Jr. of Industrial Pollution Control 33(S2)(2017) pp 1341-1344
www.icontrolpollution.com
Research Article

STUDY ON BEHAVIOUR OF GEOPOLYMER CONCRETE COLUMN

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(Received 11 July, 2017; accepted 24 October, 2017)

Key words: Geopolymer concrete, Fly ash, Ground Granulated Blast Furnace Slag (GGBS), Sodium silicate, Sodium hydroxide

ABSTRACT

Geopolymer is an eco-friendly replacement of Ordinary Portland Cement and possess strength and durability similar to or greater than the conventional concrete. Geopolymer concrete is a combination of fly ash or GGBS or both along with hydroxide and silicate solutions. In this paper a combination of both fly ash and GGBS were used to make geopolymer concrete along with sodium hydroxide and sodium silicate solutions. This paper focuses on the study of reinforced geopolymer concrete columns. The objectives of this paper are to experimentally study the ultimate load and deflection of geopolymer columns with varying reinforcement under axial loading and eccentric loading. The experimental study included testing of six geopolymer concrete short columns. In addition the mechanical properties of geopolymer concrete were studied. The mechanical properties include compressive strength, and split tensile strength. The final results showed that Geopolymer concrete column with reinforcement percentage of 3.21% showed higher load capacity of 392 kN, minimum deflection of 4.35 mm and higher stiffness of 90.1 kN/m^2.

INTRODUCTION

Concrete is a widely used construction material which is second in usage next only to water. It is the most essential material in construction industry for building various infrastructures. One of the widely used material in concrete is Ordinary Portland cement (OPC). (Davidovits, 1994) The production of Ordinary Portland cement is not environmentally friendly nor sustainable since the production of Ordinary Portland cement emits large amount of carbon dioxide. (Davidovits, 1994) Currently the cement industry produces about 1.5 billion tonnes of OPC annually emitting the same amount of CO_2 into the atmosphere which is not good considering the rise of global warming in recent times. (Lloyd and Rangan, 2010) Hence it is essential to find alternative to the conventional cement used in present days. Geopolymer is an alternate to the Ordinary Portland cement which is environmental friendly as well as sustainable. (Hardjito, *et al.*, 2007) As per Davidovits, the person who coined the term Geopolymer geopolymerisation is a process of geological synthesis that chemically integrates materials containing silicon and alumina. The silicon and aluminium atoms combine to form a substance which is similar in structure to that of a natural rock. (Malkawi and Al-Mattarneh, 2016) Fly ash is a widely available material and so is GGBS. In this study Geopolymer concrete was made using fly ash and GGBS as binder material and sodium hydroxide and sodium silicate solutions were used as alkaline solutions (Aleem and Arumairaj, 2012).

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MATERIALS USED

Fly Ash

Fly ash is a fine, grainy particle obtained as a waste from the combustion of coal in thermal power plants. When coal is burnt to generate heat, the residue contains 80 per cent fly ash. (Al-Bakri, *et al.*, 2011) The properties of fly ash are shown in Table 1.

GGBS

Ground Granulated Blast furnace Slag (GGBS) is a fine powdery by-product of the blast furnaces used to make iron (Sujatha, *et al.*, 2012). The properties of GGBS are given in Table 2.

Fine Aggregate

The sand used conforms to grading zone II of IS 383:1970. The properties of fine aggregate are given in Table 3.

Coarse Aggregate

The crushed aggregate was used from local quarry. The properties of coarse aggregates are shown in Table 4.

ALKALI ACTIVATOR SOLUTIONS

Sodium Hydroxide

Sodium hydroxide solution of 12 molar was used. The solution was purchased from a local supplier. A 12 molar solution indicates that 12 × 40 = 480 grams of sodium hydroxide per litre of solution (Ranjini and Narasimha, 2014).

Sodium Silicate

The sodium silicate solution (Na_2O=13.7%, SiO_2=29.4%, and water=55.9% by mass) was purchased from a local supplier (Nath and Sarker, 2014).

Table 1. Properties of fly ash

S. No	Property	Results
1	Specific gravity	2.2
2	Bulk Density	740 kg/m^3

Table 2. Properties of GGBS

S. No	Property	Results
1	Specific gravity	3.2
2	Bulk Density	2900 kg/m^3

Table 3. Properties of fine aggregate

S. No	Property	Results
1	Specific gravity	2.67
2	Bulk density	1600 kg/m^3

Table 4. Properties of coarse aggregate

S. No	Property	Results
1	Specific gravity	2.74
2	Bulk density	1750 kg/m^3

EXPERIMENTAL INVESTIGATION

The experimental investigation was carried out to determine the mechanical properties of geopolymer concrete such as compressive strength, and split tensile strength along with the load carrying capacity and deflection of Geopolymer short columns.

Mix Proportions

(Hardijito and Rangan, 2005) have noted that unlike conventional concrete geopolymer are a new class of materials and no standard mix design is set for geopolymer concrete. Hence the same mix design procedure for conventional concrete of M 30 grade was adopted. (IS 10262, 2009) A solution to geopolymer solids ratio of 0.5 was assumed as w/c ratio. A fly ash + GGBS ratio of 50:50 was used.

i. Fly ash+ GGBS: Fine aggregate: Coarse aggregate = 1:1.5:2.5

ii. Assumed solution: Geopolymer solids ratio = 0.5.

Compressive Strength

The compressive strength of geopolymer concrete was found out by testing cube specimens of size 150 × 150 mm. The specimens were tested in a Universal compression testing machine and the failure load were noted and the compressive strength of each specimen were calculated. The cubes were tested on 7 and 28 days respectively. The compressive strength of geopolymer specimen was about 33.78 N/mm^2 at the end of 28 days (Table 5 and Fig. 1).

Split Tensile Strength

The split tensile strength for both geopolymer was found out by testing cylinder specimens. The size of the cylinder specimens was 100 × 200 mm. The specimens were tested in a Universal compression testing machine and tested on 7 and 28 days. The failure load of each specimen were noted and the corresponding split tensile strength were calculated. The split tensile strength at the end of 28 days was found out to be 3.2 N/mm^2 (Table 6 and Fig. 2).

Testing of Short Column Specimens

In this study low calcium class-F fly ash obtained from Ennore power station, Chennai was used along with GGBS obtained from local supplier as binder materials. The alkaline solutions used were sodium hydroxide and sodium silicate both in solution form. The two solutions sodium hydroxide and sodium silicate were mixed in the ratio 1:2.5. In order to

Table 5. Compressive strength of geopolymer concrete

Age (Days)	Compressive Strength (N/mm²)
7	27.29
28	33.78

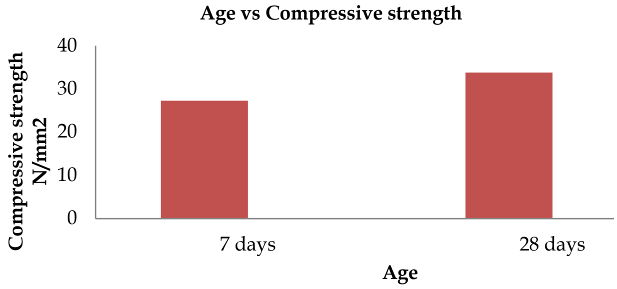

Fig. 1 Variation of compressive strength.

Table 6. Split tensile strength of geopolymer concrete

Age (Days)	Split tensile strength (N/mm²)
7	2.36
28	3.2

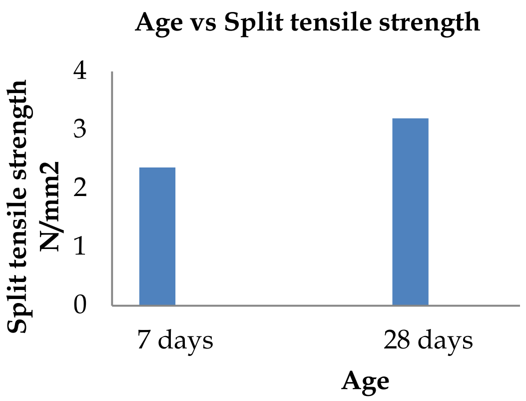

Fig. 2 Variation of split tensile strength.

facilitate quick setting and room temperature curing blast furnace slag (GGBS) was used.

Six geopolymer short column specimens were cast and tested in a compression testing machine and the mid deflection was noted by placing a deflectometer at the mid height of each specimen. All specimens were of the same cross section 120 × 120 mm and height of each specimen was 1000 mm. The reinforcement percentage was varied by providing three columns with 4 main bars of 10 mm diameter and another three columns with 6 main bars of 10 mm diameter. Shear reinforcement was provided with 8 mm horizontal bars. The reinforcement percentage of three columns with four main bars accounted to 2.18% (4#10 mm) and the other three columns with six main bars accounted to 3.21% (6#10 mm). The graph was plotted for load vs. deflection and load vs. stiffness shown in (Fig. 3-6). The value of stiffness of each column was calculated by the formula stiffness = load/deflection. The test setup and the reinforcement detailing of the specimen columns are shown in (Fig. 3-6) and Table 7.

Fig. 3 Test setup of columns.

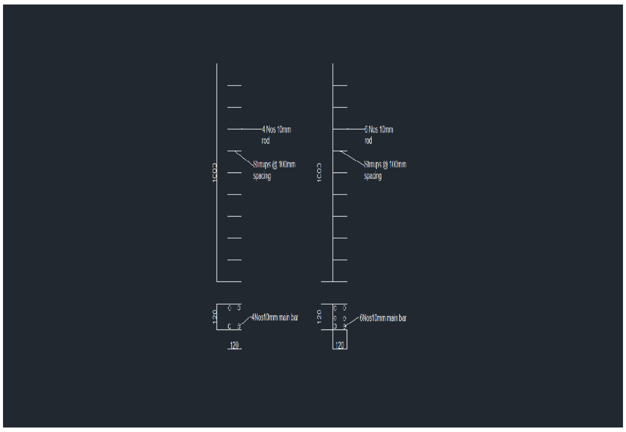

Fig. 4 Reinforcement for short columns.

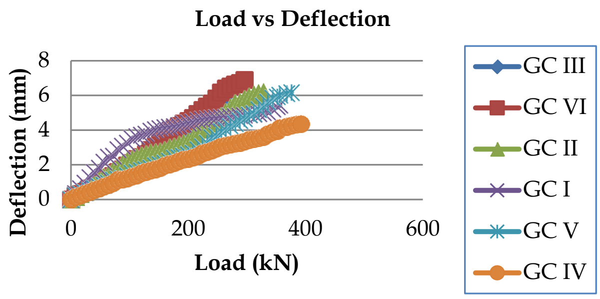

Fig. 5 Load vs. Deflection graph of geopolymer columns.

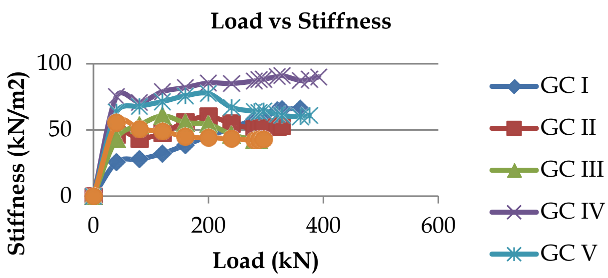

Fig. 6 Load vs. Stiffness graph of geopolymer column.

Table 7. Experiment results for geopolymer concrete short columns

Column No.	Longitudinal Reinforcement		Load eccentricity (mm)	Test Results		
	Bars	Ratio %		Failure load (kN)	Mid-Height deflection at failure load (mm)	Stiffness (kN/m^2)
GC I	4N10	2.18	0 (Axial)	360	5.44	66.18
GC II	4N10	2.18	15	328	6.18	53.07
GC III	4N10	2.18	30	288	6.72	42.85
GC IV	6N10	3.21	0 (Axial)	392	4.35	90.1
GC V	6N10	3.21	15	376	6.17	60.94
GC VI	6N10	3.21	30	296	6.89	42.96

CONCLUSION

Based on the results obtained from this study the following conclusions can be drawn,

1. The compressive strength of geopolymer concrete is greater than that of conventional concrete for the same mix proportions on 7th and 28th days.

2. Similarly, the split tensile strength of geopolymer concrete is also greater than that of conventional concrete tested on 7th and 28th days.

3. The rate of compressive strength gaining of geopolymer concrete is faster than that of conventional concrete on 7 days.

4. The load carrying capacity and corresponding stiffness are greater for geopolymer short column specimens than that of conventional specimens of same size and mix.

The deflection is minimum for both the columns when the columns are axially loaded and for reinforcement percentage of 3.21% and the load carrying capacity and stiffness are maximum when compared to other columns.

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