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RESEARCH ARTICLE

EFFECT OF SCBA SUBSTITUTION ON MECHANICAL PROPERTIES OF CLAY BRICKS

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ABSTRACT

The present work reports the recycling of SCBA waste as a raw material in brick making industries, through replacement of natural clay up to 20wt. %. Initially the samples SCBA and BMC were characterized by XRF. The results of XRF reveal that both SCBA and BMC contain a large amount of silica and tracer amount of oxides of aluminium and iron. Using SCBA in different proportions clay brick pieces were prepared, and then tested, so as to determine their mechanical properties such as linear shrinkage, water absorption, porosity and compressive strength. The test results indicate that the SCBA waste could be used as filler in clay bricks, thus enhancing the possibility of its reuse in a safe and sustainable way. The surface morphology and the microstructure of the product were analyzed through Scanning Electron Microscope (SEM).

INTRODUCTION

Sugarcane bagasse ash is considered as a non-biodegradable solid waste material. The SCBA waste is a major concern of the sugarcane industry, with disposal to soil fertilizer currently the most common practice. Thus, the management of this abundant waste in an environmentally safe way is a challenge that must be met. SCBA waste can be characterized as a solid waste material, rich in crystalline silica (Faria *et al*., 2010) being thus also likely to be used as a ceramic raw material. Bagasse is the matted cellulose fiber residue from sugarcane that has been processed in a sugar mill. Previously, bagasse was burnt as a means of solid waste disposal. However, as the cost of fuel oil, natural gas and electricity has increased, bagasse has come to be regarded as a fuel rather than refuse in the sugar mills (Paya *et al*., 2007; Aigbodion, 2008). The reuse of SCBA waste as a possible new additive to ceramic materials is an option. (Borlini *et al*., 2005) reported on the use of SCBA waste in replacement for fluxes in vitrified ceramic tile formulation. It was found that the SCBA waste did not act as a fluxing agent in the ceramic tile compositions. (Borlini *et al*., 2005) also investigated the influence of the firing temperature on the technological properties and microstructure of SCBA waste containing red ceramic.

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They concluded that no major changes in the technological properties of red ceramic fired from 900 ºC to 1200 ºC were found. However, they observed that the red ceramic pieces incorporated with 20 wt.% of SCBA waste fired at 1200 ºC presented a large microstructural variation in relation to the other studied compositions. (Ganesan *et al*., 2007) reported on the use of SCBA waste as supplementary cementitious material. It was found that the SCBA waste is an effective mineral admixture, with 20 wt. % as optimal replacement ratio of cement.

In the context of recycling, the present study focuses on the incorporation of sugarcane bagasse ash waste into clay bricks for civil construction. Although the ceramic industry is highly promising for the final disposal of solid wastes, little is known about reuse of sugarcane bagasse ash waste in clay ceramics (Faria, 2011). (Tiexeira *et al*., 2008) reported on the use of SCBA waste as a potential quartz replacement in red ceramic. It was found that the SCBA waste has a very high quartz concentration and low concentrations of fluxing oxides. (Cordeiro *et al*., 2009) reported that SCBA waste has adequate properties to be used as pozzolan in building materials. (Lima *et al*., 2010) reported on the use of SCBA waste in replacement of fine aggregate in the manufacture of concrete. (Aigbodian *et al*., 2010) reported on the potential utilization of SCBA waste characteristics are adequate for ceramic products such as insulation, membrane filters and structural ceramics.

MATERIALS AND METHODS

The SCBA waste was collected from sethiathoppu sugar mill, Cuddaolre district, Tamilnadu, India. SCBA and BMC (brick making clay) in the form of powder were mixed with sufficient amount of water for the formulation of ceramic pastes and kept at room temperature. Selected mixtures containing 0, 5, 10, 15 and 20 wt. % waste were prepaed (Table 1). The test specimens were prepared by hand shaping, molding and hand pressing. The samples obtained with these techniques were 90 mm X 25 mm X 30 mm rectangular bars. The specimens were dried at room temperature for a day and then sun dried for 3 days. Finally the specimens were fired in an electrical furnace, at temperature ranging from 800 - 1100 °C after reaching desired temperature, the specimens were kept in furnace for 4 hour and cooling occurred by natural convection after it was turned off. The fired samples were subjected to SEM and Mechanical properties. Two important parameters are the alkali Index (AI) and the base-to-acid ratio ($R_{b/a}$) of SCBA can be calculated using XRF analysis.

Table 1. The proportions of the mixtures for the formulations (wt.%)

Formulation	Clay (%)	SCBA (%)
RC 0W	100	0
RC 5W	95	05
RC10W	90	10
RC15W	85	15
RC20W	80	20

Vamvuka, 2009 noted that the alkali index (AI) expresses the quantity of alkali oxides in the fuel per unit of fuel energy

$$AI = \frac{\text{kg}\ (K_2O + Na_2O)}{GJ} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots..(1)$$

The base-to-acid ratio ($R_{b/a}$) can also be used to determine the likely hood of fouling of the ash. This can be written as follows

$$(R_{b/a}) = \frac{\%\ (Fe_2O_3 + Cao + MgO + K_2O + Na_2O)}{\%\ (SiO_2 + TiO_2 + Al_2O_3)} \qquad \text{---------------}\ (2)$$

The particle size distribution was determined by a combination of sieving and sedimentation procedures. The morphology of the SCBA waste powder particles was observed by secondary electrons (SE) under a scanning electron microscopy (SEM) with a coupled energy dispersive spectroscopy (EDS), at 10 KV, after gold coating.

Mechanical properties

Water absorption test

Water absorption is a key factor affecting durability of brick samples. The less water infiltration into a brick samples, the more durable is the brick samples and the better is its resistance to the natural environment. The test specimens are SCBA added brick samples in the form of bars. The dry SCBA added brick samples are sintered at different temperature (800, 900, 1000 and 1100 °C) were weighted and then submerged in water at a temperature between 55 ° C and 30 °C. After 24 hours, the specimens were taken out of water. Then, the surface water of each specimen was wiped off with damp cloths and the specimens were weighed again.

$$\%\ \text{of water absorption} = \frac{W_2 - W_1}{W_2}\ X\ 100 \qquad \text{---------}\ (3)$$

Where W_1 - weight of the dry specimen and
W_2 - weight of the specimen after 24 hours of immersion in water.

Porosity

Role of porosity

The density or porosity affects a number of the properties of the brick samples but probably the most important effect is its strength (Norsker, 1987). Highly porous clay brick samples are mechanically weak. A clay brick with the highest porosity has the lowest strength. The water absorption method adopted to measure the porosity values of the ceramic body is described below. The samples were heated continuously in boiling water for about six hours and left to cool over night which enables the pores to get filled up with water to saturation. The saturated specimens were then weighed by immersing in water as (W_1) and in air as (W_2). The samples were then placed in hot air oven at 200 °C and dried for about six hours to remove the water contents completely and then weighed as (W_3). To standardize the values of the results the percentage of porosity was calculated using the relation

$$\%\ \text{of porosity} = \frac{W_2 - W_3}{W_2 - W_1}\ X\ 100 \qquad \text{--------}\ (4)$$

The stated procedure was repeated a number of times until consistency in the values were obtained and the average value was taken.

Compressive strength

Compressive strength were tested using a universal testing machine (UTM) column shaped samples of 30 mm X 90 mm (diameter X length) were used for evaluation of compressive strength and was obtained from dividing the area of load – displacement curve by the value of maximum load.

$$\text{Compressive Strength} = \frac{\text{Maximum load at failure(N)}}{\text{Average area of bed face}(mm^2)} \qquad \text{------}\ (5)$$

Linear shrinkage

Bricks were shrunk after drying and firing process. Therefore allowance is made in the forming process to achieve the desired size of finished the brick. Both drying and firing were determined by using the formula

$$\%\ \text{of Linear shrinkage} = \frac{OL - DL}{OL}\ X\ 100 \qquad \text{--------}\ (6)$$

Where OL = Original Length
DL = Dry Length

$$\% \text{ of Firing shrinkage} = \frac{DL-FL}{DL} X\ 100 \quad \text{-------- (7)}$$

Where DL = Dry Length
FL = Firing Length

RESULTS AND DISCUSSION

The SCBA and BMC were analyzed for elemental composition (using XRF) and the obtained results are provided in Table 2. As shown in table sugarcane bagasse ash contained SiO_2 as the major compound with lower concentrations of aluminium and iron oxides. It also has a low concentrations of fluxing agents but higher than those found in the brick making clay material. The brick making clay material showed a typical composition of clay minerals of the Kaolinite group, with low percentage of fluxes and high content of Al_2O_3. According to Vamvuka 2009, when AI values are in the range 0.17 – 0.34 kg / GJ fouling and slagging is probable, while when these values are greater than 0.34 fouling or slagging is virtually certain to occur. The value of AI in SCBA is 9.624 kg / GJ. Therefore fouling or slagging is virtually certain to occur. The value of $R_{b/a}$ in SCBA is 0.2959. The label for each compound makes reference to its weight concentration in the ash. As $R_{b/a}$ increases, the fouling of a fuel ash increases. The particle size distribution of the SCBA was taken by using texture analysis. The result revealed that the sample presented a wide range of particle sizes. It has 10.45 wt.% clay (< 2 mm), 30.22 wt.% silt (2 ≤ x ≤ 63 mm) and 59.32 wt.% sand (> 63 mm). This result is in accordance with the presence of a high content of silica particles in the ash waste sample.

Table 2. Chemical composition of the sugarcane bagasse ash and brick making clay samples

Element composition	SCBA Concentration (%)	BMC Concentration (%)
SiO_2	69.64	61.84
Al_2O_3	1.94	18.22
CaO	6.26	4.67
Fe_2O_3	2.05	6.89
K_2O	8.71	2.57
MgO	3.28	1.91.
MnO	0.08	0.10
Na_2O	0.90	2.15
TiO_2	0.14	1.09
SO_3	2.55	0.05

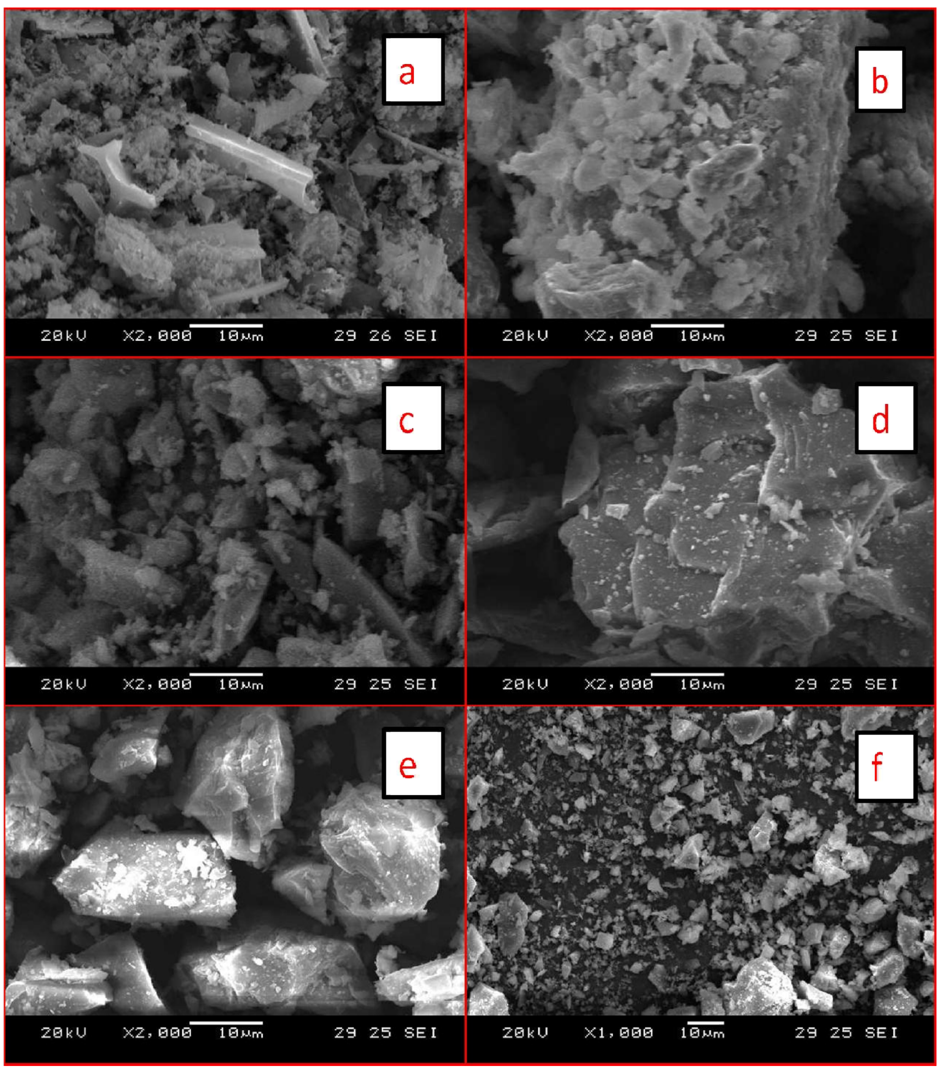

Fig.1. SEM images of (a) SCBA sample, (b) BMC and (c-f) sample (S_4) fired at different temperatures (800-1100 °C)

Microstructure

SEM micrograph of the SCBA sample is shown in Fig. 1a. From the micrgrphs, it can be clearly seen that SCBA samples were composed of different grain sizes and that particles are irregular in shape. Highly cylindrical porous plates of sugarcane bagasse unburnt are also seen in the SCBA sample (Fig. 1a).

The typical microstructure of the clay brick pieces containing SCBA waste 15 wt.% (S_4) were fired between 800 – 1100 °C is shown in Fig 1(c–f). As can be observed, the sintered microstructure of clay bricks containing SCBA waste tends to be more porous than those of waste-free clay bricks. These results are consistent with the values of the technological properties (linear shrinkage, water absorption, porosity and compressive strength). Thus, the SCBA waste powder as added to a clayey body causes modification on the texture and porosity of the fired clay brick pieces. In particular, the addition of very high SCBA waste amounts in clay bricks should be avoided, because it impairs the mechanical properties of the fired pieces.

Mechanical properties

Water absorption

The results of the water absorption test for SCBA added bricks fired at different temperatures (800-1100 °C) as shown in Fig. 2a. The water absorption values are varied between 9.99 – 28.27 % with respect to addition of SCBA for 0, 5, 10, 15 and 20 wt.% respectively. The obtained results indicate that water absorption increases with the increase of SCBA addition.

Porosity

Usually porosity is related to internal brick structure and geometry. Porosity is directly proportional to water absorption. The porosity values varied from 20.46 – 45.75 % as shown in Fig. 2b. As the percentage SCBA admixture increased it leads to increased percentage of pores when the samples was fired at 1000 °C the porosity values should be decreased. The similar result was reported by other researchers (Chesti,1986; Li *et al*., 2008).

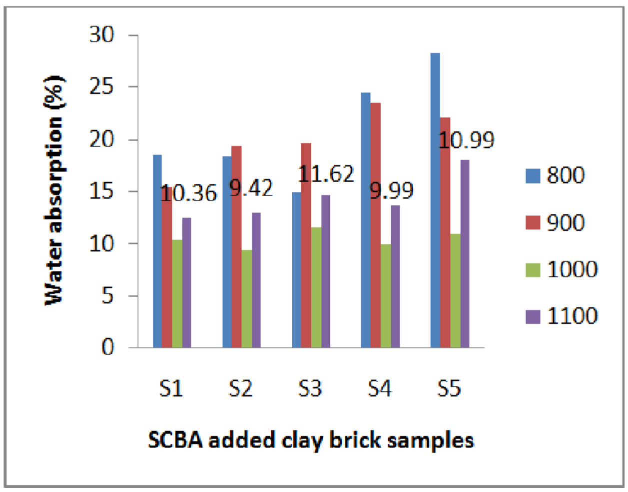

Fig. 2a Water absorption for different wt.% of SCBA added clay brick samples at different temperatures

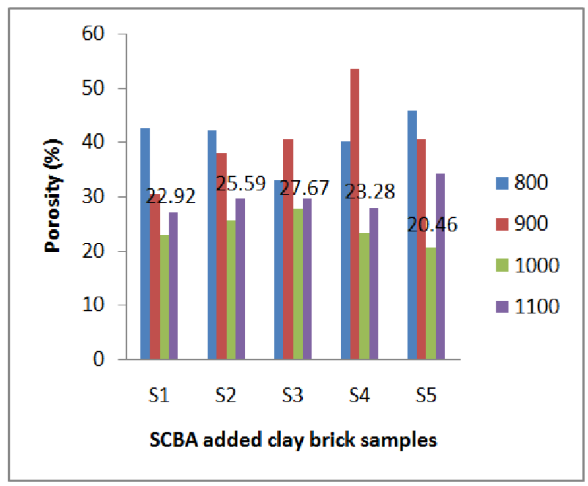

Fig. 2b Porosity for different wt.% of SCBA added clay brick samples at different temperatures

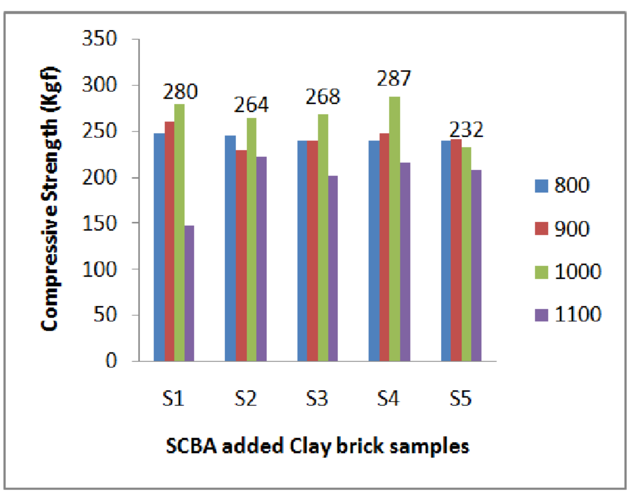

Fig. 2c Compressive Strength for different wt.% of SCBA added clay brick samples at different temperatures

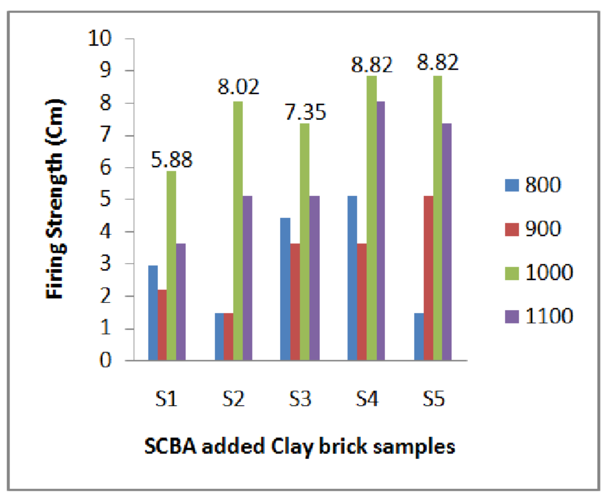

Fig. 2d Firing Shrinkage for different wt.% of SCBA added clay brick samples at different temperatures

Compressive Strength

The Compressive Strength test results on the brick indicated that the strength is greatly dependent on the amount of SCBA in brick. For all the proportions, the samples fired at 1000 °C have shown higher strength than all other fired samples. In addition, the optimum proportion at which maximum compressive strength occurred was 15 wt.%. After the SCBA waste addition (15 wt.%) the expected properties of decrease in the water absorption and the increase of the mechanical strength were noted.

Firing Shrinkage

The quality of brick can be further considered by examining the shrinkage of brick. The shrinkage of a studied normal clay brick is 1% after heating at 1000 °C. However, the SCBA incorporated bricks exhibit increase of firing shrinkage with increase of SCBA addition (Fig. 2c) upto 15 wt.%. Further addition decreases the firing shrinkage (1100 °C).

Conclusion

With the aim of utilizing sugarcane bagasse ash waste as a raw material in clay brick making, SCBA in different proportions was mixed with brick making clay. The prepared products were analyzed for SEM and Mechanical strength analyses. SEM micrographs of SCBA revealed that SCBA waste powder is composed of a mixture of mineral particles of different morphologies and unburned bagasse particles. The results of mechanical study suggest the limitation of incorporation of SCBA as 15 wt.%. Further addition resulted in increase of water absorption and decrease of mechanical strength. These results suggest that only lesser percentage of SCBA addition can yield quality clay bricks.

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