Processing of Sugarcane Bagasse ash and Reactivity of Ash-blended Cement Mortar

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Abstract

Sugarcane bagasse ash (SCBA), a sugar-mill waste, has the potential of a partial cement replacement material if processed and obtained under controlled conditions. This paper discusses the reactivity of SCBA obtained by control burning of sugarcane bagasse procured from Punjab province of India. X-ray diffraction (XRD) and scanning electron microscopy (SEM) techniques were employed to ascertain the amorphousness and morphology of the minerals ash particles. Destructive and non-destructive tests were conducted on SCBA-blended mortar specimens. Ash-blended cement paste specimens were analyzed by XRD, thermal analysis, and SEM methods to evaluate the hydration reaction of SCBA with cement. Results showed that the SCBA processed at 600°C for 5 hours was reactive as ash-blended mortar specimens with up to 15% substitution of cement gave better strength than control specimens.

Key words: Bagasse ash, Blended mortar, Pozzolanic activity, X-ray diffraction, Thermal analyses, Scanning electron microscopy

1. INTRODUCTION

Scientists and researchers all over the world are always in a quest for developing alternate cement binders that are environment friendly and could contribute towards sustainable development. Some industrial by-products like fly ash and blast furnace slag (Singh et al., 1995); earlier termed as wastes, have proven to be cost effective materials when used as partial replacement cementitious materials. Many agricultural wastes such as rice husk ash (James and Rao, 1986; Mehta, 1992), wheat straw ash (Bircik et al., 1999), saw dust, cork granules, coconut pith or fibers (Payá et al., 2002), ashes from oil-pace waste (Tay, 1990) and dry leaves of various plants and grass have been reported as pozzolanic materials. All these materials are rich in silica which shows pozzolanic reactivity towards lime.

Sugarcane bagasse ash (SCBA) is an abundantly available waste of sugar-mills. Sugarcane is one of the major crops grown in over 110 countries and its total production is over 1500 million tons (FAO, 2006). After the extraction of all economical sugar from sugarcane, about 40-45% fibrous residue (Deepchand, 1986) is obtained, which is reused in the same industry as fuel in boilers for heat generation that leaves behind 8 -10 % ash as waste (Payá et al., 2002), known as SCBA. It contains high amounts of un-burnt matter, silica, aluminum and calcium oxides (Deepchand, 1986). It is a very valuable pozzolan material if carbon free and amorphous ash could be obtained by further combustion. SCBA procured directly from sugar-mill furnaces are produced under uncontrolled and non uniform burning conditions with temperatures sometimes rising above 1,000°C. As reported by Baguant (1995), crystallization of the minerals occurs at temperature higher than 700°C. Also, some times during burning coal is mixed with bagasse that leaves high carbon contents in SCBA (Payá, et al., 2002).

Sugarcane production in India is over 300 million tons/year. The processing of it in sugar-mills generates about 10 million tons of SCBA as waste material. Very few studies have been reported on use of bagasse ash directly obtained from the sugar-mills A few studies (Baguant, 1995; Hernández et al., 1998; Singh et al., 2003) have reported on the suitability of sugar cane bagasse ashes as partial cement replacement binders that are obtained directly from the sugar-mills. Present study was carried out to evaluate the SCBA processed and obtained by control burning of sugarcane bagasse which was procured from the Punjab province in India. After characterizing the SCBA with regards to its chemical and physical properties, effect of SCBA on the rheological behavior was evaluated. Reactivity of SCBA with cement was evaluated by carrying out strength development (destructive and non-destructive) tests on SCBA-blended mortar specimens. Hydration reaction of SCBA with cement was analyzed by X-ray diffraction (XRD), thermal analyses and scanning electron microscopic (SEM) techniques.
2. EXPERIMENTAL PROGRAMME

2.1 Materials

2.1.1 Cement and Sand

Ordinary Portland cement (OPC), conforming to Japan Industrial Standards, JIS R 5210-2003 and standard sand as per JIS R 5201 were used for the preparation of cement paste and cement mortar specimens.

2.1.2 Sugarcane Bagasse

A representative sample of sugarcane bagasse was collected from Ludhiana district (north latitude 30°-34' and 31°-01' and east longitude 75°-18' and 76°-20') of Punjab province (India). Care was taken to remove any clay fractions, soil particles or any other foreign matters from the bagasse by thoroughly washing it with water. It was then sun-dried for two days to facilitate the subsequent burning.

2.2 Ash Production from Sugarcane Bagasse

In order to obtain amorphous SCBA, optimum burning with respect to time and temperature was evaluated by conducting trial burnings of sugarcane bagasse at 400, 500, 600, 700 and 800°C for 3, 5, 6 and 8 hours (James and Rao, 1986; Chandrasekhar et al., 2006; Ajay et al., 2007). Biricik et al. (1999) on wheat straw and Patel (1987) on rice husk; have reported that burning time, temperature, cooling time, and grinding conditions effect the pozzolanic reactivity of the ashes. Carbon contents (%) were measured after each burning (Fig.1) which indicated that combustion was almost complete at 800°C for 5 hours burning. According to Chandrasekhar et al. (2003), carbon contents get reduced at low burning rate, but the amount of amorphous matter gets decreased. Mehta (1979) and Visvesvaraya (1986) have reported in their work carried out on rice-husk ash that crystalization of minerals occurs at temperatures higher than 650°C. Chopra et al. (1981) have also reported that at burning temperatures up to 700°C, silica remains in amorphous form and silica crystals grow with increase in the time of incineration. Hence considering the rate of burning, residence time and the carbon contents, the suitable burning condition was identified as 600°C for 5 hours. The temperature was raised at a rate of 5°C/minute with residence time of 3 hours. At this condition brownish white color indicated complete burning. Amorphous nature of the ash was further ascertained by XRD analysis.

To obtain SCBA for further tests, burning was carried out in two stages - open burning of sugarcane bagasse to reduce the volume of dry matter, followed by controlled burning at 600°C for 5 hours in a thermostatically controlled electronic furnace (KDFP-90). Bui et al. (2005) have reported that strengthening capability of a mineral admixture not only depends on the pozzolanic reactivity, but also on the relative fineness of the filler material. SCBA so formed was not fine enough to be blended with cement. Therefore, to achieve fineness comparable to OPC, the SCBA obtained after burning was grinded in a ball mill (25×35g· 30mm φ balls) for about 4 hours and subsequently screened through 53μm (No.270) sieve (Nair et al., 2006).

2.3 Pozzolana Reactivity of SCBA

The pozzolana reactivity of SCBA with OPC was evaluated in two ways:
(a) By analyzing the results of mechanical strength development of ash-blended mortar specimens prepared by substituting OPC with 10, 15, 20 and 25% (by weight) of SCBA; and
(b) By studying the mineralogy and morphology of hydrates present in the ash-blended hydrated pastes, with XRD, SEM and thermal analyses.

2.3.1 Preparation of Cement Mortar Specimens

Blended mortar specimens were prepared as per JIS R 5201-1997, substituting OPC with 10, 15, 20 and 25% (by weight) of SCBA. Control specimens (CTR) using only OPC i.e., without any ash substitution were also prepared for comparison of the respective results. Nomenclature of mortar and paste specimens with different SCBA substitution ratios has been given in Table 1.

A typical mixture consisting of 450g cementitious material (cement and SCBA), 1,350g standard sand
(cementitious material: sand ratio = 1:3), and 225g water was used in preparing a test set comprising of three standard size (40x40x160mm) rectangular specimens. Water cementitious material ratio (w/c) was maintained as 0.5 for mortar specimens. Effect of ash substitution on the workability of blended mortar specimens was measured by conducting the flow test on freshly prepared mortar mix. For curing purposes, hardened specimens were kept fully immersed in water maintained at 20 ± 1°C, until the day of testing and as per JIS R 5201-1997 specifications. For each mortar blend, 6 sets (6x3 = 18) specimens were subjected to destructive (compressive strength and flexural strength) as well as non destructive testing (ultrasonic pulse velocity), conducted at the age of 3, 7, 14, 28, 56 and 91 days. In total, 90 specimens with different blending ratios including CTR were prepared and all necessary precautions were observed to maintain the same working conditions while preparing these specimens.

2.3.2 Preparation of Paste Specimens
To study the effect of ash substitution on hydration, mineralogical and morphological studies of hydrated pastes were conducted. For this, separate sets of pastes were prepared, replacing OPC with 10, 15, 20 and 25% SCBA and water cementitious material ratio (w/c) as 0.35. Effect of SCBA on the water consistency was also measured as shown in Table 2. Effect of SCBA substitution on the setting time was evaluated directly by measuring the initial and final setting time. The pH values were also measured to check the effect of SCBA substitution on the alkalinity of freshly prepared blended pastes.

Micro-structural features and mineralogical composition of the hydration products formed in CTR and ash-blended pastes were ascertained and compared after 28 days and 91 days of curing by using SEM, XRD and thermo-gravimetric tests.

3. RESULTS AND DISCUSSION

3.1 Physical and Chemical Properties
Physical and chemical properties of SCBA in comparison to OPC are shown in Table 3. SCBA has low density and higher surface area (Blaine surface area) as compared to OPC. The combined chemical composition; SiO₂ + Al₂O₃ + Fe₂O₃ (>70%) and CaO (>10%) testified the pozzolanic and cementitious nature of SCBA as per ASTM C 618-03 specifications. Particle size distribution curve of SCBA samples (Fig.2) indicated that average size of the ash particles was 28.9μm and 90% particles were of size less than 45.3μm. SEM photograph (Fig.3) also testified the size and shape of particles present in SCBA. Krawood et al. (2001) has reported that large surface area favors the pozzolanic reactivity of amorphous silica and other minerals. Appearance of a hump in the X-ray diffractogram at angle between 20°-39° (Fig.4), and granular shape of the particles indicated the amorphousness of the minerals. A little crystallization of silica was noticed as shown by quartz

<table>
<thead>
<tr>
<th>Specimen</th>
<th>W.C.</th>
<th>IST</th>
<th>FST</th>
<th>pH</th>
<th>Mortar flow</th>
</tr>
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<tr>
<td>CTR</td>
<td>33.0</td>
<td>125</td>
<td>230</td>
<td>12.5</td>
<td>178</td>
</tr>
<tr>
<td>SC-10</td>
<td>33.5</td>
<td>145</td>
<td>300</td>
<td>12.6</td>
<td>168</td>
</tr>
<tr>
<td>SC-15</td>
<td>33.8</td>
<td>155</td>
<td>310</td>
<td>12.6</td>
<td>165</td>
</tr>
<tr>
<td>SC-20</td>
<td>34.2</td>
<td>160</td>
<td>310</td>
<td>12.7</td>
<td>165</td>
</tr>
<tr>
<td>SC-25</td>
<td>34.5</td>
<td>170</td>
<td>315</td>
<td>12.7</td>
<td>160</td>
</tr>
</tbody>
</table>

W.C.: Water consistency, IST: Initial setting time, FST: final setting time

Table 3 Physical and chemical properties of OPC and SCBA

<table>
<thead>
<tr>
<th>Chemical properties</th>
<th>Physical properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical Composition (wt.%)</td>
<td>Density (g/cm³)</td>
</tr>
<tr>
<td>SiO₂</td>
<td>Al₂O₃</td>
</tr>
<tr>
<td>OPC</td>
<td>62.43</td>
</tr>
</tbody>
</table>

Fig.2 Particle size distribution curve of SCBA

Table 2 Water consistency, setting time, flow and pH values of CTR and ash-blended specimens
(Qc) peaks in Fig.4.

3.2 Setting Time and Water Consistency Limit

SCBA addition affected the flow characteristics as indicated by the water consistency values of ash-blended cement pastes which increased with increase in the amount of SCBA (Table 2). It was due to the large surface area of SCBA that caused more water absorption than OPC. Initial and final setting times were also increased with increase in the amount of SCBA contents. Results indicated that SCBA retarded the setting; however this retardation was negligible and within specified limits as prescribed by ASTM C 150-03. It was caused due to more adsorption of water at the surface of the SCBA particles. The higher the proportion of the SCBA, the higher was the adsorption of water. Thus the more quantity of water added to maintain the consistency increased the setting time (Singh et al., 2000). Further, the increase in the setting time was due to the reduction in the amount of calcium hydroxide in the SCBA-blended pastes. Also the development of films of silica gel around cement grains, and a mutual coagulation of components with in the paste resulted in the increase in setting time (Neville, 1995). Flow values (Table 2) for the ash-blended mortars were also decreased with the increase in the amount of SCBA. But this decrease was insignificant from all practical considerations. As the w/c ratio was kept same for all blends; this decrease in flow values was due to the higher specific surface area of the SCBA which required more water to wet the surface than that required by OPC in the CTR.

3.3 Mechanical Strength Tests

3.3.1 Compressive Strength (CS)

Results of CS tests conducted on mortar specimens (Fig.5) showed that compressive strength of 3 and 7 days cured ash-blended specimens was higher than that of the CTR. This was due to the combined effect of relative fineness and the pozzolanic activity of SCBA (Detwiler and Mehla, 1989). But decrease in CS with increase in the substitution ratio, indicated that filler effect was dominant only up to 15% substitution of OPC with SCBA. According to Bui et al. (2005), smaller ash particles improved the particle density, leading to a reduced volume of larger pores and a more homogenous microstructure of the cement gel. SC-10 and SC-15 mortar specimens showed more CS than that of CTR over the entire curing period of 91 days. At 91 days CS for SC-10 and SC-15 specimens was 104 and 102% of that of CTR. But for SC-20 and SC-25 specimens, the respective values were 92 and 84% of that of CTR. It showed that at later stages of hydration reaction the pozzolanic reaction was more dominant than the filler effect of fine ash particles.

As a measure of pozzolanic activity, strength activity index (AI) was also calculated at 7, 28 and 91 days. According to ASTM C 311-02 it is defined as AI = 100 A/B, where 'A' is the average compressive strength of ash-blended specimens and 'B' is the average compressive strength of CTR at the same age. As shown

![Graph showing compressive strength of SCBA-blended mortar in comparison with CTR (all values are average of 3 test results)]

**Table 4: Strength activity index of SCBA blended mortar specimens at 7, 28 and 91 days**

<table>
<thead>
<tr>
<th>Specimen</th>
<th>Curing age of specimens</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>7 days</td>
</tr>
<tr>
<td>SC-10</td>
<td>118.9</td>
</tr>
<tr>
<td>SC-15</td>
<td>116.9</td>
</tr>
<tr>
<td>SC-20</td>
<td>106.2</td>
</tr>
<tr>
<td>SC-25</td>
<td>100.5</td>
</tr>
</tbody>
</table>
in Table 4, $AI$ for all ash-blended mortars at 7, 28 and 91 days, was higher than the minimum requirement of 75 specified by ASTM C 618-03.

### 3.3.2 Flexural Strength (FS)

Center point loading flexural strength test was conducted on all mortar specimens as per JIS R 5201-1997. Universal testing machine was employed to test the standard mortar specimens of size $40 \times 40 \times 160$mm. The specimen was simply supported with a clear span of 100mm and load was applied at the center of the specimen at a constant rate. As a measure of FS, modulus of rupture was calculated with maximum load at the failure. Results of FS test conducted at 3, 7, 14, 28, 56 and 91 days are graphically shown in Fig.6. At 91 days, the FS for SC-10, SC-15, SC-20 and SC-25 was 104, 101, 96 and 89% of that of CTR. The trends of FS test results were similar to the CS test results.

The increase in CS and FS in the SC-10 and SC-15 was due to the combined effect of physical and chemical processes. According to Singh et al. (2000), physical action was caused by the high specific surface area of SCBA which lead to the segmentation of large capillary pores, and may also have introduced a large number of nucleation sites in the system for the rapid precipitation of hydration products. Pozzolanic reaction between calcium hydroxide (CH) and silica (SiO$_2$) and also the hydration of SiO$_2$ itself in the alkaline environment was responsible for increase in the CS. But in case of SC-20 and SC-25, decrease in FS and CS was due to the retardation of the hydration reaction. It was because of the slow reactivity of present in the SCBA. Reduction in the ultimate strength of SC-20 and SC-25 was also due to the decrease in the CaO amount. In case of SC-10 and SC-15, the relative increase in CS and FS with respect to the CTR, at different age of curing is shown in Fig.7 and Fig.8, respectively.

As a non destructive measure, ultrasonic pulse velocity (UPV) was measured as per ASTM C597-03 to observe the hydration and strength development (Malhotra and Cárno, 1991) of SCBA-blended specimens till 91 days of curing. All blended specimens showed uniform development, but SC-10 and SC-15 continuously showed more UPV and hence better strength than that of CTR (Fig.9). After the sharp increase in the early strength due to filler effect, development of UPV was gradual. The rate of development was greater than 1.0 for all blends even after 91 days. It was the confirmation of gradual pozzolanic reaction between silica in SCBA and available
CH in the cement gel.

3.4 Analyses of Hydrates in SCBA-blended Cement Pastes

Different hydrates formed in SCBA-blended cement pastes were examined and analyzed by XRD, SEM and thermal analyses. Discussion is mainly based on the typical pozzolanic reaction of SiO$_2$ and alumina (Al$_2$O$_3$) present in SCBA with available calcium hydrates CH in the hydrated gel, forming additional calcium silicate hydrate (C-S-H) and calcium aluminate silicate hydrates (C-A-S-H).

3.4.1 X-ray Diffraction (XRD) Analysis

Comparison of XRD patterns (Fig.10) obtained for SCBA-blended and CTR paste specimens after 28 days and 91 days of curing showed that in 91 days cured specimens; the intensity of peaks ‘C’ representing CH was significantly reduced with corresponding increase in the C-S-H peaks represented by ‘S’. Also the peaks ‘Q’ at $2\theta = 26.66^\circ$, representing SiO$_2$ got diminished in 91 days cured specimens than as compared to 28 days specimens. It was a clear indication of the fact that the free CH available in 28 days cured specimens was gradually consumed by the excess amount of SiO$_2$ present in the SCBA. As shown in Fig.10, the intensity of CH peaks in the SCBA-blended specimens got diminished with the appearance of additional peaks. According to Pane and Hansen (2005), these peaks represent the formation of additional C-S-H and C-A-S-H. It confirmed the pozzolanic reactivity of SCBA beyond any doubt.

Appearance of peak representing C$_4$AH$_6$ was also noticed in SC-20 and SC-25 specimens. Gengyiong and Xiaohua (2003) have reported that these products act as nucleating sites that hinder the further hydration reaction. This explained the reason for low strength development in specimens with higher percentages of SCBA. Higher peaks of SiO$_2$ were noticed in SC-20 and SC-25 paste specimens, both in 28 and 91 days patterns, which indicated that more amount of SCBA added more silica, and was left un-reacted. This could be another reason for low strength development in specimens with higher percentages of SCBA in SC-20 and SC-25 specimens.

3.4.2 Thermal Analysis

According to Langan et al. (2002); Pane and Hansen (2005), differential thermal analysis (DTA) combined with thermo-gravimetric analysis (TGA) is more suitable for studying the hydration or pozzolanic reaction that takes place at later stages of hydration. DTA locates the ranges corresponding to thermal decompositions of different phases in the hydrated paste, while TGA measures the simultaneous weight loss due to the thermal decomposition. In this study thermo-gravimetric tests

![XRD patterns at 28 days](image)

![XRD patterns at 91 days](image)

| C | CH |
| Q | SiO$_2$ |
| S | C-S-H |
| A | C-A-S-H |
| E | Ettringite |

**Fig.10** Comparison of XRD patterns obtained for SCBA-blended and CTR paste specimens after 28 days and 91 days of curing
were performed on Rigaku-TG810 ID Thermoflex TAS200 by gradually raising the temperature from 20°C to 1,000°C at a rate of 6°C/min. TGA and DTA diagrams for 91 days cured CTR and ash-blended specimens are shown in Fig.11 and Fig.12, respectively. DTA diagrams show two significant peaks for CTR and all ash-blended specimens hydrated at 91 days; (a) endothermic peak at 130 - 150°C indicate the hydration of C-S-H (Mackenzie, 1972; El-Didamony et al., 1996) and (b) the peaks at temperatures between 420 - 480°C correspond to CH decomposition (Oriol and Pera, 1995). As seen from the DTA curves, the endo-thermal effects in the temperature range of 100-150°C was attributed to the loss of free water and dehydration of inter-layer water from the C-S-H phase (Mackenzie, 1972; El-Didamony et al., 1996). A small step obtained at temperatures close to 700°C was probably due to the release of CO₂. It was through the decomposition of CaCO₃ formed by carbonation (Taylor, 1993).

As reported by Midgley (1979), the CH can be measured by the amount of water loss, which is very close to the water present in CH and therefore, is proportional to the amount of CH. Loss of water (%) measured for 91 days hydrated pastes, representing the amounts of CH at temperatures between 420 - 480°C and corresponding amounts of C-S-H at temperatures between 70 - 400°C is shown in Table 5. In CTR, the amount of CH was higher (2.19) than that present in the SC-10 (2.00) and SC-15 (2.16). It indicated the presence of excess amount of CH available in the CTR. Corresponding amounts of C-S-H, in SC-10 and SC-15 were higher than that present in the CTR. It clearly indicated that excess amount of CH formed in the SCBA-blended specimens was consumed by the SiO₂ present in the SCBA with the formation of additional C-S-H. It was a typical pozzolanic reaction as explained by Ramachandran et al. (2003). Abrupt loss of weight between temperatures 420 - 480°C was also associated with the de-hydroxylation of CH (Oriol and Pera 1995), and it was less in SC-10 and SC-15 (Table 5). It further indicated that the amount of CH present in these samples at 91 days hydration was less as compared to the CTR and other ash-blended specimens.

Formation of these hydrates indicated that pozzolanic reaction took place between the SiO₂ present in the SCBA and the free CH present in the cement. Up to 15% substitution of OPC with SCBA was enough to consume the excess CH present in the hydrates. With more than 15% substitution of OPC with SCBA, the amount of CH increased with corresponding decrease in the amount of C-S-H hydrates.

Overall analyses of TGA and DTA data proved that SC-10 and SC-15 reacted more than the other blends thus signifying 15% SCBA as optimum percentage of OPC substitution. This trend was also vindicated by the XRD analyses and mechanical strength test results as explained in earlier sections.

### 3.4.3 Scanning Electron Microscopy (SEM)

Morphological investigation together with the

<table>
<thead>
<tr>
<th>Specimen</th>
<th>C-S-H* Weight loss (%)</th>
<th>CH** Weight loss (%)</th>
<th>Total Weight loss (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>70 - 400°C</td>
<td>420 - 480°C</td>
<td>70 - 700°C</td>
</tr>
<tr>
<td>CTR</td>
<td>15.02</td>
<td>2.19</td>
<td>24.30</td>
</tr>
<tr>
<td>SC-10</td>
<td>17.92</td>
<td>2.00</td>
<td>23.83</td>
</tr>
<tr>
<td>SC-15</td>
<td>17.64</td>
<td>2.16</td>
<td>24.16</td>
</tr>
<tr>
<td>SC-20</td>
<td>16.95</td>
<td>2.27</td>
<td>27.17</td>
</tr>
<tr>
<td>SC-25</td>
<td>16.87</td>
<td>2.27</td>
<td>25.59</td>
</tr>
</tbody>
</table>

*C-S-H: Calcium silicate hydrate  **CH: Calcium hydroxide
TGA/DTA and XRD analyses was done to further elucidate the pozzolanic reaction and the formation of hydrates in the ash-blended specimens. Fig. 13 shows the SEM pictures of CTR and SCBA-blended specimens obtained at 28 days and 91 days of hydration. SC-10 and SC-15 blends were chosen for SEM investigation as these blends exhibited more mechanical strength than that of CTR. SEM pictures confirmed the presence of denser matrix with the progression of hydration. The structure became coarser indicating the formation of additional C-S-H and C-A-S-H (Maltails and Marchand, 1997). More compact and well arranged microstructures were seen in 91 days cured specimens than in 28 days cured specimens. Traces of un-reacted particles were also observed, which was the reason as to why strength was reduced with increase in the SCBA contents (CUR, 1992).

4. CONCLUSIONS

Following conclusion can be drawn from the present study:

1) Controlled burning of bagasse at 600°C for 5 hours produced amorphous bagasse ash with very low carbon contents in it. Processed SCBA possessed high specific surface area, high percentage of amorphous silica and calcium oxide which fulfilled the principal requirements of a pozzolanic material.

2) Thermal analyses (DTA/TGA) of hydrates, interpretations of XRD diagrams and SEM observations of the SCBA-blended pastes confirmed the pozzolanic reactivity of the SCBA.

3) Mechanical strength test results of SCBA-blended mortar specimens showed that by substituting 10 to 15% OPC with SCBA, better strength can be achieved.

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REFERENCES


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