Experimental Investigation on Fly Ash and Bagasse Ash Based Geopolymer Concrete

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Abstract-This paper reports the comparison of bagasse ash and fly ash-bagasse ash based geopolymer concrete. In which cement is fully replaced by pozzolanic material that is rich in silicon and aluminium like fly ash and bagasse ash referred to as "Geopolymer concrete" which is a contemporary material. Geopolymer concrete was actually manufactured by reusing and recycling of industrial solid wastes and by products. Fly Ash, a by-product of coal obtained from the thermal power plant is plenty available worldwide. Fly ash is used as ingredients in concrete which enhance the properties of concrete and utilization of fly ash is helpful for consumption. Bagasse ash is a final waste product of sugar obtained from the sugar mills. The base material, viz. fly ash and bagasse ash, is activated by alkaline solution that is sodium hydroxide and sodium silicate to produce a binder which is rich in silica and aluminium. Trial 1 is cement replaced by 100% bagasse ash and trial 2 is cement replaced by 80% fly ash and 20% bagasse ash. This paper presents the strength and durability of bagasse based geopolymer concrete and fly ash-bagasse ash based geopolymer concrete.

Keywords : sodium hydroxide; sodium silicate; super plasticizer; bagasse ash; Fly ash.

I. INTRODUCTION

Geopolymer concrete, an unindustrialized material in India, is going to be a revolution not only in the research field but also in the construction industry. Geopolymers, and unique class of inorganic polymers are new promising binders and are manufactured by the activation of a solid state alumino-silicate with a highly alkaline activating solution using thermal drive. In the recent past, Geopolymer binders have been found to be the best alternate to cement binders due to its environmental pleasantness. Its performance in aggressive environment is promising and these binders could become a replacement for cement concrete in aggressive situation where cement concrete is vulnerable.

Cement is the most sought after material by the concrete industry throughout the world. Day by day, the requirement of cement in the concrete industry and in the construction field is increasing quite alarmingly. The production of such huge quantity of cement leads to the emission of 80% of that quantity of CO_2, the greenhouse gas, into atmosphere. The production of1 tone of rock based Geopolymer cement requires 3.5 times less energy than that of Portland cement. It generates 0.184 to 0.218 tonnes of CO_2, from combustion carbon-fuel, compared with one tonnes of CO_2 for Portland cement (Joseph Davidovits 2010).

The production of Portland cement exhausts the resources and also it is an energy intensive process that releases large amounts of the greenhouse gas CO_2 into the atmosphere. Approximately 2.8 tons of raw materials, which include fuel and other material, are required to manufacture 1 ton of Portland cement (Nugteren et al 2005). It has now become mandatory mixing pozzolonic material like fly ash to cement to partially replace Portland cement. Recently, another cementitious material, manufactured from analumino-silicate precursor activated in a high alkali solution has been developed and this cementitious material is termed as Geopolymer. Geopolymer has recently emerged as a novel engineering binder material with environmentally sustainable properties (Palomo et al 2004).

It is also well known that alkali activation of alumino-silicates can produce X-ray amorphous alumino-silicate gels, or Geopolymers, with excellent mechanical and chemical properties. These gels can be used to bind aggregate, such as sand or natural rock, to produce mortars and concretes. Geopolymers are inorganic binders that function as the Portland cements. The Geopolymer gel network is comprised of tetrahedral alumino-silicate structures charge-balanced by alkali cations. In the first stage of Geo polymerisation, (Van Jaarsveld et al 2003) the activating agents of there acting slurry attack the solid alumino-silicate components, releasing aluminate and silicate monomers to the solution. These monomers and small poligomers polycondense and crosslink to form a three-dimensional aluminosilicate gel network (Joseph Davidovits 2008).

II. MATERIALS

The current study used class F fly ash with a specific gravity of 2.06 and raw bagasse ash with a specific gravity of 1.61. The bagasse ash received from the sugar industry was processed with minimum effort (oven drying and sieving through 75μm sieve). The chemical composition of fly ash and bagasse ash are presented in the Table 1. The main interpretations from the chemical analysis is that the bagasse ash is deficient in alumina (Al_2O_3), where as equally constitutes silica. Additionally bagasse ash underwent more loss on ignition may be due to the presence of unburnt carbon in the raw bagasse ash.

The fly ash was comparatively rich in iron and magnesia, whereas bagasse ash was containing more SO_3. The current study used laboratory grade NaOH (pellets of 97% purity) and sodium silicate solution (Na_2O and SiO_2; 7.5–8.5% and 25.0–28.0% respectively). River sand with specific gravity 2.66 and siliceous granitic coarse aggregate with a specific gravity of 2.61 were used to prepare mortar and concrete.

Table 1: Chemical composition of fly ash and bagasse ash

Composition	Class F Fly ash	Bagasse ash
CaO	05.01	05.90
SiO_2	59.57	59.63
Al_2O_3	19.87	01.57
Fe_2O_3	06.01	01.01
MgO	07.23	02.11
SO_3	00.05	3.25
Loss On Ignition	01.25	18.3
Total chlorides	00.10	-
K_2O	00.19	07.94
Na_2O	00.29	00.41

III. MATERIAL DESIGN

The present investigation was carried out in three phases. In the first phase geopolymer paste was studied incorporating bagasse ash alone.Later it was extended to geopolymer mortars and concrete respectively For all the mixes, the solid sodium silicate to sodium hydroxide ratio was fixed at 1.5 and activator (solution) to binder (pozzolana) ratio was based on a minimum flow of 200 mm in flow table test (to ensure enough workability for casting specimens).

A 12 molarity NaOH solution was used for the entire study. A ratio of 1:1.5:3 (binder: activator) mortars was used. Meanwhile, a nominal mix ratio of 1:1.5:3 (binder: fine aggregate: coarse aggregate) was used for concrete. The specimens were hot air cured for 24 hours at 65 °C. The cube specimens used for the present study were 50 mm, aggregate: coarse aggregate) was used for concrete. The specimens were hot air cured for 24 hours at 65 °C. The cube specimens used for the present study were 100 mm, , mortar mixes. A specialized paste mixer with an efficient blade was used for preparing pastes and mortars (Figure 1 and Figure 2). The Figures 7 and 8 provide snap shots of flow table test on geopolymer paste. Additionally, the images in Figures 9 and 10 depict specimen casting and hot air curing in oven.

Figure 1: Paste / Mortar Mixer

Figure 2: Mixer Pan and blade

Figure 3: Thermal curing

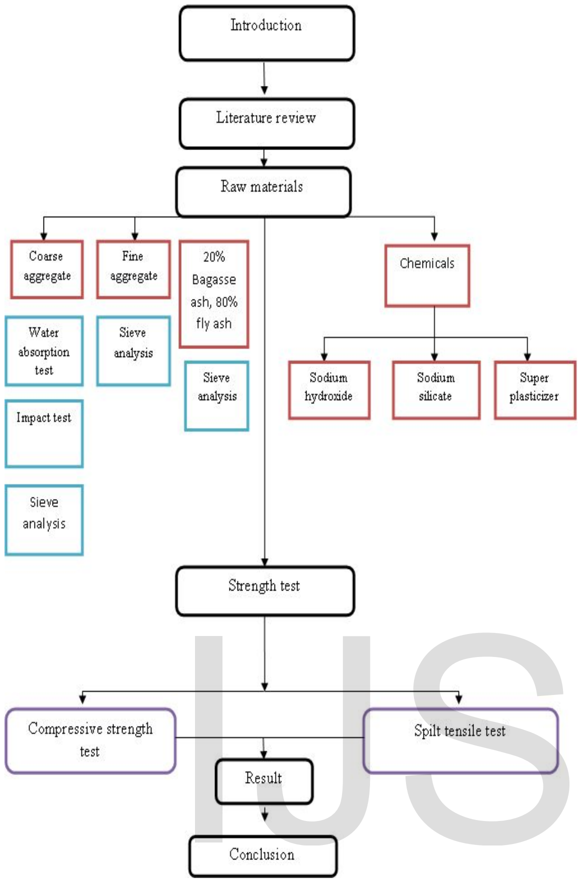
Figure 4: Fresh concrete

IV. MIX PROPORTION

Table 2:Mix proportion for GPC for 1 m^3 of concrete

Materials	**Kg/m^3**
Fly ash	**408**
Bagasse ash	**81.6**
Fine aggregate	**612**
Coarse aggregate	**1346**
Sodium silicate	**103**
Sodium hydroxide	**41**

V. METHODOLOGY



VI. LABORATORY INVESTIGATION

A. Oven curing for concrete

Curing used in this study at an elevated temperature of 60ºC in laboratory oven. After casting, the concrete mix is allowed to settle in the mould for 30 minutes. For air curing the specimens were allowed to cool in air, demoulded and kept open until the day of testing as shown in Figure 3. The specimens were kept in the hot air oven for curing at 60oC as shown in Figure 3.6. During the curing process, the geopolymer concrete experiences polymerization process. Due to the increase in temperature, polymerization become mor rapid and the concrete gain 70% of its strength within 3 to 4 hrs of curing

B. Compressive strength

Compressive strength of specimens are tested by compression testing machine after 7 days, 14 days and 28 days curing. Load should be applied gradually at the rate of 140 kg/cm2 per minute till the Specimens fails. Load at the failure divided by area of specimen gives the compressive strength of concrete.

C. Tensile strength

Tensile strength of specimens are tested by compressive testing machine after 7 days, 14 days and 28 days curing. Load should be applied gradually at the rate of 140 kg/cm2 per minute till the Specimens fails. Load at the failure divided by area of specimen gives the Tensile strength of concrete.

VII. RESULT

A. Compressive strength

Table 3:Compressive strength

Days	**Normal concrete**	**Bagasse ash**	**Fly ash**
7 days	13 N/mm^2	11 N/mm^2	13.8 N/mm^2
14 days	28 N/mm^2	25 N/mm^2	27 N/mm^2
28 days	32 N/mm^2	38 N/mm^2	41 N/mm^2

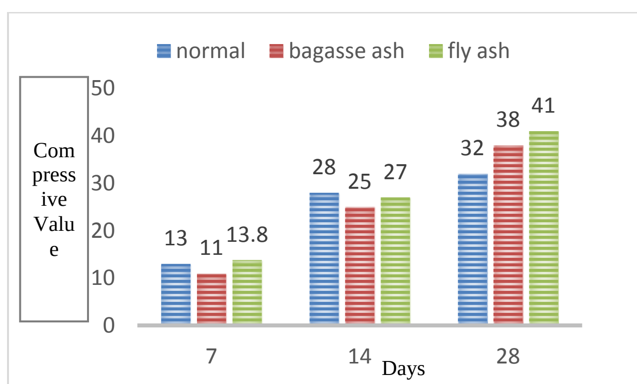


Figure 5: Compressive strength chart

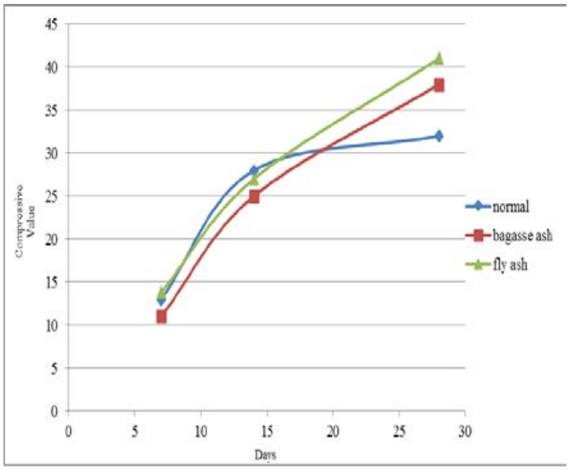


Figure 6: Compressive strength graph

B. *Tensile strength*

Table 4: Tensile strength

Days	Normal concrete	Bagasse ash	Fly ash
7 days	6.3 N/mm^2	3.2 N/mm^2	3.98 N/mm^2
14 days	7.6 N/mm^2	6.5 N/mm^2	7.96 N/mm^2
28 days	8.2 N/mm^2	10.5 N/mm^2	11.9 N/mm^2

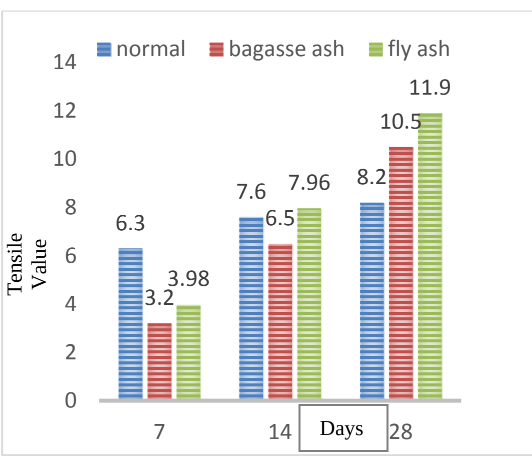


Figure 7: Tensile strength chart

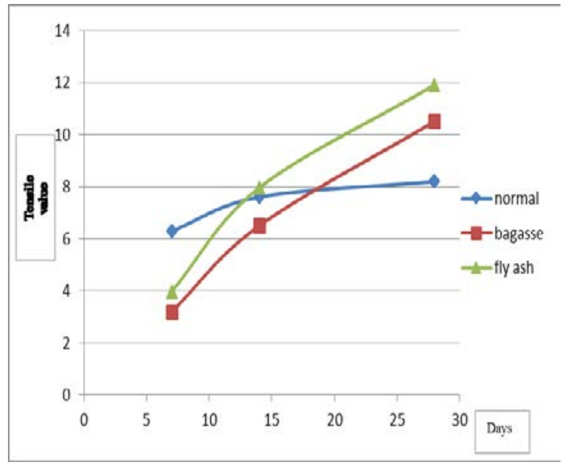


Figure 8: Tensile strength graph

VIII. CONCLUSION

Based on the experimental work reported in this study, the following conclusions are drawn:

- The compressive strength of Fly ash based Geopolymer concrete increases 28.13% compared to conventional concrete.
- The compressive strength of Bagasse ash based Geopolymer concrete increases 18.75% compared to conventional concrete.
- Fly ash based Geopolymer concrete has increased compressive strength compared to Bagasse ash based Geopolymer concrete.
- The Tensile strength of fly ash based Geopolymer concrete increases 45.12% compared to conventional concrete.
- The Tensile strength of Bagasse ash based Geopolymer concrete increases 28% compared to conventional concrete.
- Fly ash based Geopolymer Concrete has increased Tensile strength compared to Bagasse based Geopolymer concrete.
- The use of Fly ash in Geopolymer concrete increase the Compressive strength as well as Tensile strength than Bagasse ash.

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