9kg/m3 (Say 380 kg/m3)

2.4.5 Concrete Density

Relative density of aggregate (SSD) =2.70(Known)
Free-water content=180kg/m³
Wet concrete density of the mix=2440kg/m³,
Total aggregate content, TAC=wet density-free water content-cement content
TAC=2440-180-380
=1880kg/m³

2.4.6 Coarse aggregate content

With fineness modulus of sand as 2.7 and nominal maximum aggregate of 20mm, percentage of coarse aggregate was found as 0.638 (By Interpolation),

Coarse aggregate content=0.638X1880
=1200kg/m3

2.4.7 Fine aggregate content

TAC-Coarse aggregate content
=1880-1200=680kg/m3
Summary of requirements is outlined below;
For 60 minutes ground bagasse ash
Considering 0% replacement of cement and the required tests (Density, Compressive strength, Tensile splitting strength and Water absorption), 18 cubes and 6 cylinders will be required for the 28-day, 60-day and 90-day testing.
Volume of cubes=18(0.150X0.150X0.150) =0.061 M3
Volume of cylinders=6(Π/4X0.152X0.3) =0.0318 M3
Total volume needed=0.061M3+0.0318M3=0.0928 M3
Water content=180X0.0928=16.7kg
Cement content=380X0.0928=35.26kg
Coarse aggregate=1200X0.0928=111.36kg
Fine Aggregate=680X0.0928=63.10kg

Item	Water (kg)	Cement (kg)	Bagasse ash(kg)	Coarse aggregate(kg)	Fine aggregate(kg)
0%Replacement	16.7	35.26	0	111.36	63.10
10%Replacement	16.7	31.73	3.53	111.36	63.10
20%Replacement	16.7	28.21	7.05	111.36	63.10
Total	**50.10**	**95.2**	**10.58**	**334.1**	**189.3**

Mix proportions used

The same table was used for the 30 minutes and unground SCBA.

3.0 RESULTS & DISCUSSIONS

3.1 Chemical composition of the SCBA

The following was the findings for the chemical composition of the bagasse ash;
The chemical composition of the SCBA was found to be within the recommendations of ASTM C618 and it was found to be close to class C fly ash [01]. Class C Fly Ash in addition to being a pozzolan is also cementitious. Because of its pozzolanic properties, it also increases strength and durability in concrete applications. Because Class C fly ash is self-cementitious it can also be used in a variety of geotechnical applications to stabilize soils and aggregate
It is however worth noting that the Loss on Ignition (L.O.I) was found to be very high. This implies that the SCBA was not burnt at appropriate temperature. This means that there is high carbon content and hence workability may be lowered. The silica content was found to be 60.4%, implying that the SCBA was an effective pozzolanic material and cementitious.

No.	Chemical		Sample A (%)	Sample B (%)	Average (%)
1	Silica(SiO_2)	Soluble	16.69	16.50	16.595
		Insoluble Residue	43.87	43.81	43.84
2	SiO2		60.56	60.31	60.435
3	Fe as FE2O3		2.64	2.64	2.64
4	Alumina		10.14	10.46	10.30
5	Sulphates		1.8968	1.7562	1.8265
6	Ca as CaO		8.4	8.4	8.4
7	Mg as MgO		4.5324	3.7584	4.1454
8	Chlorides		0.1773	0.154	0.166
9	Iron and Alumina		12.78	13.10	12.94
10	L.O.I		31.48	31.81	31.645

Chemical composition of the SCBA

3.2 Specific Gravity of the SCBA

The following results were obtained after the test for specific gravity was conducted;
The 60 minutes grounded ash had the highest specific gravity value of 2.14, followed by 30 minutes ground SCBA (1.90) and lastly unground SCBA which had a specific gravity of 1.81, producing an average specific gravity of 1.98. This difference in specific gravity is brought about by the grinding which reduces the size of particles, increasing the surface area per given volume, consequently making them have a higher parking density, hence the high specific gravity in the ground SCBA
These values were however lower than that of the cement used, which had a specific gravity value of 3.15. This implies that even the grinding did not reduce the particles to sizes comparable to those of cement as outlined below. Cement thus still had higher parking density. This low value of specific gravity (compared to that of cement) is of economic significance because the more the percentage replacement of cement in the concrete, the lesser the overall weight of the concrete and structure at large. This would be an economic gain for the massive structures such as storey buildings and bridges. Lighter concrete would mean less logistics and costs of handling it. Lighter structures or members thereof would also result in lower reinforcement costs due to the reduction in dead load.

Sample Number	60 min Ground	Ungrounded	30 min ground
Bottle Number	A	B	C
Mass of empty bottle(W1),g	65.40	68.80	65.50
Mass of bottle + Soil (w2),g	81.20	78.88	76.61
Mass of bottle + Soil + Water (W3),g	194.22	193.80	190.27
Mass of bottle full of water (W4),g	185.80	189.30	184.74
Mass of water used (W3-W2),g	113.02	114.92	113.66
Mass of soil used (W2-W1),g	15.80	10.08	11.11
Volume of soil (W4-W1)-(W3-W2),g	7.38	5.58	5.58
Specific Gravity of soil Gs=(W2-W1)/(W4-W1)-(W3-W2)	**2.14**	**1.81**	**1.99**
Average Gs	**1.98**		

Specific gravity results

3.3 Compaction Factor Results

Unground SCBA		30 min ground SCBA		60 min ground SCBA	
%	**C.F**	**%**	**C.F**	**%**	**C.F**
0	0.79	0	0.73	0	0.654
10	0.89	10	0.87	10	0.79
20	0.96	20	0.94	20	0.81

It is evident from that slump values increased with replacement up to a certain limit and then started decreasing. 10% replacement of SCBA produced concrete with slightly higher slump value than the control, which dropped slightly when the replacement was 20%. The same observation is made with the compaction factor values.

It is also worth noting that the slump values increased with increase in time of grinding. The 60 min. ground SCBA produced concrete with the highest slump values, followed by 30 min. ground SCBA while unground SCBA produced concrete with the lowest slump values, although, the differences were very minimal.

The above observations imply that workability was improved by addition of the SCBA slightly, 10% replacement producing concrete with a slightly higher workability. This can be attributed to the fact that the SCBA particles are rounder than cement particles and hence allows water to move around them easily hence improving workability of concrete.[02] The other reason for the increase in workability is that SCBA has slightly bigger particles than cement, making them to

have a lower surface area to volume ratio hence few particles that are easily wetted. Grinding improves workability slightly since as the particle sizes reduce, the roughness also reduce [02]. The reduction in workability as the SCBA increase can be attributed to the fact that as the SCBA increase, the surface area to volume ratio of the ash increase, increasing roughness and carbon content with subsequent reduction in workability.

However, the values of slump obtained are lower than those found by previous researches at the same w/c ratio. This is because of the high Loss on Ignition value-31.6%! This means that the SCBA was not well burnt hence had a high carbon content, were rougher and hence absorbed more water, leading to lower workability compared with previous studies.[03].

3.4 Compressive Strength Results

28 Days

% Repl.	Force(N)	Area(mm²)	Strength(N/mm²)
0	560000	22500	24.88888889
10	510000	22500	22.66666667
20	475000	22500	21.11111111

60 Days

% Repl.	Force(N)	Area(mm²)	Strength(N/mm²)
0	610000	22500	27.11111111
10	725000	22500	32.22222222
20	700000	22500	31.11111111

90 Days

% Repl.	Force(N)	Area(mm²)	Strength(N/mm²)
0	615000	22500	27.33333
10	760000	22500	33.77778
20	710000	22500	31.55556

It was seen that compressive strength increases with increase in days of curing. This is because hydration of cement is a continuous process that goes on forever, as long as favourable conditions are provided. With increase in time of curing, more C-S-H is produced hence the increase in compressive strength with time of curing. Also, at early age, concrete has more pores hence low strength. With increase in time, these pores are replaced with C-S-H hence the increase in strength.[07]

The compressive strength for the control (0% replacement) was the highest at early ages of concrete. As time of curing increase, the concrete having SCBA had higher compressive strength values, which reduces slightly as the content of SCBA increase further. At early age, 0% SCBA concrete has the highest compressive strength because of the high Tricalcium silicate and Dicalcium Silicate hence high C-S-H than the 10% SCBA and 20% SCBA concrete.[05] As the time of curing increase, the 10% SCBA concrete has the highest compressive strength because in addition to C-S-H from hydration, the calcium hydroxide formed as a product of hydration contributes to strength by; i) Providing a P.H medium for reaction with Silica from SCBA, ii) Silica from SCBA reacts with it to produce more C-S-H. [04,06] As outlined earlier, at 20% SCBA, the strength is lower than the 10% SCBA concrete since the reduction in cement implies that there is less Dicalcium and Tricalcium silicates to form C-S-H.[06]

It was also observed that compressive strength increases with grinding, with 60 min. ground SCBA giving the highest compressive strength. This can be attributed to i), the higher surface area to volume ratio implying that more particles and more silica for reaction with calcium hydroxide to form C-S-H, ii) Smaller particles ensure faster reactions hence faster rate of formation of C-S-H and iii), The higher specific gravity(Density) hence more compact concrete and subsequently higher strength.

In this section, various factors which has been found by reviewing different literature articles are brought to the surface. Total 19 numbers of literature articles has been reviewed in sub-section A. In the sub-section B, analysis of the reviewed articles has been carried out to formulate the conclusion of the study.

4.0 Conclusion

The following conclusions can be drawn from this research;

a) Sugarcane bagasse ash (SCBA) is highly pozzolanic, based on the chemical composition obtained, with a silica content of 60.4% and it was found to be similar to class C fly ash according to ASTM C618.
b) Use of SCBA as partial replacement of cement improves workability up to a certain limit before starting to drop, with 10% replacement giving the highest workable concrete of 58mm compared with 56mm and 50mm for the 20% and 0% replacements respectively for the 30 minutes ground SCBA.
c) The compressive strength and tensile strength of concrete is increased by replacing cement partially with SCBA up to a certain limit. It was found out that a replacement of 10% gave concrete with the highest compressive and tensile strength. This is particularly the case at longer times of curing the concrete. For instance, at 90th day of curing, 10% replacement concrete gave a compressive strength of 33.56N/mm2 compared with 31.33N/mm2 and 29N/mm2 for the 20% and 0% replacements respectively.
d) The density of concrete is increased as SCBA replacement increases up to 10% replacement before starting to drop. For instance, at 60th day of curing, 10 % replacement concrete gave a density of 2430kg/m3 compared with 2420kg/m3 and 2414kg/m3 for the 20% and 0% replacements respectively.
e) Water Absorption reduces as the SCBA replacement increases up to 10% before dropping. For instance, at 90th day of curing, 10% replacement concrete gave a water absorption value of 0.4%, compared with 0.5% and 0.8% for the 20% and 0% replacements respectively. This low water absorption and the increase in density thus means that the concrete will be more durable and the reinforcements will not rust too much.
f) Grinding of SCBA improves the performance of concrete since at 10% replacement, 60 minutes ground SCBA gave concrete with the highest 90th day compressive and tensile strengths, highest 90th day density and lowest 90th day water absorption values. For instance, at 90th day of curing, 60 minutes ground SCBA at 10% replacement gave concrete with a compressive strength of 33.56N/mm2 compared with 31.3N/mm2 and 29.96N/mm2 for 30 minutes ground and unground SCBA respectively.
g) The physical properties of concrete made from partial replacement of cement with SCBA improved with increase in time of curing. For instance, the compressive strength for 10% replacement of cement with 60 minutes ground SCBA was found to be 33.56N/mm2 after 90 days of curing, compared with 31.67N/mm2 and 22.11N/mm2 for the 60th and 28th days of curing respectively.

From these findings, it can be concluded that 60 minutes ground SCBA with a 10% replacement gave concrete with the best performance. It is worth noting that the cement used was class 32.5 and hence the lower strength values. The compressive machine used was not calibrated hence the values obtained by another person may vary from those recorded.

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