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Experimental Investigation on Flexural Strength of Geopolymer Concrete Paver Block

K. Ashok Kumar[1] and Dr. P. Partheeban[2]

[1]Assistant Professor, Department of Civil Engineering, Dr. M.G.R. Educational and Research Institute, University, Chennai, Tamil Nadu, India.

Orcid: 0000-0003-1806-446x

[2]Professor and Dean (Academic), St. Peter's College of Engineering and Technology, Avadi, Chennai, Tamilnadu, India.

Abstract

The cement industry uses the raw materials and energy that are non-renewable and it extracts raw materials by mining and manufactures a product that cannot be recycled. To minimize the usage of cement, the waste by-product from the thermal power plant can be altered with the cement as well as the energy used in the production of the cement industry can be considerably reduced. The present study examines the strength properties of fly ash based geopolymer concrete. Mix proportion was done based on the earlier research studies for M35 geopolymer concrete and the test results were analyzed for the similar strength control concrete. The tests such as flexural strength test and abrasion resistance test were conducted. The geopolymer concrete specimens were cast and without de-moulding the specimens were exposed to 80º C in the oven for 72 hours and then after de-moulding, the specimens were left at atmospheric curing for the desired period.There is a significant increase of 13.27 % in flexural strength was observed for geopolymer concrete paver block as compared to M35 grade control concrete paver block.

Keywords: fly ash, splitting tensile strength, atmospheric curing

MATERIALS AND METHODOLOGY

A. Materials Used In The Study

The following are the materials used in the investigation.

- Cement (Ordinary Portland Cement)
- Class 'F' fly ash
- Crushed Granite Aggregates (CGA)
- Catalytic Liquid System (CLS)
- River sand

B. Materials Properties

Ordinary Portland cement confirming to IS 12269: 1987 (Specification for 53 grade ordinary Portland cement), fine aggregates, coarse aggregates and potable water were used for the control Ordinary Portland cement concrete specimens. The geopolymer concrete was obtained by mixing calculated quantities of fly ash, fine aggregates, coarse aggregates with optimized Catalytic Liquid System (CLS). Fly ash confirming to grade 1 of Indian Strandard 3812:2003 (Specifications of fly ash) was used. River sand available in Chennai was used as fine aggregates and tested as per IS 2386: Part I: 1963 (Methods of Test for Aggregates for Concrete). In this investigation locally available blue granite crushed stone aggregates of maximum size 20 mm was used and characterization tests were carried out as per IS 2386: Part I: 1963 (Methods of Test for Aggregates for Concrete).

C. Fly Ash

In the present investigation, fly ash obtained from Ennore Thermal Power Station was used. It's typical properties were satisfying the requirements of IS:3812:2003. It is well known that fly ash is the finely divided residue resulting from the combustion of ground or powdered coal (to a fineness of 70% to 80% passing through 75 µm sieve) and it is transported from the firebox through the boiler by flue gases. Fly ash is also known as Pulverized Fuel Ash (PFA). Table 2.1 shows the physical and chemical composition of fly ash.

D. Crushed Granite Aggregate

In the present investigation, locally available crushed granite aggregate obtained from the local source was used. The course aggregate was found with specific gravity 2.68, bulk density 1.61 gm/cm^3 and water absorption 0.53%.

E. River Sand

River sand obtained from local source was used as a fine aggregate. The sand was screened at site to remove deleterious materials and tested as per procedure given in IS: 2386 (Part I) – 1963 (Methods of test for aggregates for concrete - part 1 - particle size and shape).

F. Catalytic Liquid System For Geopolymerization

The chemical activation of geopolymer concrete is carried out by high alkaline "catalytic liquid system", which is prepared by mixing commonly available chemicals such as sodium hydroxide and sodium silicate solution, besides distilled water **[Rajamane, 2005a to 2005f]**. It was also found that potassium silicate solution, which is commercially available can also be used. These alkali silicate solutions (ASS) can have different "Molar Ratios", which is defined by ratio of contents of silicon di oxide (SiO_2) and alkali oxide (Na_2O or K_2O) present in the ASS.

EXPERIMENTAL INVESTIGATIONS

A. Development Of Geopolymer Concrete Mix

The present study is aimed at identifying and optimizing the salient parameters which influences the mixture proportions of the geopolymer concrete. Also an attempt has been made to simplify the process of manufacturing geopolymer concrete compared to earlier production methods by avoiding very high alkaline concentrations, which can be injurious, so that the process involved is almost similar that of the conventional concrete. In order to develop the fly ash based geopolymer concrete, a meticulous trial-and-error process was used. The compressive strength was selected as the standard parameters to finalize the mixtures.

B. Procedure Adopted In Formulating The Mixtures

Unlike conventional cement concrete geopolymer concretes are a new class of construction materials and therefore no standard mix design approaches are available for geopolymer concretes. While Rangan and Hardjito have suggested some approaches, some of the trials carried out using these procedures indicated that the workability and strength characteristics of such mixes were not satisfactory. It is possible because geopolymer concrete involves more constituents in its binder (fly ash, sodium silicate, sodium hydroxide and distilled water), whose interactions, final structure and chemical compositions are still a matter of research whereas the chemistry of cement and its structure and chemical composition are well established due to extensive research carried out over more than century. While the strength of cement concrete is known to be well related to its water-cement ratio, such a simplistic formulation may not hold good for geopolymer concretes.

Therefore, the formulation of the geopolymer concrete mixture was done by trial and error basis. Number of trail mixes were cast and tested for compressive strength at end of 14 days and 28 days. The ratio of alkali activated solution to geopolymer solids were varied suitably. The primary objective for performing the trial and error procedure is to obtain desired compressive strength of 35 MPa to 40 MPa at the end of 28 days. The secondary objective was to obtain a good cohesive mix with good workability. The proportions of geopolymer solids and alkali activated solution were so decided that the strength could be realized.

C. Preparation Of Test Specimens And Curing

In this experimental work, low-calcium Class 'F' dry fly ash obtained from a local Thermal Power Station (Ennore) was used as the source material. Analytical grade sodium hydroxide (NaOH with 98% purity) flakes dissolved in water and sodium silicate solution (Na_2O=14.7%, SiO_2=29.4% and water=55.9% by mass) were used. Both the liquids were mixed together and the activator solution was prepared at least one day prior to its use. To improve the workability of fresh concrete, a commercially available naphthalene based super plasticiser was used. A combination of locally available aggregates, i.e. granite-type coarse aggregates and fine sand, in saturated surface dry condition, were mixed together. The grading of the combined aggregates had a fineness modulus of approximately 4.5. The aggregates and fly ash were mixed in a pan mixer for about 3 minutes. Then added with the activator solution, super plasticiser and extra water and the mixing continued for another 3 to 5 minutes. The fresh geopolymer concrete had a stiff consistency and glossy appearance. De-moulding was done 72 hours after casting, left in oven of 80^{o} C and placed at the room temperature for further curing to the desired periods.

Table 1: Proportion of ingredient material for geopolymer concrete

S.No.	Material	Mass, Kg / m³
1	Coarse Aggregate - 20 mm - 10 mm	425 Kg 425 Kg
2	Fine Aggregate	600 Kg
3	Fly Ash	425 Kg
4	Sodium Silicate Solution (SiO_2/Na_2O)	200 Kg
5	Sodium Hydroxide Solution (8 Molar)	75 Kg

D. Tests Conducted

At the end of desired curing period, the casted specimens were subjected to the following strength and durability tests to study the effectiveness of geopolymer concrete.

- Flexural Strength test

Table 2 shows the details of specimens used for conducting various studies.

Table 2: Details of specimen used in various studies

S.No.	Type of test	Specimen Description
1	Flexural strength test	200mm x 100mm x 60mm

E. Flexural Strength Test

The flexural strength test was carried out as per BIS 516-1968- Methods of Tests for Strength of Concrete, to find the flexural strength of geopolymer concrete. Totally four specimens of size 200x100x60mm were subjected to flexural strength test. The test was carried out at the age of 20 days curing period for both control and geopolymer concrete specimens.

The test was carried out in a Universal Testing Machine of capacity 1000kN. The specimen was placed on the lower platen over the rollers to give the effect of simply supported end. The top surface of the specimen was fitted with specially made fixed roller arrangement to apply middle third loading effect on the specimen. The load was applied gradually without shock until failure of specimen. The failure load and the failure region were noted. The flexural strength of the specimen was expressed as modulus of rupture.

If 'a' equals the distance between the line of fracture and the nearer support, measured on the centre line of the tensile side of the specimen, in cm, the flexural strength shall be calculated to the nearest 0.5 kg/sq cm as follows:

$$\text{Flexural strength} = P\,L/bd^2 \text{ (MPa)}$$

When 'a' is greater than 20.0 cm for 15.0 cm specimen, or greater than 13.3 cm for a 10.0 cm specimen, or

$$\text{Flexural strength} = 3P \times a\,/bd^2 \text{ (MPa)}$$

When 'a' is less than 20.0cm but greater than 17.0 cm for 15.0 cm specimen, or less than 13.3 cm but greater 11.0 cm for a 10.0 cm specimen

Where

P – Maximum load in N applied to the specimen

L – Length in mm of the span on which the specimen was supported

b – Breadth of the specimen in mm

d – Depth of the specimen in mm

For concrete specimen,

L = 200mm, b = 100mm, d = 60mm.

If 'a' is less than 17.0 cm for a 15.0 cm specimen, or less than 11.0 cm for a 10.0 cm specimen, the results of the test shall be discarded.

Table 3: Observation on flexural strength for geopolymer concrete

S.No.	Description	Specimen1	Specimen2	Specimen3	Specimen4	Average Flexural Strength
1.	Control concrete – M35	9.80	9.75	9.80	9.80	9.80 MPa
2.	Geopolymer concrete	11.10	11.0	11.10	11.20	11.10 MPa

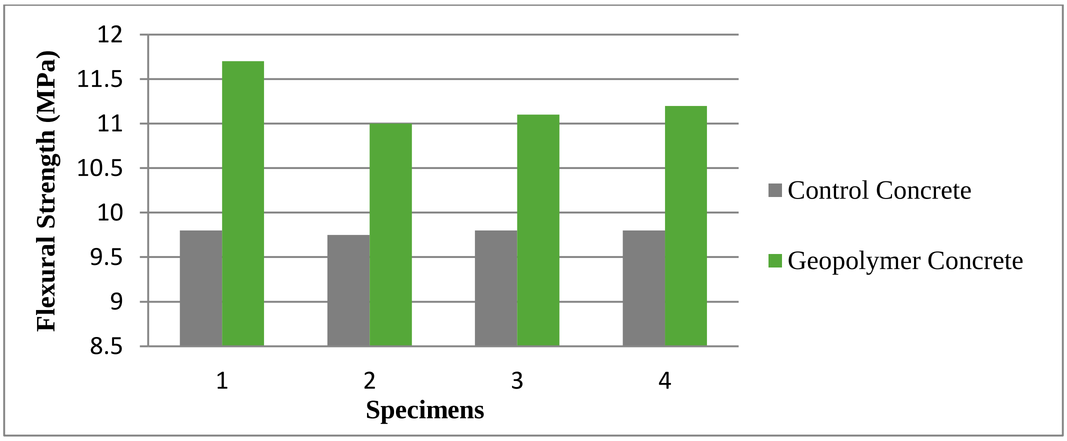

Figure 1: Comparison of flexural strength of geopolymer concrete

CONCLUSIONS

A. General

Totally 8 specimens were tested to study the flexural strength of geopolymer concrete. The obtained test results are compared with the control concrete as indicated in Indian Standards (IS 456:2000) for similar strength of cement concrete.

B. Conclusions

Based on the tests results and further analysis, the following conclusions were drawn:

- There is a significant increase of 13.27% in flexural strength as compared with the values of M35 control concrete paver block.
- The flexural strength property of geopolymer concrete can be improved further by adequate modification in mixing and curing methods with appropriate proportion.

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