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Experimental Investigations on Geopolymer Bricks/Paver Blocks

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Abstract

Objective: This study mainly focused on use of quarry dust on replaced with river sand for making geopolymer bricks and paver blocks. **Method:** Investigations were done on usage of eco-friendly Geopolymer Concretes in lieu of OPC concrete for producing geopolymer bricks and paver blocks. Fly ash, GGBS, aggregates and pellet form of sodium hydroxide were mixed together, then, distilled water was added to form alkaline condition. After one-day period, sodium silicate solution was mixed with concrete mixtures to prepare geopolymer concrete. The geopolymer concrete specimen were tested against compressive strength, split tensile strength and flexural strength. **Findings:** GPCC with 50% sand and 50% quarry dust produced excellent compressive strength, flexural strength and split tensile strength. GPC paver block using 75% GGBS and 25% fly ash shows excellent compressive strength. Geopolymer brick using 65% FA & 35% GGBS produced good compressive strength. **Applications/Improvements:** A high volume fly ash based geopolymer concrete (mix proportion of 65, 70, 75 and 80% FA) used for bricks and high volume ground granulated blast furnace slag based geopolymer concrete (mix proportion of 65, 70, 75 and 80% GGBS) used for pavers blocks.

Keywords: Fly Ash, Geopolymer Bricks, GGBS, Paver Blocks, Quarry Dust

1. Introduction

Concrete consists of cement, sand and granite aggregates. Cement is determined the global economy, because of an indispensable for construction purposes. Cement releases greenhouse gases, when it is in production stage. During production, limestone releases CO_2 directly as a results of heat reaction, which may lead to depletion of ozone layer. The CO_2 emission is directly related to how much quantity of cement used in the concrete mix. For example, 900 kg of CO_2 are emitted during the manufacture of each ton of cement. The cement may be reduced by using the other cementing materials[1,2]. Fly ash from the thermal power plants may be replaced with cement as a replacement.

Geopolymer is prepared by binding of silicon (Si) and aluminium (Al) in alkaline solution[3]. Several studies conducted on Geopolymer concrete, which showed that it is potentially substitute to Portland cement concrete[4–6]. Achieved the compressive strength of the concrete for the high molar ratio of NaOH[7]. Geopolymer cement is stronger, fireproof, and waterproof characteristics, in general and it is not expanding or contract, foam in nature, high resistant to salts, acids and alkalis, as a result, it is extensively used for construction of buildings and industries[8].

The huge demand from housing industry due to the more population explosion has entailed the need for sustainability to building materials especially bricks. Researchers have tried to use FA, GGBS, rice husk ash, lime stone dust, welding flux slag and other waste products into bricks so as to improve its sustainability[9,10]. An interesting area of research which has attracted interest of many research scholars in Geopolymer binder which utilizes industrial waste products to form sustainable green binders. The increase over 200Mt by the year 2017, the fly ash may be substitute for cement[11]. Unless, the waste product of fly ash can be utilized properly, it will greatly endanger the environment[12].

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The main objectives of this present study are producing Geopolymer bricks and paver blocks using the different ratios of Fly ash and GGBS. The study was extended to find the comparison of compressive strength, split tensile strength and flexural strength of Geopolymer concrete with OPC concrete.

2. Experimental Investigations

2.1 Materials Used to Produce GPC

a. Fly ash
b. Ground Granulated Blast Furnace Slag.
c. Fine aggregate
d. Coarse aggregate
e. Alkaline activator solutions

2.2 Fly Ash

Fly ash is obtained from the thermal power plant, since it is coal based product.

2.3 GGBS

GGBS is obtained from the by-product of iron and steel and is quenched in water or stream. The used FA and GGBS in this study are conforming to grade I of IS 3812 and IS 12089 respectively. River sand was selected as fine aggregate, which were tested as per IS 2386. Table 1 presents the physical properties of FA and GGBS.

The present study utilized the FA with the grade of class F and GGBS procured from Ennore thermal power station, and Andhra cements Ltd., Chennai respectively. The chemical analysis of FA and GGBS are presented in Table 2.

2.4 Alkaline Activator Solution

In this study, geopolymerisation process was done by mixing sodium hydroxide and sodium silicate solution with certain ratio. The resultant solution is called Alkaline Activator Solution (AAS). It acts as binder between Si and Al.

Table 1. Physical Properties of Cement, Fly ash and GGBS

S.No	Descriptions	OPC	Fly ash	GGBS
1	Fineness (sq.m/kg)	306	419	400
2	Normal Consistency (%)	31	–	–
3	Setting Time(minutes)			
	a) Initial	55	–	–
	b) Final	100	–	–
4	Specific gravity	3.15	2.20	2.90

Table 2. Chemical analysis of fly ash and GGBS

Parameters	% by mass Fly ash	% by mass GGBS
LOI	0.76	
SiO_2	62.1	43.4
Al_2O_3	27.44	12.5
Fe_2O_3	4.57	1.3
CaO	0.83	40.3
MgO	0.55	1.5
Na_2O	0.04	0.9
K_2O	1.17	0.6
TiO_2	1.09	–
Mn_2O_3	0.04	–
Insoluble residue	93.64	–
SO_3	0.4	–
Free lime	–	–
Chlorides	0.02	–

3. Development of Geopolymer Bricks and Paver Blocks

The binding properties are determined the different between the characteristics of geopolymer concrete and Portland cement concrete.

The technique used in the preparation of OPC, is used for preparation of Geopolymer concrete. The fine aggregates, coarse aggregates, fly ash, GGBS and aggregates were mixed together in a pan mixer. The pellet form of sodium hydroxide was mixed with distilled water to prepare AAS solutions. Then AAS was produced by adding sodium hydroxide and sodium silicate solutions. Thus, Geopolymer concrete is produced after adding AAS to fine aggregates, coarse aggregates, fly ash and GGBS mixture.

3.1 Mix Design

Mix design was completed as per ACI-211.1 (part-1) code. Table 3 presents the mixes formulated for GPC and OPC.

In this study, 5M of sodium hydroxide solution (5 × 40 g) of sodium hydroxide pellets were weighed and they dissolved in 1 litre of distilled water.

3.2 Casting, Curing and Testing

The geopolymer bricks/Paver blocks of size 225 × 105 × 75 mm, cubes of size 100 × 100 × 100 mm (compressive strength), cylinders of size 150 × 300 mm (split tensile strength) and beams of size 100 × 100 × 500 mm (flexural strength) were casted and kept under ambient temperature for curing. After one day of casting the specimens were de-moulded. And after attaining the suitable age of strength the specimens were tested.

4. Results and Discussion

4.1 Basic Properties of Geopolymer Concrete

The test specimens were taken as 105 × 75 × 225 mm bricks/paver blocks, 100 × 100 × 100 mm cubes, 150 × 300 mm cylinders and 100 × 100 × 500mm prism. The test specimens were cast and cured at ambient laboratory conditions. Table 4 shows the basic properties of geopolymer concrete.

4.2 Compressive Strength

A Compression testing machine (CTM) of 200T capacity was used to measure compressive strength of concrete cubes at 7 and 28 days of curing time. Compressive strength was measured by applying load on concrete. Figure 1 shows the compression testing of geopolymer concrete cubes.

Figure 2 shows the details of compressive strength for OPC and GPC with 100% sand and the compressive strength of GPC and OPC with 50% replacement of sand with quarry dust.

The comparison of OPC and GPC strength was measured at 7 and 28 days (Figure 2). It may be found that the compressive strength was decreased by maximum of 30% by using 50% sand and 50% quarry dust. Further, it was found that the strength characteristics of Geopolymer concrete is similar to OPC concrete.

4.3 Compressive Strength of Geopolymer Bricks and Paver Blocks

Fly ash based geopolymer concrete (65, 70, 75 and 80% FA) used for bricks and high volume ground granulated blast furnace slag based GPC (65, 70, 75 and 80% GGBS) used for pavers blocks. The replacement of 50% quarry dust for sand is used in geopolymer bricks/paver blocks. The compression testing machine (CTM) of 200T capacity was used to measure the compressive strength of geopolymer bricks and paver blocks. Grade design for geopolymer bricks as per IS 2185 (Part II) 1979. Grade design for paver blocks as per IS 15658-2006. Table 6 presents the compressive strength of geopolymer bricks and paver blocks 3. Table 5 represents the compressive strength at 28th day curing period of geopolymer brick against the different mix proportions.

Figure 3 shows casting of geopolymer brick/paver block and Figure 4 shows the compression testing of geopolymer brick / paver block.

Figure 5 shows the variation of compressive strength of geopolymer bricks and paver blocks. From Figure 5, it was found that the combination of 75% GGBS and 25% of Fly ash produced maximum compressive strength for paver block (GGB2s). Further, it may be found from Figure 5 that the combination of 65% FA and 35% GGBS produced maximum compressive strength for Geopolymer bricks (FAB4s). The compressive strength of Geopolymer brick varies from 14-19 MPa which is on a par with the compressive strength of country clay brick is 19 MPa. The compressive strength results for both paver blocks and Geopolymer bricks are found within the standard limit prescribed by IS 2185.

Table 3. Mix proportions of OPC and GPC

Mix ID	Binder composition	Mix proportion (Binder : Sand : CA)	LS/GPS
GPC	75% GGBS and 25% Fly ash	1 : 1.31 : 2.16	0.65
OPC	100% Cement	1 : 2.46 : 2.8	0.45

Table 4. Basic properties of geopolymer concrete

MIX ID	Compressive strength (7days) MPa	Compressive strength (28 days) MPa	Flexural strength (MPa)	Split tensile strength (MPa)
GPCC with 100% Sand	42	55	5.89	3.97
OPCC with 100% sand	30	48	5.53	4.48
GPCC with 50% sand and 50% quarry dust	40	52	5.35	4.6
OPCC with 50% sand and 50% quarry dust	24	37	3.2	4.5

Figure 1. Set up for compression test.

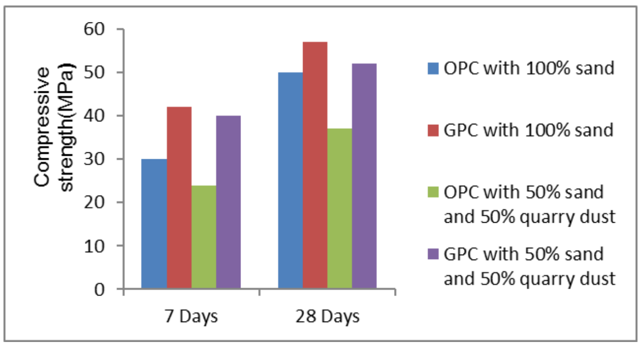

Figure 2. Variations of compressive strengths at the end of 7 days and 28 days.

Table 5. Compressive strength of geopolymer brick

S.No	Mix composition	Compressive strength of brick at 28th day in MPa	Suitable application
FAB1s	80% FA & 20% GGBS	14	Geopolymer brick
FAB2s	75% FA & 25% GGBS	15	Geopolymer brick
FAB3s	70% FA & 30% GGBS	16	Geopolymer brick
FAB4s	65% FA & 35% GGBS	19	Geopolymer brick
GGB1s	80% GGBS & 20% FA	54	Paver block
GGB2s	75% GGBS & 25% FA	60.5	Paver block
GGB3s	70% GGBS & 30% FA	44.8	Paver block
GGB4s	65% GGBS & 35% FA	43.56	Paver block

Figure 3. Casting of geopolymer brick/paver block.

Figure 4. Compression testing of geopolymer bricks / paver blocks.

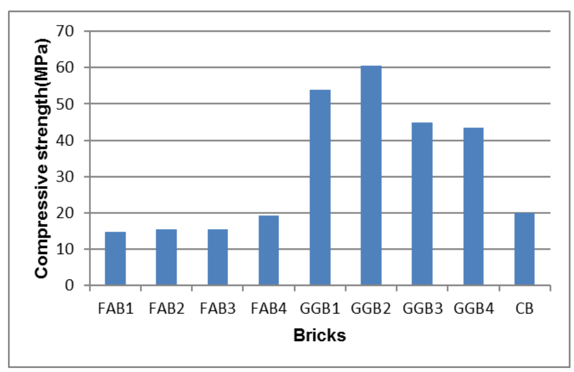

Figure 5. Variation of compressive strength of geopolymer brick/paver block.

5. Conclusion

Studied the strength behaviours of Geopolymer concrete over ordinary Portland cement concrete and focused to produce Geopolymer bricks and paver blocks using the different ratios of FA and GGBS. The results are as follows.

GPCC with 50% sand and 50% quarry dust produced maximum compressive, Flexural strength and Split tensile strength, which is on a par with Ordinary Portland cement concrete. Thus, this study reduced the cost of 50 % for sand and utilize 50 % of quarry dust, which are considered as waste product. GPC paver block using 75% GGBS and 25% fly ash shows excellent compressive strength (up to 50MPa). Geopolymer bricks using 75% GGBS & 25% FA shows excellent compressive strength (up to 19MPa).

The study has demonstrated the feasibility of producing GPC paver blocks and building blocks of different grades. These blocks are non-Portland cement based blocks and utilized large volumes of industrial wastes and thus, this study concluded that they are considered to be a viable eco-friendly alternative to conventional concrete blocks.

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