

Sugarcane Bagasse Ash and Its Role During the Hydration of Portland Cement

Sarita Rai^{1*}, Shivani Tiwari¹

Abstract

The utilization of waste materials in concrete manufacture provides a satisfactory solution to some of the environmental concerns and problems associated with waste management. Agro wastes such as rice husk ash, wheat straw ash, hazel nutshell and sugarcane bagasse ash are used as pozzolanic materials for the development of blended cements. India being one of the largest producers of sugarcane in the world, produces 300 million tons per year and large quantity of sugarcane bagasse is available from sugar mills. Sugarcane bagasse is partly used as fuel at the sugar mill. In the present paper, sugarcane bagasse was burned at 600°C and the ash obtained is known as sugarcane bagasse ash (SCBA) and characterized by using different techniques. SCBA was mixed with OPC in different proportions and the hydration studies were made. Mechanism of hydration has been discussed

Keywords: Compressive Strength, Portland Cement, Bagasse Ash, DTG & FTIR

1. Introduction

Ordinary Portland cement (OPC) is recognized as the major construction material throughout the world. Production of Portland cement is responsible for about 5%-8% of global CO₂ emissions. This environmental problem will most likely be increased due to exponential demand of Portland cement: By 2050, demand is expected to rise by 200% from 2010 levels, reaching 6000 million tons/year. Cement industries are trying to minimize CO₂ emissions by making use of blended cements. Blended cement is a hydraulic binder composed of Portland cement and one or more inorganic materials that take part in the hydraulic reaction. Industrial wastes, such as blast furnace slag, fly ash and silica fume are being used as supplementary cement replacement materials. In addition to these, agricultural wastes such as rice husk ash, wheat straw ash, and sugarcane bagasse ash are also being

used as pozzolanic materials [1-4]. When pozzolanic materials are added to cement, the silica (SiO₂) present in these materials reacts with free lime released during the hydration of cement and forms additional calcium silicate hydrate (CSH) as new hydration products, which improve the mechanical properties of concrete formulation.

Scientists are always in search of waste materials that can be used as a blending component in cements to improve its quality and reduce the cost and CO₂ emissions. When juice is extracted from the cane sugar, the solid waste material is known as bagasse. When this waste is burned under controlled conditions, it gives ash having amorphous silica, which has pozzolanic properties. In the present article, Sugarcane Bagasse was burned at 600°C and the ash (SCBA) was characterized by X-ray diffraction and thermal methods. Hydration of SCBA blended cement in the presence of superplasticizers was studied at room temperature and the results discussed. On the basis of results, mechanism of hydration has been proposed.

2. Experimental

2.1. Materials

Ordinary portland cement (OPC) has a Blaine surface area of 4450 cm²/g and its chemical composition is given in Table 1. Sugarcane (Fig.1) were taken, cleaned and juice extracted. The residue known as bagasse was dried (Fig. 2).

The dried bagasse was fired under controlled temperature at 600°C for 4 hours in muffle furnace. After cooling, the ash was ground in to fine powder (Scheme 1) and allowed to pass through a sieve of 75µm and stored in desiccators for further use. The chemical composition of the sugarcane bagasse ash (SCBA) is also given in Table 1.

¹ Department of Chemistry, Dr. Harisingh Gour University (A Central University) Sagar, Madhya Pradesh, India.

* Corresponding author: dr_saritar@yahoo.co.in

Table 1: Chemical Composition of OPC and SCBA

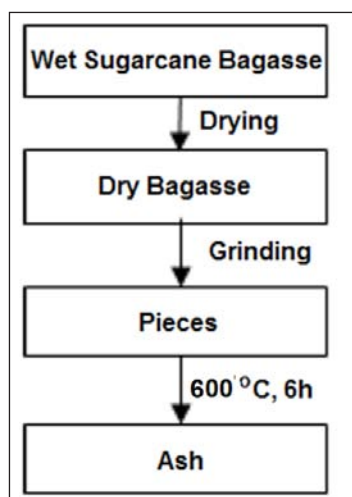
Samples/Composition (%)	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	K ₂ O	Na ₂ O	TiO ₂	SO ₃	IS	LOI
OPC	21.4	6.0	4.4	61.1	1.7	0.6	0.2	-	2.3	1.4	0.6
SCBA	70.9	8.6	3.6	6.5	2.8	1.8	0.9	0.5	0.8	-	2.6



Fig. 1: Sugarcane



Fig. 2: Dried Bagasse



Scheme 1: Preparation of Sugarcane Bagasse Ash (SCBA)

2.2. Blended Cements

Blended cements were prepared by mixing OPC with different amounts of SCBA (10, 20 and 30 wt.%). The mixtures were thoroughly homogenized in polythene bottles.

2.3. Methods

XRD, FTIR and TG/DTG of SCBA were recorded. Water consistency and setting times were determined by standard

method using Vicat apparatus (Fig.3). Hydration of OPC and blended cements (W/S=0.5) was stopped at different intervals of time (1, 3, 7, 15 and 28 days) with the help of isopropyl alcohol and ether. The hydrated samples were dried at 105°C and stored in a desiccator in polythene bags. Free lime contents were determined by modified Franke method and non-evaporable water contents by measuring the weight loss at 1000°C. Rate of heat evolution as a function of time was recorded with a calorimeter. Compressive strengths were determined by using compressive strength testing machine (Fig.4) in accordance with Indian standard specifications IS:4031, 1988.



Fig. 3: Vicat Apparatus



Fig. 4a: Compressive Strength Testing Machine



Fig. 4b: Moulds

Results and Discussion

Particle size distribution is given in Fig.5 and the results show that the particles of SCBA are nearly four times finer than those of OPC and the finer particles of SCBA are more uniform in their distribution.

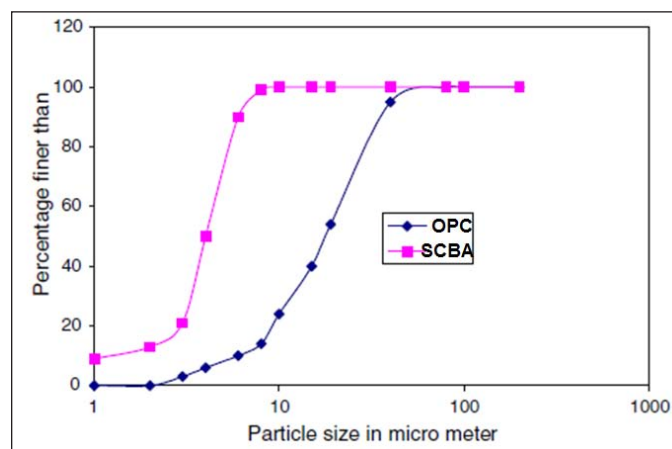


Fig. 5: Particle Size Distribution

X-ray diffraction pattern of SCBA is given in Fig. 6 and it is found that it consists essentially of an amorphous silica structure with a wide scattering peak (hump) centred at about $2\theta = 22^\circ$, Cu K_α radiation. Some quantities of crystal-phases as quartz and cristobalite are also present.

FTIR spectrum of SCBA in the region of 4000-400 cm^{-1} is shown in Fig.7. The peaks at 466 are assigned to

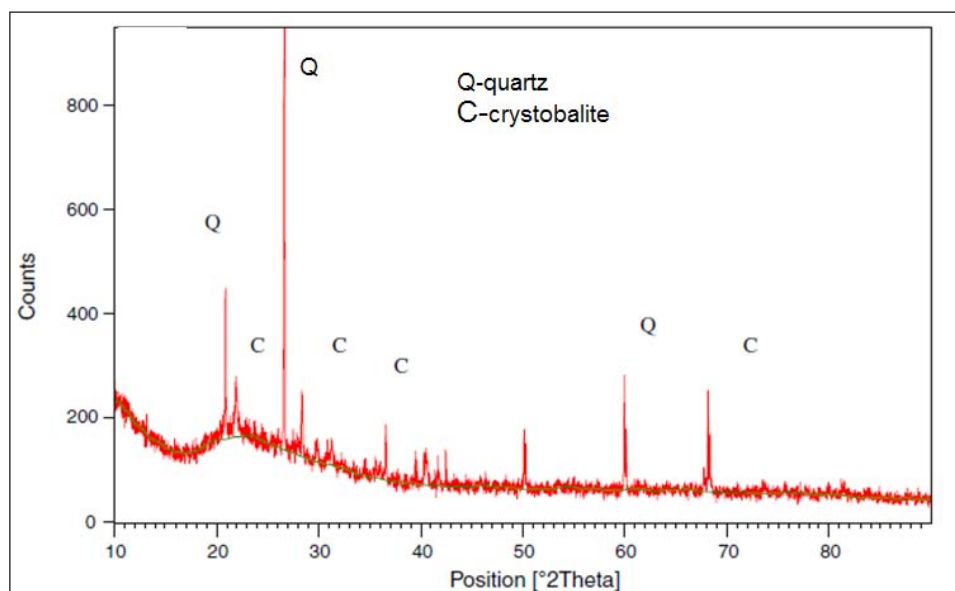


Fig. 6: X-ray Diffraction Pattern of SCBA

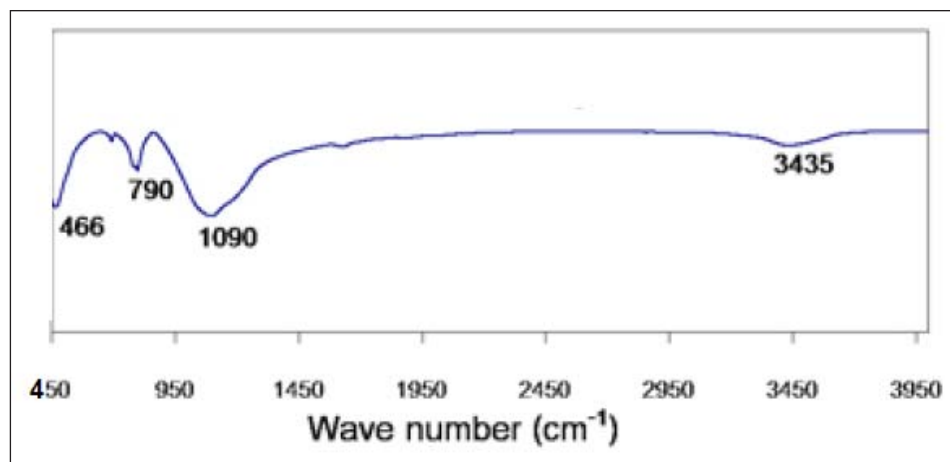


Fig. 7: FTIR Spectra of SCBA

Si-O bending, 791 cm^{-1} and 1090 cm^{-1} from vibration in symmetric and asymmetric of $\leftarrow\text{OT}\rightarrow\leftarrow\text{O}$ stretching (T=Si, Al) functional group in tetrahedral arrangement, respectively. Adsorbed water molecule shows a peak at 3435 cm^{-1} .

Figure 8 shows the thermogravimetric curve (TG/DTG) for the SCBA (heated in air at $20\text{ }^{\circ}\text{C}/\text{min}$ heating rate, using alumina crucible). It is noticed that part of the mass loss (25%) was produced in the $250\text{--}650\text{ }^{\circ}\text{C}$ range, which belongs to organic matter volatilization and oxidation. However, a part of the mass loss (7 %) was observed at $700\text{--}800\text{ }^{\circ}\text{C}$ range, which corresponds to the decomposition of calcium carbonate.

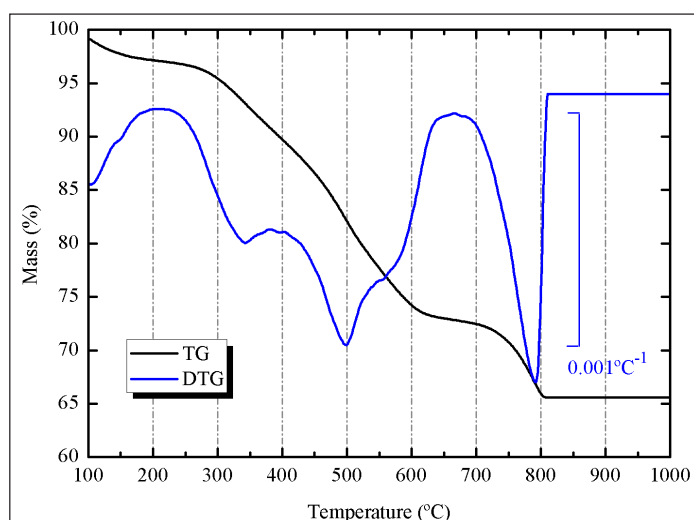


Fig. 8: TG/DTG Curves for SCBA

The percentage of cement replacement level versus consistency graph (Fig.9) indicates that the water required

for normal consistency increased with an increase of SCBA. For example, the consistency measured in the presence of 0% and 20% SCBA was found to be 0.32 and 0.5, respectively.

Both initial and final setting times increased with SCBA (Fig.10).

On the basis of water consistency and setting time, the optimum level of SCBA replacement is taken to be 20%. The non-evaporable water content (W_n) in the presence and absence of 20% SCBA was measured. In the presence of 20% SCBA, W_n values are higher up to 3 days of hydration, and after that the values are lower up to 28 days of hydration as compared to that of the control. The higher values during the early days of hydration in the presence of SCBA may be due to the unburned carbon present in SCBA. The lower values indicate the lower extent of hydration in the presence of SCBA. This may be due to a dilution effect. Free lime values were also determined. In the case of control, the free lime increased with hydration time, indicating an increase of hydration. In the presence of SCBA the values are always lower than that of the control up to 20% SCBA. The free lime values increased up to 3 days and then there was a decrease. These results clearly indicate that SCBA acts as a pozzolanic material and the decrease in free lime values is due to pozzolanic reaction.

The rate of heat evolution and total heat evolved as a function of time in the case of OPC and 20%SCBA-OPC are shown in Figs. 11 and 12. Cement hydration is a strongly exothermal reaction, which takes place in a number of stages [5]: (I) rapid initial processes (dissolution of ions

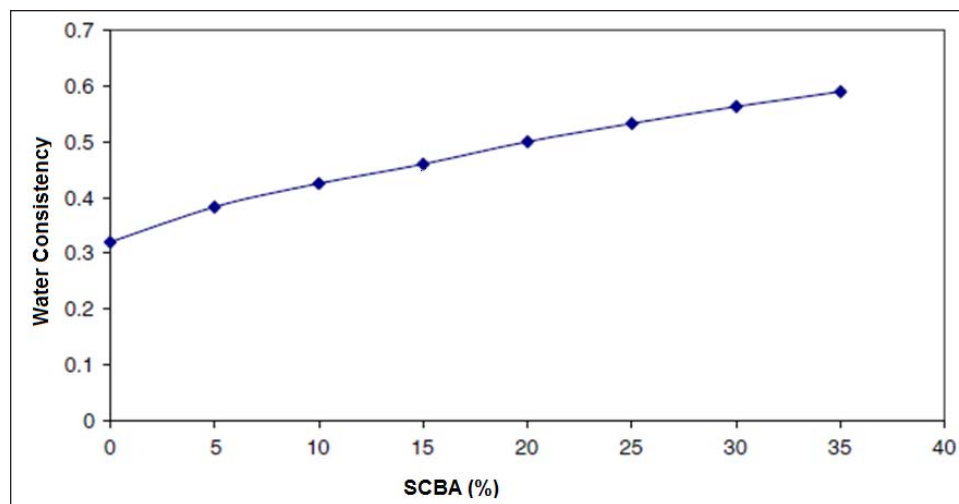


Fig. 9: Water Consistency SCBA Replacement

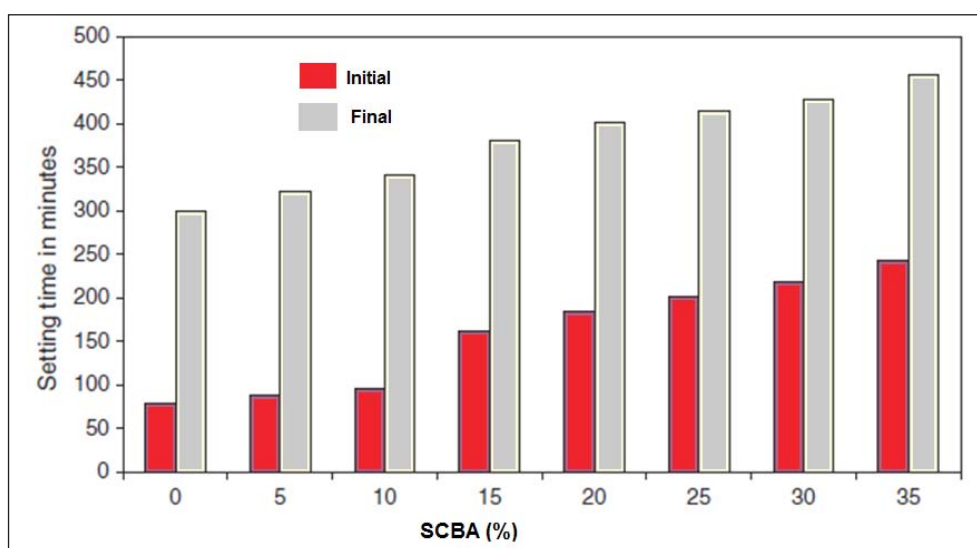


Fig. 10: Setting Times with SCBA Replacement

and initial hydration); (II) induction period (formation of ettringite); (III) acceleration period (Initiation of silicate hydration) – next 12 h (IV) retardation period (depletion of sulphate); (V) long-term reactions. In the presence of 20% SCBA, the hydration is retarded and the time of maximum heat evolution is shifted to longer time.

The compressive strength values of SCBA blended cement mortars are shown in the Fig. 13. Comparison of the data for 7 and 28 days of curing time shows that the compressive strength increases with SCBA up to 10% and then at 20% SCBA the compressive strength of mortar attains the equivalent value as observed for control mortar. The increase in strength may be partially due to the pozzolanic reaction and partially to high specific

surface area of SCBA leading to number of nucleation sites for additional hydration products

3. Conclusions

From the results it is concluded that SCBA burnt under controlled conditions has higher surface area and when mixed with OPC by 20 wt%, improves the properties of OPC because of high pozzolanic activity.

Acknowledgement

We acknowledge the financial support from UGC –New Delhi for their financial support as Start-up grant.

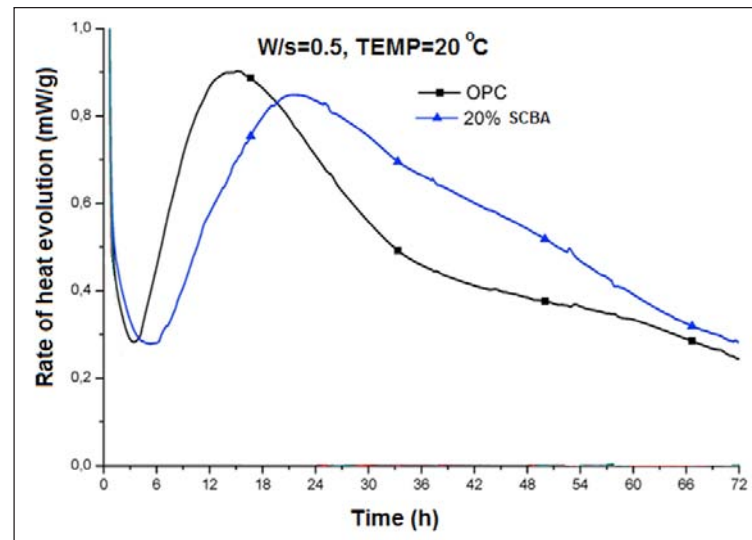


Fig. 11: Rate of Heat Evolution as a Function Of Time

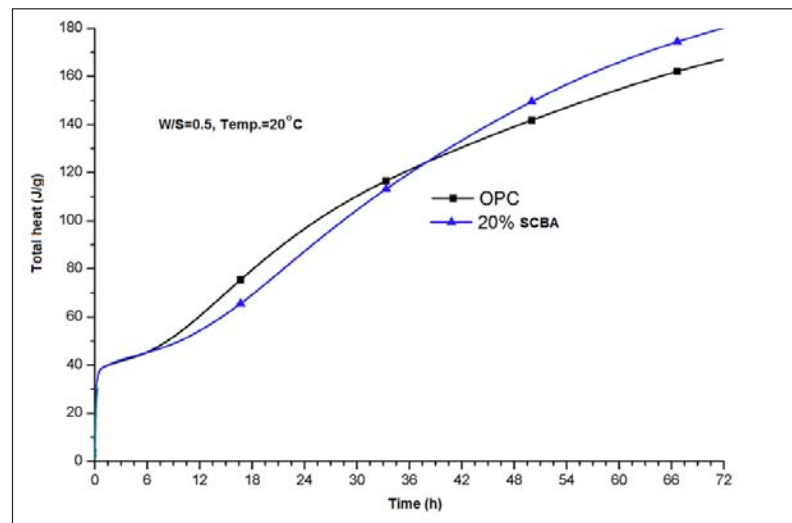


Fig. 12: Total Heat Evolved as a Function of Time

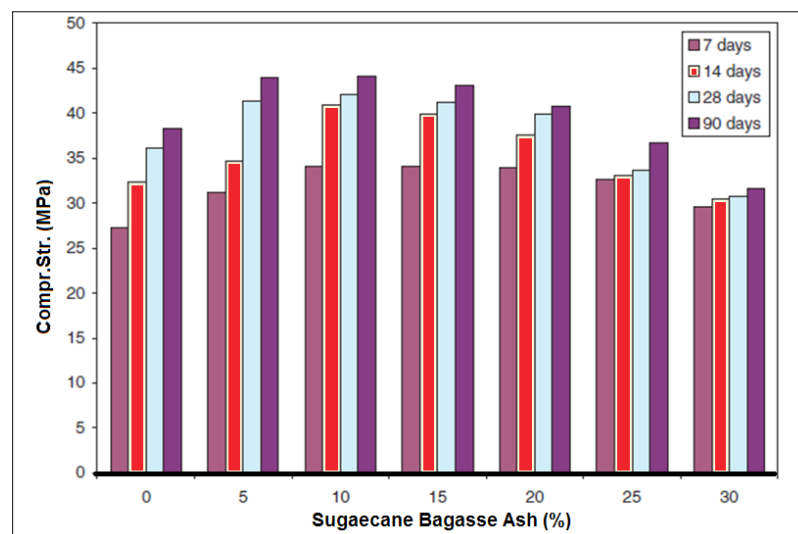


Fig. 13: Compressive Strength of OPC Mortar as a Function of SCBA at Different Time

References

1. Uchikawa, H. (1986). Effect of blending components on the hydration and structure formation. Proc 8th Int Cong Chem Cem, Rio de Janeiro, 2, 250.
2. Ganesan, K., Rajagopal, K., and Thangavel, K. (2007). Evaluation of bagasse ash as supplementary cementitious material. *Cement and Concrete Composites*, 29, 515-524
3. Bahurudeen, A., Marckson, A. V., Kishore, A., Santhanam, M. (2014). Development of sugarcane bagasse ash based Portland pozzolana cement and evaluation of compatibility with superplasticizers. *Construction and Building Materials*, 68, 465-475
4. Bahurudeen, A., Kanraj, D., Gokul Dev, V., and Santhanam, M. (2015). Performance evaluation of sugarcane bagasse ash blended cement in concrete. *Cement and Concrete Composites*, 59, 77-88
5. Tkaczewska, E. (2014). Effect of the superplasticizer type on the properties of the fly ash blended cement. *Construction and Building Materials*, 70, 388-393