Properties and Reactivity of Sugarcane Bagasse Ash

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1. INTRODUCTION

With the ever increasing demand and consumption of cement and in the backdrop of waste management, scientists and researchers all over the world are always in quest for developing alternate binders that are environment friendly and contribute towards sustainable management. Sugarcane bagasse (SCB) which is a voluminous by-product in the sugar mills when juice is extracted from the cane. It is, however, generally used as a fuel to fire furnaces in the same sugar mill that yields about 8-10% ashes containing high amounts of un-burnt matter, silicon, aluminum, iron and calcium oxides. But the ashes obtained directly from the mill are not reactive because of these are burnt under uncontrolled conditions and at very high temperatures. The ash, therefore, becomes an industrial waste and poses disposal problems. For obtaining amorphous and reactive sugarcane bagasse ash (SCBA), several trials were conducted to define optimum burning time and temperatures. SCBA used in this study was obtained by burning SCB at 600^{o}C for 5 hours (James and Rao, 1986) under controlled conditions and its physical, chemical, and mineralogical characterization was done to evaluate the possibility of its use as binder partially replacing cement in the mortar applications.

Table 1 Physical and chemical properties of OPC and SCBA

	Chemical properties								Physical properties			
	Chemical composition (wt. %)								Density	Blaine surface area	Particle size	color
	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	K_2O	LOI	g/cm^3	cm^2/g	μm	
OPC	18.4	5.6	3.0	66.8	1.4	2.8	0.5	2.0	3.15	3250	36.2	Dark grey
SCBA	62.43	4.38	6.98	11.8	2.51	1.48	3.53	4.73	2.52	5140	28.9	Redish grey

2. EXPERIMENTAL PROCEDURE

Sugarcane production in India is over 300 million tons/year that cause about 10 million tons of SCBA as un-utilized and waste material. SCB used in this study was obtained from Punjab province (India). The suitable burning condition was determined as 600^{o}C for 5 hours after trial burnings were made at 400, 500, 600, 700, and 800^{o}C temperature and for 3, 5, 6 and 8 hours. Ashes then obtained were grinded and sieved through 53μm sieve in order to increase the specific surface area. Physical and chemical properties of SCBA used in preparing blended mortars and pastes are shown in **Table 1**. Water consistency, setting time of pastes and flow values of mortar were checked before preparing the final specimens. Mortar specimens (40 x 40 x 160 mm) and pastes were prepared with four replacement ratios (**Table 2**). Strength development was studied by subjecting blended mortars to destructive (compressive and flexural strength) and non-destructive [ultrasonic pulse velocity (UPV)] tests after 3, 7, 14, 28, 56, and 91 days of curing. To verify hydration reaction and the hydration products, the SCBA-blended pastes were examined by X-ray diffraction (XRD), Thermo-gravimetry (TGA/DTA) and scanning electron microscopy (SEM).

Table 2 Symbols used for blended specimens

Blending ratio (by wt %)	Mix (symbol)
100%OPC + 0% SCBA	CTR
90% OPC + 10% SCBA	SC 10
85% OPC + 15% SCBA	SC 15
80% OPC + 20% SCBA	SC 20
75% OPC + 25% SCBA	SC 25

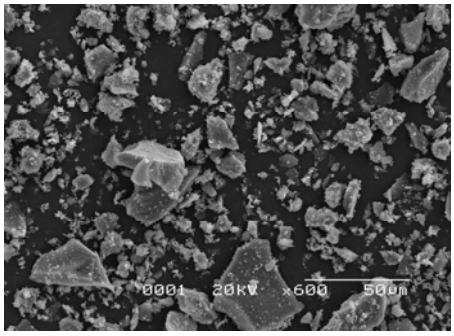

Fig.1 SEM photograph of SCBA

3. RESULTS AND DISCUSSION.

High specific surface area and chemical composition (SiO_2 + Al_2O_3 + Fe_2O_3 > 70% and CaO >10%) suggested the pozzolanic and cementitious nature of SCBA according to ASTM C-618 standards. A hump between 2θ: 20^{o}~39^{o} in the XRD

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Keywords: *Sugarcane bagasse, pozzolan ash, silica, hydration reaction, blended mortar.*

pattern and the granular structure in the SEM photograph (**Fig.1**), showed the amorphousness of minerals, though a little crystallization of the minerals was noticed. Retardation in setting time was also recorded with the increase in SCBA %age, which might have been due to the reduction in the calcium hydroxide (CH) contents (Neville, 1995).

Compressive strength (CS) values of blended mortars at 3days were higher than CTR. It can be attributed to densely packed structure owing to the higher specific surface area of SCBA. At 91days CS values for SC10 and SC15 were 104 and 102% of that of CTR. The respective values for SC20 and SC25 were 92 and 84% of CTR. At 91days flexural strength (FS) for SC10 and SC15 was 104 and 101% of CTR; almost same trends as in CS tests. This may have been both due to physical and chemical processes. It may also have introduced a large number of nucleation sites in the system for the rapid precipitation of hydration products (Singh et al., 2000) coupled with pozzolanic reaction that took place between CH and active SiO_2 and also the hydration of silica itself in the alkaline environment. But the hydration reaction was slow in SC20 and SC25, possibly due to low reactivity of SiO_2 and the reduction in CaO contents. Relative CS (%) and FS (%) as compared to CTR is shown in **Fig.2** and **Fig.3** respectively. UPV values for SC10 and SC15 were also higher than CTR showing the continuous progression in strength development.

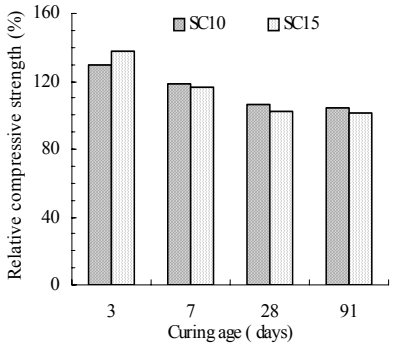
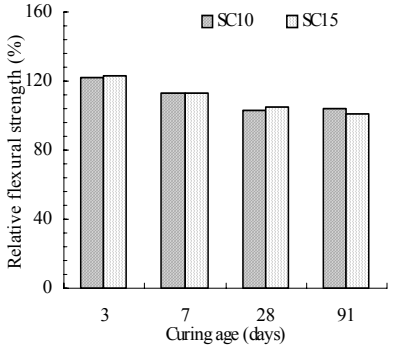


Fig.2 (*above*) and **Fig.3** (*below*)



XRD patterns clearly showed diminished SiO_2 peaks in 91days cured samples than in 28days cured samples. Appearance of additional peaks representing calcium silicate hydrate (C-S-H) in blended specimens and significant reduction in the relative heights of CH peaks in 91days cured sample as compared to 28days cured; clearly indicated that reaction took place between silica and free CH present in the hydrated gel. 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 (Pane, 2005). At 91days, the abrupt loss of weight at temperatures between 420°C ~ 480°C (associated with CH loss) in SC10 and SC15 pastes was less as compared to CTR specimen. Also the weight loss at temperatures between 70°C~400°C representing C-S-H and calcium aluminum silicate hydrate (C-A-S-H) was more in SC10 and SC15 pastes as compared to CTR and other blends (**Table 3**). Both the above factors proved the pozzolanic reaction with SCBA substitution. Morphological investigation also indicated the presence of coarser structure highlighting the formation of C-S-H and C-A-S-H.

Table 3 TGA data of 91 days hydrated paste specimens

	Weight loss [water (%)]		
	C-S-H*	CH**	Total
Sample	70°C ~ 400°C	420°C ~ 480°C	70°C ~700°C
CTR	17.02	2.19	24.30
SC10	17.92	2.00	23.83
SC15	17.64	2.16	24.16
SC20	16.95	2.27	27.17
SC25	16.87	2.27	25.59

4. CONCLUSIONS.

1) Ashes obtained after control burning of SCB at 600°C/5hour were reasonably reactive given by the fact that little crystallization of minerals occurred. Morphological, XRD and TGA/DTA study of the blended pastes confirmed the hydration reaction of SCBA with in the cement gel.
2) Compressive and flexural strength tests confirmed the actual behavior of SCBA blended mortars and it suggested that up to 15% substitution of OPC with SCBA can be made with better strength results than that with pure cement.

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