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Effect of sugarcane bagasse ash in GGBS geopolymer composites

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Abstract

This paper reports the results of an experimental program performed to study the effect of incorporation of sugarcane bagasse ash (SCBA) in Ground granulated blast furnace slag (GGBS) based geopolymer composites by performing various destructive and non-destructive tests. GGBS was replaced by SCBA in dosages of 5%, 10%, 15% and 20% by weight and activated by a solution of sodium hydroxide and sodium silicate. Some of the test performed during the experimental investigation were compressive strength, water absorption, bulk density, rebound hammer test, ultrasonic pulse velocity etc. It is observed that compressive strength and bulk density decreases with increase in the dosage of SCBA. The results of the present study indicates suitability of replacing SCBA in the GGBS based geopolymer composites.

Keywords:Sugar cane bagasse ash, GGBS, geopolymer, compressive strength, bulk density

1. Introduction

Due to industrialization and rapid growth of population, there has been increasing use of cement which results in a rising the level of carbon dioxide in the atmosphere [1]. It is reported that globally the production of cement contribute approximately 5% to 7% of total carbon dioxide emission into the atmosphere. Hence, to protect the environment and to conserve limestone ore to some extent, we must come up with a sustainable alternative for ordinary Portland cement [2,3]. Geopolymer concrete is a new innovative concreting technology which emits lesser carbon dioxide and is considered as a green concrete [4]. It not only reduces emission of carbon dioxide but also utilizes large amount of industrial wastes such as ground granulated blast furnace slag (GGBS), fly ash, granite waste powder, silica fume etc. It is an excellent alternative construction material to the existing plain cement concrete. Geopolymer concrete can be produced with or without using any amount of cement[5]. The name 'geopolymer' was formed by Davidovits, a French professor in 1978 to represent a broad range of materials characterized by networks of inorganic molecules[6]. An alkaline activator and the source of aluminosilicate materials are two main components of geopolymer concrete. Geopolymer binder is produced by activating the alumina and silica rich materials by an alkaline activator solution. These alumina and silica is dissolved in an alkaline activator solution and subsequently polymerized into molecular chain and becomes a binder just like cement. The most common alkaline activator solution is a combination of sodium hydroxide and sodium silicate. However, potassium hydroxide and potassium silicate can also be used. It plays an important role in the polymerization process. Fly ash has been the most widely used material for making geopolymer in the past research. GGBS as a source material is also found in some literature. However, blending of sugar cane bagasse ash with GGBS in manufacturing geopolymer composites has not been reported yet by any authors.

This paper is aimed to study the effect of sugarcane bagasse ash on various properties of GGBS based geopolymer by partially blending or replacing GGBS with sugarcane bagasse ash up to 20% at equal increments of 5%. The tests carried out included various destructive and non-destructive tests on the geopolymer specimens such as compressive strength, bulk density, water absorption, rebound hammer, ultrasonic pulse velocity etc. The outcome of the present work might serve as an useful information in the field of geopolymer for suitable applications in construction activities.

2. Experimental Details

2.1 Materials

The materials used for the preparation of geopolymer composites were ground granulated blast furnace slag (GGBS), sugarcane bagasse Ash (SCBA), sodium hydroxide, sodium silicate and water. GGBS powder was brought from Jindal Steel and Power Ltd. Kolkata, West

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Table-1:Physical properties of materials

Property	GGBS	SCBA
Colour	Whitish Grey	Black
Form	Fine powder	Fine powder
Specific Gravity	2.75	1.69
Particle size	<75 microns	<75 microns

Bengal, India. GGBS is by-product from steel plant which is obtained by quenching molten iron slag in water or steam, to produce a glassy, granular product that is then dried and ground into a fine powder. Sugarcane bagasse ash were brought from ManbhavanOrganic, Chhattisgarh, India. Sugarcane bagasse is a by-product of sugar industries which is burnt at high temperature and then ground into fine powder to get sugarcane bagasse ash.The physical properties of the aluminosilicate materials are shown in Table-1.

Sodium hydroxide and sodium silicate are the alkaline activator solution used to activate the binders Sodium hydroxide was purchased from local chemical store in Imphal, Manipur, India and sodium silicate in the liquid form was supplied by MPM Processors Pvt. Ltd. Chatribari, Guwahati, Assam, India. Sodium hydroxide (NaOH) pellets 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.

2.2 Specimen Preparation and Details

For the preparation of geopolymer composites, initially required quantities of NaOH pellets and water were mixed in a glass beaker to make sodium hydroxide solution of desired molarity. For this study, 10M NaOH solution was used. The prepared sodium hydroxide solution was then mixed with required amount of sodium silicate solution in the proportion of 1NaOH : 2 Na2SiO$_3$to make activator solution. The resulting activator solution was left in ambient temperature for 24hrs before using in the preparation of geopolymer mix. GGBS and SCBA were mixed in dry condition before adding the alkaline activator solution to get the homogenous slurry. The homogenous slurry was transferred into the mould of size 50x50 x50mm and vibrated for around 2-3mins in a vibrating machine to remove entrapped air. The specimens were removedafter 24hrs and then kept in room temperature for 28 days for curing. Table-2 shows the details of specimens casted for the experimental program.

Table-2. Details of paste specimens

SpecimenID	GGBS (%)	SCBA (%)
GS0	100	0
GS5	95	5
GS10	90	10
GS15	85	15
GS20	80	20

3. Results and discussion

3.1 Rebound Hammer Test

Rebound hammer test [12] is a non-destructive test performed to check the quality of concrete. Compressive strength of the specimens in N/mm^{2}can be determined by calibration from the graphical chart attached in the rebound hammer with the rebound number obtained from the test. Table3 presents the quality grading of the specimens with respect to the rebound number. Up to 10% replacement of GGBS by SCBA, the quality grading of the geopolymer specimen is very good. However, beyond 10% up to 20% replacement, the quality of the resulting geopolymer specimen is found to be good grading. It is observed that no significant decrease occurred in the rebound hammer values up to 10% blending by SCBA.

3.2 Ultrasonic pulse Velocity Test

Ultrasonic pulse velocity test [11] is another non-destructive test performed to check the quality of concrete. In this test, the quality of concrete is assessed by measuring the velocity of an ultrasonic pulse passing through a concrete structure. The quality of the specimen as per IS-13311(1992)-part-2 are given in the Table-3. Similar to the results obtained in rebound hammer test, geopolymer specimens made by replacing GGBS with SCBA up to 10% yields good quality. As the replacement quantity of sugar cane bagasse ash was increased beyond 10%, the paste quality reduced to good. The information from rebound hammer and ultrasonic pulse tests could be related to other properties including the compressive strength of the specimens.

Table-3. Rebound hammer test results

Specimen	Rebound Number	Quality grading
GSO	45	Very good
GS5	42	Very good
GS10	41	Very good
GS15	38	Good
GS20	34	Good

Table-4. Ultrasonic pulse velocity test results

Specimens	Pulse velocity by cross probing (km/s)	Quality grading
GSO	4.202	Good
GS5	4.202	Good
GS10	3.731	Good
GS15	3.356	Medium
GS20	3.247	Medium

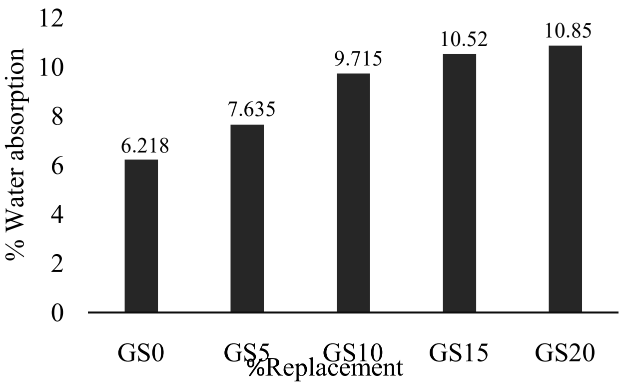

Fig. 1. Water absorption of specimens

3.3 Water absorption

Results of water absorption tests on the blended geopolymer composites is presented in Fig. 1. It is observed that water absorption of the specimen increases with increase in the dosage of sugarcane bagasse ash in the GGBS geopolymer.GS0 specimen without blending sugar cane bagasse ash performs best in terms of water absorption at 6.218% among the geopolymer paste specimens. On the contrary, GS20 which has a replacement of 20% by SCBA yielded a comparatively higher water absorption at 10.85%.

Though the increase in water absorption is not remarkable due to incremental percentage of SCBA, it could affect the strength and other physical properties of the resulting geopolymer. The higher water absorption caused by incorporation of SCBA might be due to the porous nature and rough surface of the SCBA particles. This could result in lower bulk density of the geopolymer specimens and hence decrease in mechanical strength.

3.4 Bulk Density

The bulk density of geopolymer specimens was determined after 28 days of ambient curing. Results of bulk density of the specimens is shown in Fig. 2. From the figure, it is clearly evident that blending SCBA into GGBS

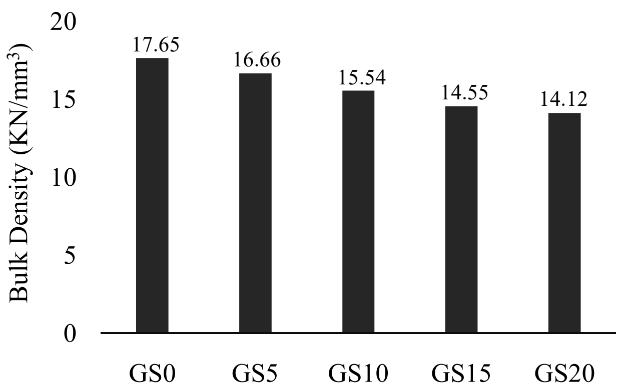

Fig. 2. Bulk density of geopolymer specimens

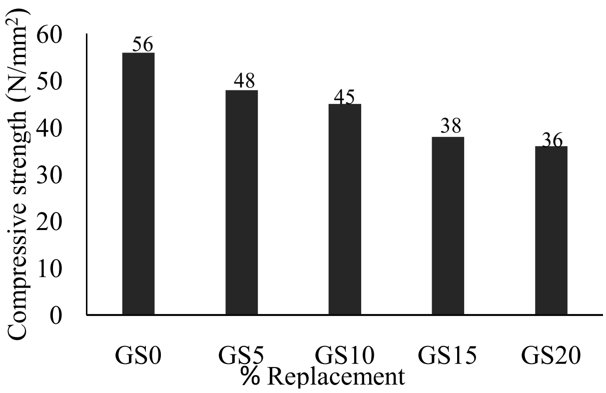

Fig. 3. Compressive strength of geopolymer specimens

based geopolymer decreases the bulk density. This could be due to the fact that specimens become more porous as the replacement increases. Bulk density is highest for GS0 specimen at 17.65 kN/m^3. GS20 specimen having a replacement level of 20% by SCBA shows a comparatively low bulk density of 14.12 kN/m^3. These values could be related with other physical properties such as water absorption and porosity. Moreover, bulk density has a direct relationship with compressive strength.

3.5 Compressive Strength

After 28 days from casting, the geopolymer specimens were tested for compressive strength in a compression testing machine. The results of compressive strength for the geopolymer specimens is presented in Fig. 3. As expected, geopolymer specimens showed a decreasing trend with increasing replacement of GGBS by SCBA. Geopolymer specimen without SCBA resulted in highest compressive strength of 56 MPa. The lowest strength among the specimens was for GS20 geopolymer. However, even at high replacement of 20%, the compressive strength of the specimen is still reasonably high at 36 MPa. This could prove to be beneficial for use of SCBA in blending with GGBS to produce good geopolymer.

4. Conclusion

Following conclusions are drawn based on the findings of the present study:

1. GGBS geopolymer exhibit very good properties in terms of strength and physical properties.
2. The compressive strength of geopolymer decreases with increasing dosage of SCBA though the strength is still comparatively high at replacement up to 20%.
3. Bulk density of the geopolymer composites decreases with increase in quantity of SCBA which indicates its potential application in the construction of tall structure due to lighter weight.
4. The GGBS geopolymer replaced with SCBA up to 20% resulted in good and medium quality grading as per UPV tests.

Blending SCBA in some suitable proportion with GGBS in making geopolymer could result in economy in construction works. Moreover, due to lighter weight, it might prove to be beneficial in regions of high seismic zones.

Disclosures

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