Scba Bleneded Concrete As Sustainable Building Material: Assessment of Optimum Replacement Percentage using Mechanical Strength Parameter

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***Abstract*—Sugarcane plays a major role in worldwide economy as it is a raw material of two most widely used commercial commodities namely sugar and ethanol. The production process generates bagasse as a byproduct which is then employed as fuel for steam generation in stokes boilers. The final product of the incineration process is sugarcane bagasse ash (SCBA) which creates a problem for its safe disposal although currently this ash is either land filled or used as fertilizer. Many ashes doesn't possess hydraulic or pozzoloanic property but can be used as filler in construction industry as a sustainable construction practice. The present study used ash collected from sugarcane processing mill and studied the effect of the ash on the strength development in the blended concrete when sand is replaced by different replacement percentage of ash by volume of sand. The ash sample was subjected to chemical analysis test and sieve analysis test. The concrete thus produced was subjected to compressive strength test. The results showed that SCBA sample showed physical properties as similar to natural sand. The concrete produced with SCBA in replacement showed better compressive strength at 20 percent but decreased substantially for further increase in the replacement percentage for both the early (7 days) and later ages (28 days). Thus, 20 percent was concluded to be optimum replacement percentage for sand with SCBA in this study. SCBA can be used as a partial replacement of sand in concrete up to optimum replacement percentage.**

***Keywords*— sugarcane, ash, sand, compressive strength, sustainable**.

I. INTRODUCTION

With growing environment concerns and health risks especially related with the construction industry like concrete, cement and sand mining, industries are coming under great scrutiny by government and environmentalist alike. The waste production has also increased manifold which is creating problem of its disposal. These industrial and agricultural wastes are majorly the byproducts of oil and coal incineration , slag, rice husk, bagasse, fly ash, cement dust, stone crusher dust, marble dust, brick dust, sewer sludge, wood ash, tires, waste PET etc. These wastes are produced on a daily basis in massive amount and if not discarded properly, they pose environmental problems like air pollution and leaching of dangerous chemicals like (arsenic, beryllium, boron, cadmium, chromium, chromium(VI), cobalt, lead, manganese, mercury, molybdenum, selenium, strontium, thallium) when they are dumped in landfills, quarries, rivers and oceans[1] Concrete production is energy intensive and has high capital demand and thus researchers have focused recently on other alternatives which can partially replace its constituent. Researchers have shown that many agricultural and industrial by products can be successfully used in all kind of concrete structures.Rice husk ash, bagasse ash, palm oil fuel ash (POA) is some of the agro waste ashes which are studied and widely used in the construction industry. Agro wastes have pozzoloanic properties in which amorphous silica combines with lime (calcium hydroxide) and forms cementitous material [2]. But a major problem with the usage o agro ash as binder or mineral addition is its almost negligible reactivity. The process employed for ash generation has minimum control over the combustion temperature of wastes and type of cooling of ashes which tend to produce ashes without hydraulic conductivity [3]. Bagasse is the fibrous matter that remains after sugarcane or sorghum stalks are crushed to extract their juice for sugar and ethanol production. Due to high consumption rate of ethanol and sugar their production rate has increased thereby increasing bagasse accumulation. . In major sugar cane producing areas this major volume of bagasse is used to generate energy by incineration and after it is incinerated, it produces a large quantity of ashes (SCBA). For each 10 tonnes of sugarcane crushed, a sugar factory produces nearly 3 tonnes of wet bagasse [4]. And for each ton of burned bagasse generates 25 kg of ash[5].Thus,the usage of agro waste ash such as SCBA is considered as sustainable construction development since it provides partial solution to the issues regarding economic and environment factors. It lowers the direct and indirect cost with added environmental advantages over conventional materials with acceptable performance profile in terms of durability, safety and strength.

II. OBJECTIVE

The basic aim of this study is to investigate the effect of SCBA obtained from sugar milling industry in Tamilnadu, India on Compressive strength development of concrete for water cement ratio of 0.45 and thus, through the analysis of the result, assess the optimum replacement percentage of sand with SCBA which can yield strength as compared to conventional concrete.

III. LITERATURE REVIEW

Several researchers [9-12] have conducted study to fathom the feasibility of replacing natural fine aggregate with wastes from various origins. Though some researchers have reported on this area such as Khattib and ellies[3] whopartially replaced sand with 3 types foundry sand and studied the change in properties of concrete and concluded that Strength of concrete was decreased due to increasing percentage of foundry sand among other such conclusions[14].Akcaozoglu et al. [15] studied the strength properties of two group of mortars which waste PET lightweight aggregates (WPLA) have been used as partial and full substitutes for sand. As a result of the study, the compressive strengths of mortar specimens were over 20 MPa, flexural–tensile strengths were over 4.7 MPa. The authors concluded that, the specimens can be put into structural lightweight concrete category in terms of unit weight and strength properties. Other wastes like ash from burning municipal solid waste (MSW) was also studied as a substitute for sand and Portland cement in production of concrete and it was concluded by authors that 20 % was the optimum replacement percentage from technical and economic point of view[16]. Sugar cane bagasse ash has been studied as mineral additives by various researchers but notwithstanding the poor results they concluded that due to high temperature and incomplete combustion, the reactivity of ash get reduced by the presence of high carbon content and presence of crystalline silica [13, 8, 3]. But SCBA has high content of silica in form of quartz one of the principle components of sand [6] which makes SCBA a viable by-product for application in construction material.

IV. EXPERIMENTAL PROGRAM

A. *Materials*

a) *Cement*

Ordinary Portland cement (Type 1) conforming to IS 8112:1995 was used. The physical and chemical property of cement is in Table 1.

TABLE I: THE CHEMICAL ANALYSIS AND PHYSICAL PROPERTIES OF CEMENT

Physical and Chemical Properties		
S.No	*Chemical Properties*	*Value*
1.	SiO_2 (%)	20.30
2.	Al_2O_3 (%)	5.0
3.	Fe_2O_3 (%)	3.18
4.	CaO (%)	64
5.	MgO (%)	4.47
6.	Na_2O (%)	0.08
7.	K_2O (%)	0.47
8.	Loss on ignition	3.12
	Physical Properties	*Value*
1.	Specific gravity	3.1
2.	Mean size	23 μm

b) *Aggregates*

Normal weight graded natural sand having a maximum particle size of 4.75 mm and specific gravity 2.6 was used as fine aggregate. The bulk specific gravity of sand is 2.62 and absorption (%) is 0.70 and its size distribution is according to requirements of ASTM C33/C33M-08. The coarse aggregate used was crushed gravel with mean size of 10 mm and having bulk specific gravity of 2.6.

c) *Sugarcane bagasse ash*

Sugarcane bagasse ash from the state of Tamilnadu, India was selected to evaluate its suitability as ash for sand replacement. The Sugarcane bagasse ash was obtained from open field burning with average temperature being 600°C. The material was dried and carefully homogenized. An adequate SCBA particle size was obtained by mixing SCBA and coarse aggregate together for a fixed amount of time of 12 minutes as followed by R. Zebrino et al. (2011). SCBA generally consists of irregular shaped particles, and based on the degree of combustion, range from grey to deep black in colour. The physical and chemical properties of SCBA are presented in table 2. These results are in close collaboration with the findings of Sales et al(2010). Figure 1 shows the comparison between SCBA and sand particle.

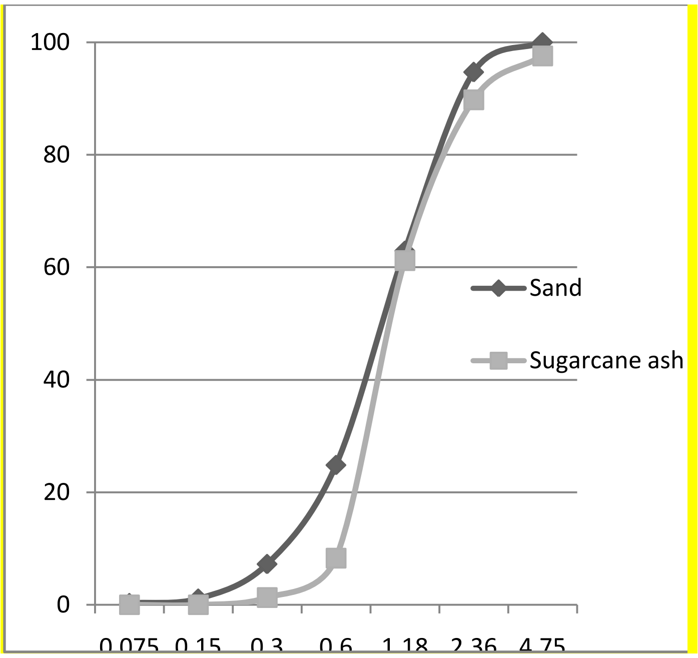

Fig 1. Comparison of sieve analysis between SCBA and sand

TABLE II: THE CHEMICAL ANALYSIS AND PHYSICAL PROPERTIES OF SCBA

Physical and Chemical Properties		
S.No	*Chemical Properties*	*Value*
1	SiO_2 (%)	58.6
2	Al_2O_3 (%)	3.8
3	Fe_2O_3 (%)	6.1
4.	CaO (%)	1.1
5.	MgO (%)	0.8
6.	Na_2O (%)	0.3
7.	K_2O (%)	3.1
8.	Loss on ignition	17.3
9.	TiO_2 (%)	3.6
10.	P_2O_5 (%)	0.9
	Physical Properties	*Value*
1.	Specific gravity	1.20
2.	Average size (mm)	1.18
3.	Fineness modulus	4.39

B. Concrete Mix Proportion

For the study, three different proportion of concrete mixes (SCBA replacement by 20%, 30%, 40% by volume of sand) including the control mixture were prepared with water to binder ratio of 0.45 for design compressive strength of 20 N/mm^2.

C. Casting of Specimen

For the compression test, blocks were casted in cube of dimension 10x10x10 cm for each replacement percentage keeping water-cement ratio same. Compacting of concrete was done by vibration as per IS: 516-1959. After casting all the test specimens were stored at room temperature and then de-molded after 24h, and placed into a water-curing tank with a temperature of 24°C-34°C until the time of testing. 6 cubes were cast per mix, 3 for each period of strength measurement, resulting in a total of 24 cubes of concrete for the entire project. The average of results is reported in this paper.

D. Testing Program

Test carried on the hardened concrete were compressive strength test (Conforming to IS: 516-1959) for 7 days and 28 days strength determination. For compressive strength, digital compression testing machine (conforming to IS: 516-1959) was used. The maximum load at failure was taken for strength comparison. The results are reported.

V. RESULTS AND DISCUSSION

A. Physical Comparison of Sand and SCBA

The physical properties of cement and RHA are given in Table 1 and Table 2. The fineness modulus of SCBA was calculated to be 4.39 which place it in ZONE 1 but sand used in design mix of concrete lies in ZONE 2. The comparison of sieve anlaysis is presented in Fig 1 which shows that SCBA used for concrete was coarser compared to sand employed for the same purpose. Maximum retention of SCBA was on sieve of 600µm while for sand maximum quantity was retained on 600µm followed by 1.18mm sieve. The total composition of pozzoloanic essential compound namely silica, alumina and ferric is 68.5 which is way less thanminimum required for class N and F type pozzoloan as shown in Table 3. Thus the SCBA can be employed as sand replacement rather than pozzoloanic substance in concrete. The low unit weight and specific gravity of SCBA as compared to sand can reduce the unit weight of concrete produced by SCBA blended concrete.

TABLE III: PROPERTIES OF DIFFERENT TYPES OF POZZOLOANS AS DEFINED BY ASTM C618

Properties of Pozzolans			
Properties	*Class N type pozzoloan*	*Class F type pozzoloan*	*Class C type pozzoloan*
Min. SiO_2 $+Al_2O_3$ + Fe_2O (%)	70.0	70.0	50.0
Max. Sulphur trioxide (SO_3) (%)	4.0	5.0	5.0
Max. Na_2O + 0.658 K_2O	1.5	1.5	1.5
Max. Loss on ignition	10.0	6.0	6.0

B. *Compressive Strength*

Test results of compressive strength are presented in table 4.From the 7 day strength we gather that, at 20% replacement of sand by SCBA, the strength of the concrete (20.7 N/mm²) is quite similar to that of the control mix (20.6 N/mm²). However, with the increasing content of SCBA is concrete, the strength begins to deteriorate. The compressive strength for the cubes at 30% replacement of sand is roughly two-thirds of the control mix (14.6 N/mm²), while for those at 40% replacement, the strength is less than half of the control mix (9.93 N/mm²). Hence, initial results indicate that if we replace 20% of fine aggregate by SCBA in M20 concrete, a similar value of compressive strength can be achieved.

The 28 day strength results show the same pattern. The compressive strength of the control mix and the cubes in which 20% of sand has been replaced by SCBA, are comparable, at 26.3 N/mm² and 25.3 N/mm² respectively. The strength for the mix involving 30% replacement of sand is about 60% of the design strength, and is 16.1 N/mm².For the mix in which 40% of the sand has been replaced by SCBA, the strength is the lowest, at 11.1 N/mm².

TABLE 4: TEST RESULTS

Compressive Strength of Concrete		
Design Mix	*7 days strength*	*28 days strength*
0%	20.6	26.3
20%	20.7	25.3
30%	14.6	16.1
40%	9.93	11.1

VI. CONCLUSION

SCBA can be employed as sand replacement because the total composition of pozzoloanic essential compound namely silica, alumina and ferric is less than minimum required for class N and F type pozzoloan. From the average compressive strength of each mix, obtained after a 7 day and 28 day period, we see that the mix in which 20% of the fine aggregate had been replaced by SCBA, shows a compressive strength similar to the M20 control mix, at both 7 and 28 days, of 20.7 N/mm² and 25.3 N/mm² respectively. The concrete mixes in which 30% and 40% of fine aggregate had been replaced by SCBA showed lesser strength compared to the control mix, and were deemed unsuitable for practical or industrial use. Thus, the mix of concrete at 20% replacement of sand with SCBA is the optimum replacement percentagefor sand with SCBA and hence can be considered for industrial purposes where economic use of M20 grade concrete is desired, which simultaneously gives the same strength as the control concrete.

VII. RECOMMENDATION

The process employed for generation of SCBA can be improved as this research employed the ash obtained fromsugarcane mills which burn bagasse at a wide range of temperatures. Quantity and quality ash depend on several factors namely combustion temperatures of the bagasse biomass and type of incineration method employed. So, as such any future work must focus on the above factors to produce a more reactive ash (with pozzoloanic properties) by working out optimum combustion environment.

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