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# FLYASH AND SUGARCANE BAGASSE ASH AS GEOPOLYMER COMPOSITE

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**Abstract—***Geopolymer concrete is an innovative construction material which shall be produced by the chemical action of inorganic molecules. Geopolymer concrete can be produced without using any amount of cement. This paper reports the results of an experimental program performed to investigate the suitability of incorporating Sugarcane Bagasse Ash (SCBA) in manufacturing Fly ash based geopolymer composites. The percentage of SCBA incorporated into the fly ash was up to 10%. Activator solution used for preparing geopolymer was sodium silicate and sodium hydroxide (10 molar). The specimens were heat cured at 80$^{o}$C for 24 hours. Some of the properties studied are bulk density, compressive strength, apparent porosity, water absorption and water sorptivity. The bulk density was found to decrease with increasing SCBA in the specimen. Changes in compressive strength is not significant. The results of the study indicate the suitability of SCBA for use in the fly ash based geopolymer.*

## 1. INTRODUCTION

Concrete is the world's most versatile, durable and reliable construction material. Next to water, concrete is the most used material, which required large quantities of Portland cement. Ordinary Portland cement production is the second only to the automobile as the major generator of carbon dioxide, which polluted the atmosphere. In addition to that large amount of energy was also consumed for the cement production [1, 2]. Hence, it is inevitable to find an alternative material to the existing most expensive, most resource consuming Portland cement. Geopolymer concrete is an innovative construction material which shall be produced by the chemical action of inorganic molecules. It is an excellent alternative construction material to the existing plain cement concrete. Geopolymer concrete can be produced without using any amount of ordinary Portland cement.

Sugarcane is main food crop in tropical and subtropical countries. It is the major resource for the sugar production. Sugarcane bagasse is the waste created after juice extraction from sugarcane. The Sugarcane bagasse ash is acquired through the control burning of sugarcane bagasse [3]. The sugarcane bagasse creates the environmental nuisance due to direct disposal on the open lands and forms garbage heaps in that area. It has been known that the worldwide total production of sugarcane is over 1500 million tons. Sugarcane bagasse ash has recently been tested in some parts of the world for its use as a partial cement replacement material [4].The important property of SCBA is that it has high silica content. Although the silica content may vary from ash to ash depending on the burning conditions and other properties of the raw materials including the soil on which the sugarcane is grown. The main components of raw bagasse are silica (60-70%), $K_2O$, CaO and other minor oxides including $Al_2O_3$, $Fe_2O_3$ and $SO_3$. Low of large amount of lightweight unburnt particles. The pozzolanic activity of sugarcane bagasse ash mainly depends on its particle size and fineness [5].

This paper investigates the impact of SCBA in a geopolymer concrete by partially replacing fly ash with SCBA in the ratio 0%, 5% and 10% by weight for a fly ash based geopolymer concrete. The experimental study examines the bulk density, compressive strength, apparent porosity, water absorption and water sorptivity of the specimen.

## 2. MATERIAL USED

### 2.1 Fly Ash

Typical low calcium class F fly ash procured from Kolaghat Thermal Power Plant, Kolaghat, West Bengal, India was used as the solid aluminosilicate source material for manufacturing fly ash based geopolymer. Before the commencement of research work, required quantity of fly ash was brought in bulk packed in bags from the thermal power plant. The fly ash was then remixed thoroughly to ensure homogeneity and replaced in sealed plastic containers till its use for manufacture of geopolymer composites. Chemical properties of fly ash is shown in Table-1.

**Table-1: Chemical properties of fly ash**

| Chemical composition | Percentage |
|---|---|
| $SiO_2$ | 56.01 |
| $Al_2O_3$ | 29.8 |
| $Fe_2O_3$ | 3.58 |
| $TiO_2$ | 1.75 |
| CaO | 2.36 |
| MgO | 0.30 |
| $K_2O$ | 0.73 |

| | |
|---|---|
| $Na_2O$ | 0.61 |
| $SO_3$ | Nil |
| $P_2O_5$ | 0.44 |
| LOI | 0.40 |

### 2.2 Sugarcane Bagasse Ash (SCBA)

Sugarcane bagasse is a by-product of sugar industries which is burnt at high temperature to get sugarcane bagasse ash [6]. Bagasse ash produce has a pozzolanic property that would potentially be used as a cement replacement material. SCBA contains approximately 25% of hemicellulose, 25% of lignin and 50% of cellulose. Each ton of sugarcane generates approximately 26% of bagasse and 0.62% of residual ash. The residue after combustion gives a chemical composition dominated by silicon dioxide. The Specific gravity of SCBA was found to be 1.69.Sugarcane bagasse ash passing through sieve size 75µm is used for the experimental work. Composition of sugarcane bagasse ash is shown in Table-2 [5].

**Table-2: Composition of SCBA**

| Component | Mass% |
|---|---|
| $SiO_2$ | 71.0 |
| $Al_2O_3$ | 1.9 |
| $Fe_2O_3$ | 7.8 |
| CaO | 3.4 |
| MgO | 0.3 |
| $K_2O$ | 8.2 |
| $Na_2O$ | 3.4 |
| $P_2O_5$ | Nil |
| MnO | 0.2 |

### 2.3 Alumina Powder ($Al_2O_3$)

Alumina is the common name given to aluminum oxide ($Al_2O_3$). Alumina is produced from bauxite, an ore that is mined from topsoil in various tropical and subtropical regions. It is one of the most cost effective and widely used material in the family of engineering. It can resist strong acid and alkali attack at elevated temperatures. It has good thermal conductivity, high strength and stiffness.

### 2.4 Alkaline Activator

The alkaline activating solution used in the manufacture of sugarcane bagasse ash based geopolymer composites is a mixture of sodium hydroxide pallets, sodium silicate solution and water. Sodium hydroxide (NaOH) pallets has a chemical composition of $Na_2O$ = 77.5% and $H_2O$ = 22.5%. Sodium silicate ($Na_2SiO_3$) solution had a chemical composition of $Na_2O$=14.15%; $SiO_2$=30.65% and water=55.2% and bulk density of 1410 kg/m$^3$. Initially NaOH pellets and water are mixed in a glass beaker depending on the desired $Na_2O$ content of the activator to make sodium hydroxide solution (10 molar). It is then mixed with required amount of sodium silicate solution for a desired $SiO_2$ content. The resulting activator solution is left in ambient temperature for one day before using in the preparation of geopolymer mix.

## 3. MANUFACTURING AND TESTING

For casting a geopolymer specimen, initially alkaline activator solution is prepared by mixing required quantity of sodium hydroxide and sodium silicate the resulting solution is left in ambient temperature for one day before using in the preparation of geopolymer mix. The activator solution is then mixed with the binder material to get the desired geopolymer mix and it is transferred to the mould of size 50x50x50 mm cubes. The filled mould is kept inside oven for 24hrs at a temperature of 80$^o$C for curing.

**Table-3: Specimens Details**

| Specimen | Fly ash | SCBA |
|---|---|---|
| SB0 | 100 | - |
| SB5 | 95 | 5 |
| SB10 | 90 | 10 |

Table-3 show the details of specimens casted for the experimental program. After 7days the specimens are tested to study various properties of the geopolymer composites such as bulk density, compressive strength, apparent porosity, water absorption and water sorptivity.

## 4. RESULTS AND DISCUSSIONS

### 4.1 Bulk density

**Table-4: Bulk density**

| Specimen | Bulk density(KN/m$^3$) |
|---|---|
| SB0 | 13.71 |
| SB5 | 13.22 |
| SB10 | 13.18 |

Table-4 shows that bulk density decreases with increase in the dosage of SCBA and correspondingly weight of the specimen also decreases.

### 4.2 Compressive Strength

The compressive strength test of three 50mm cubic specimen for each mix at the age of 7 day were conducted and results are presented in Figure 1.

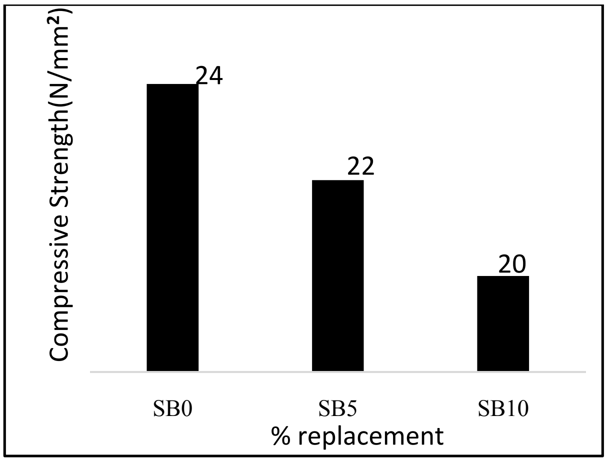


**Figure 1: Compressive Strength VS % replaced**

The results indicates that the compressive strength of the geopolymer specimen decreases with an increase in the dosage of SCBA. Mix containing 0% SCBA, 5% SCBA and 10% SCBA has a compressive strength of 24 N/mm$^2$, 22 N/mm$^2$ and 20 N/mm$^2$ respectively.

### 4.3 Apparent porosity

**Table-5: Apparent Porosity**

| Specimen | Apparent porosity % |
|---|---|
| SB0 | 31.43 |
| SB5 | 35.01 |
| SB10 | 37.6 |

Apparent porosity of specimens were determined and results are presented in Table 5. Specimen without SCBA or 100% fly ash has an apparent porosity of 31.43%. SB5 specimen yields higher apparent porosity at 35.01% while highest value of apparent porosity of 37.6% is obtained for SB10 specimen. This shows increase in apparent porosity by increasing replacement of SCBA.

### 4.4 Water absorption

Table 6 shows the water absorption values for the specimens. For the water absorption test, the specimens are dried in an oven for a specified time and temperature and then placed in desiccators to cool. Immediately upon cooling the specimens are weighed. The material is then emerged in water at agreed upon conditions, often 23°C for 24 hours or until equilibrium. Specimens are removed, patted dry with a lint free cloth, and weighed.

**Table 6: water absorption**

| Specimen | Water absorption% |
|---|---|
| SB0 | 19.57 |
| SB5 | 20.94 |
| SB10 | 24.33 |

Test result shows that water absorption percentage of the specimen increases with increase in the dosage of sugarcane bagasse ash. The high water absorption was due to the porous nature and rough surface of the particle. The water absorption percentage is a measure of pore volume or porosity in hardened concrete, which is occupied by water in saturated condition.

### 4.5 Water sorptivity

Water sorptivity test is conducted to determine the rate of capillary rise absorption by mortar cube. The specimens are initially painted with waterproof enamel paint on four side except the top and bottom surface, so as to allow capillary uptake of water only from the bottom surface. The specimen are keep in room temperature for 24 hrs. before conducting test.

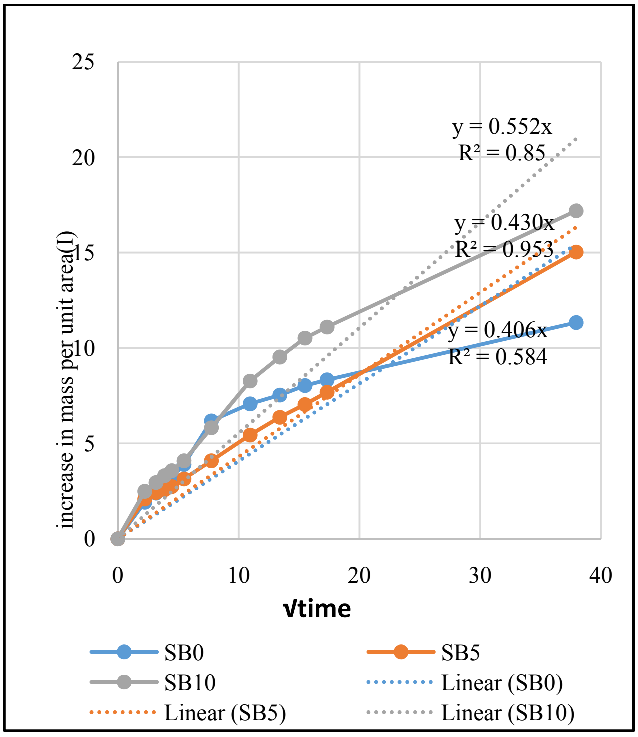


**Figure-2: I vs √time**

Figure-2 shows the plot of increase in mass per unit area of specimens with square root of time. SB10 specimen was found to exhibit higher sorptivity than other specimens.

### 5. Conclusion

The test results concluded that SCBA can suitably replace the fly ash on a flyash based geopolymer composites upto 10% as it reduce the comsumption of flyash and utilize the sugarcane bagasse which is considered as a waste product. The change in compressive strength with increase is dosage of SCBA is not much significant. Bulk density decreases with increase in percentage of sugarcane bagasse ash whereas apparent porosity and water absorption increases with increase in replacement of SCBA.

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