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# Preparation of Bio-cement using sugarcane bagasse ash and its Hydration behaviour

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***Abstract*-Ecofriendly cement may be obtained by partial replacement of cement with certain low cost waste materials. Sugarcane bagasse ash is one such material which is a residue resulting from the burning of sugarcane bagasse in boilers for power generation. Sugarcane bagasse ash (BGA) is a waste material and being disposed to open landfills causing serious environmental impacts. In this study an attempt has been made to use this ash as a partial replacement in ordinary portland cement (opc) by 10 weight %. The morphology and chemical analysis were recorded by SEM with EDS. The samples (OPC, bio-cement) were hydrated with distilled water at different intervals of time (Setting time hour, 7 day, 28 day). Compressive strength of the samples was carried out. The hydrated samples have been analyzed by FTIR spectra. FTIR peak assignment was used to identify the hydration reaction and results are interpreted with compressive strength of the sample. Bio-cement gains more strength than control due to pozzolonic reaction of BGA. Hence bagasse ash is a potential material for cement production.**

*Key words*— BGA, Cement, FTIR

## I. INTROUCTION

Manufacturing of portland cement is a resource exhausting, energy intensive process that releases large amount of the green house gas $CO_2$ into the atmosphere. Production of 1 ton of Portland cement requires about 2.8 tons of raw materials, including fuel and other materials. As a result of de-carbonation of lime, manufacturing of 1 ton of cement generates about 1 ton of $CO_2$ [1]. The cement industry has been pointed out as one of the major contributors of anthropogenic $CO_2$ emissions with about 5% globally [2]. In view of the above mentioned, several research activities [3,4 ] have been directed towards partial or total substitution of portland cement by pozzolanic binders, eg. Lime, fly ash, bagasse ash, rice straw ash and natural pozzolans among others.

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In sugarcane industry bagasse ash is a residue resulting from the burning of sugarcane bagasse in boilers for power generation. A limited amount of bagasse ash has been used as soil amendment while the rest of the bagasse ash is useless causing serious environmental impacts [5]. It has a very high silica concentration and contains aluminium, iron, alkalis and alkaline earth oxides in smaller amounts [3]. However, bagasse ash can be utilized to possible addition of bagasse ash as supplementary cementious material. Unlike other pozzolanic materials, the concrete incorporating the BGA shows excellent strength development [4,6]. This paper analyses the effect of BGA by partial replacement of cement at the ratio of 10% by weight. Therefore, main objective of this study is to evaluate and compare the hydration characteristics of bagasse ash blended cement (bio-cement) paste with OPC through mechanical and analytical studies.

## II. MATERIALS AND EXPERIMENTAL STUDIES

Raw materials used in the present work are; market available Ordinary Portland Cement (OPC - ASTM type I) and sugarcane bagasse ash collected from the Chengalvarayan sugar mills, Thirukovilur Tk, Tamilnadu, India and its chemical analysis is given in Table-1.

**Table 1 Chemical analysis (weight %) of OPC and BGA**

| compound | OPC | BGA |
|---|---|---|
| $SiO_2$ | 20.85 | 69.81 |
| $Al_2O_3$ | 5.80 | 6.73 |
| $Fe_2O$ | 3.75 | 4.35 |
| CaO | 63.20 | 9.40 |
| $K_2O$ | 0.60 | 2.65 |
| MgO | 1.55 | 2.42 |
| $Na_2O$ | 0.45 | 0.71 |
| $SO_3$ | 2.10 | 0.46 |
| LOI | 1.70 | 2.33 |

The morphology of the above material are analysed using Scanning Electron Microscope (SEM). For SEM, a powdered sample was places on the stub using double side adhesive carbon tape. Specimen was coated with the help of gold coater (JEOL auto fine coater model JFS-1600, coating time is 120 seconds with 20 mA). Micrographs were recorded using JEOL SEM model JSM-5610 LV with an accelerating voltage 20 Kv and secondary electron image (SEI).

The SEM micrographs with energy dispersive spectra (EDS) of OPC and BGA particles are shown in Fig. 1 (a) and (b) respectively. Major cement phases such as $C_3S$, $C_2S$, $C_3A$ and $C_4AF$ are detected in the control micrograph. The dispersed cement particles are extremely solid [7] and polygonal shape $C_3S$ particles are seen with irregular shape (~25 µm) and $C_2S$ are spherical in shape ( ~10µm) $C_4AF$ occurs as small needle shaped. BGA particles (<45 µm) with various sizes and geometry like prismatic, spherical and fibrous are recognized (8). The prismatic particles contain Si only. The spherical ones contain Si as well as Ca, Al, Fe, Na and K. The percentage of silica in the ash is 70%.

For reactive silica, raw bagasse ash was calcined at 650°C for 2 h with a heating rate of 10°C/min then cooled to room temperature and ground to pass through 45µm sieve. The Partial replacement of cement by the bagasse ash in weight percentage is carried out for bio-cement. The sample control (OPC + 0% BGA) and bio-cement (OPC + 10 wt % BGA) were hydrated with distilled water and water to solid ratio (w/s) is 0.4 at different hydration intervals like, final setting time (FST), 7 day, 28 day.

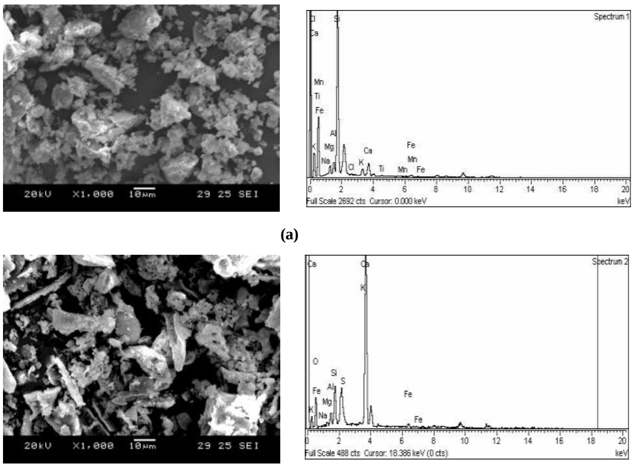


**Fig.1 SEM - EDS of a) OPC and b) BGA**

Compressive strength measurement was conducted for the control and bio cement using ASTM C 349 method and its result are given in Fig. 2. The results show that the bio-cement had significantly higher compressive strength compare to the cement without BGA. It is found that the cement could be advantageously replaced with BGA and the optimal level of BGA content was achieved with 10 % replacement [4].

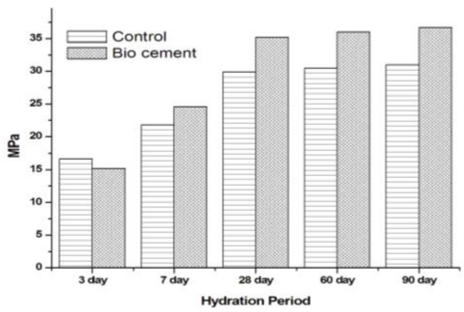


**Fig.2 Compressive strength of control and bio-cement**

III. RESULTS AND DISCUSSION

Fourier Transform Infrared (FTIR) spectra were recorded in the wavenumber range 4000 – 400 $cm^{-1}$ using Shimadzu FTIR spectrometer for the hydrated samples were made to a pellet by mixing with KBr. FTIR spectra of hydrated control and bio-cement are shown in Fig. 3 and 4 respectively. In final setting time (FST) of control hydrated spectrum (Fig. 3a), a broad band centred at 3415 $cm^{-1}$ may be symmetric stretching ($\nu_1$ – $H_2O$) vibration of absorbed water molecules is observed [9]. The sharp band at 3641 $cm^{-1}$ is due to OH stretching vibration ($\nu_3$ ) from hydration product $Ca(OH_2)$.

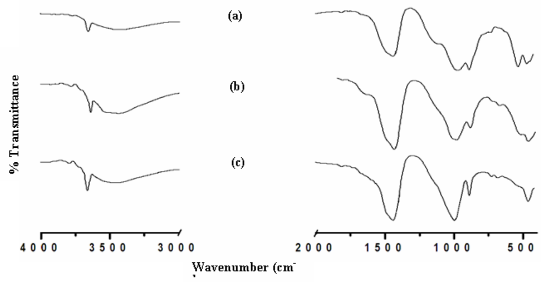


**Fig.3 FTIR spectra of control hydrated at (a) FST, (b) 7 day and (c) 28 day**

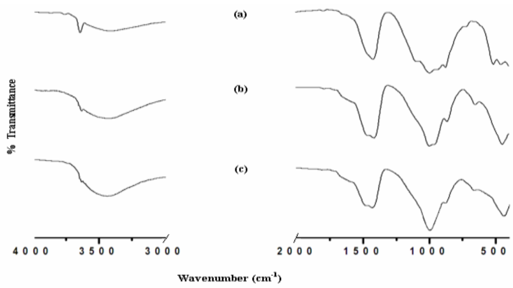


**Fig.4. FTIR spectra of bio-cement hydrated at (a) FST, (b) 7 day and (c) 28 day**

A strong band at 1425 $cm^{-1}$ is attributed to asymmetric stretching vibration ($\nu_3$) of carbonate formed by $CO_2$ absorbance from atmosphere and a sharp band at 877 $cm^{-1}$ is due to out of plane bending vibration of the same. The strong band centred at 920 $cm^{-1}$ may be attributed to asymmetric stretching vibration of silicate ($\nu_3$-Si-O). Bands at 518 and 460 $cm^{-1}$ are assigned to out of plane ($\nu_4$) and in plane ($\nu_2$) bending vibration of silicate respectively. The sulphate doublet forms a singlet at 1110 $cm^{-1}$ is an indicative of early faster dissolution of gypsum and other alkali sulphates and ettringite formation [10].

After FST water stretching band at 3415 $cm^{-1}$ has grown in intensity with a shift (3435 $cm^{-1}$) compared to FST, while the intensity of sulphates have reduced The shifting of $\nu_3$ silicate towards higher frequency (922 $cm^{-1}$to 983 $cm^{-1}$) with an increasing intensity may be attributed to precipitation of colloidal suspension of amorphous CSH [11] as a result of reaction of cement phases ($C_3S$ and $C_2S$) with water (Equation 1&2) which is responsible for the strength of the paste. The shifting of $\nu_3$ silicate indicates the development of strength. The result is well manifested through strength test.

$C_3S + H_2O \rightarrow C\text{-}S\text{-}H + CH$ --- (1)

$C_2S + H_2O \rightarrow C\text{-}S\text{-}H + CH$ -- (2)

The formation of $Ca(OH)_2$ is a by product( CH )of $C_3S$ and $C_2S$ reaction and has contributed a strong and sharp peak at 3641 $cm^{-1}$. The $v_4$ silicate band at 518 $cm^{-1}$ disappears while $v_2$ silicate at 460 $cm^{-1}$ has an increase in intensity. This is a finger print evidence for the higher degree of silicate polymerization of the precipitated CSH. It indicates the completion of the hydration.

Hydrated bio-cement (Fig. 4) has the same mode of an oxide vibration as that of control. However some differences in intensity and bands shifting are observed. In FST, a strong band at 1097 $cm^{-1}$ may be assigned to $v_3$ silicate frequency of amorphous silica [12] of BGA. The characteristic BGA band at 1097 $cm^{-1}$ gets a stronger intensity up to 3 day hydration. After 3 day, a decreasing intensity is indicates the starting of pozzolanic reaction [13]. The BGA peak at 1097 $cm^{-1}$ fades with consumptions of $Ca(OH)_2$ (peak at 3641 $cm^{-1}$) slowly but consistently consumed to yield secondary CSH hydrate (987 $cm^{-1}$) according to the following pozzolanic reaction,

Silica + CH $\rightarrow$CSH ---- (3)

As time as passes, the relative intensity changes between bending vibrations of silicates bands are also higher in bio-cement. The $v_3$ silicate band has higher energy with strong intensity in bio-cement due to the pozzolanic reaction which accelerates the rate of hydration of blended sample and enhances the strength in this stage and well coincide with the compressive strength results.

## IV. CONCLUSION

The cementious material is responsible for early hydration. However later pozzolanic activity of bagasse ash produces more amount of CSH in the bio-cement consequently accelerates and enhances the hydration with strength of the sample. Hence bagasse ash is a potential replacement material for cement production.

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