Mechanical Properties of High Calcium Flyash Geopolymer Concrete with Metakaolin Blend

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Abstract— In the present study, the Portland cement was fully replaced with high calcium fly ash to produce the geopolymer concrete. Alkaline liquids were used in different combination in the source material. The alkaline liquids used in this study for the polymerization was sodium hydroxide (NaOH) and sodium silicate (Na2SiO3).High calcium fly ash was partially replaced by metakaolin blend by 0%, 25%, 50%, 75% and 100%. Ambient curing was given to the mortar specimens. Based on many trials on compressive strength of high calcium flyash geopolymer mortar at 3, 7, 28 days, the optimum mix combination was chosen. Upon the optimum mix combination compressive strength was determined. Test results depict that high calcium fly ash geopolymer mortar specimen's attained higher compressive strength at 75% replacement of metakaolin. Compressive strength, split tensile strength, flexural strength of concrete specimens to determine by 75% replacement of metakolin.

Key words: Geopolymer, High Calcium Fly Ash, Metakaolin, Alkaline Liquid, Strength Properties

I. Introduction

Manufacturing of Portland cement is an energy intensive process and releases a large amount of green house gas to the atmosphere. Recently, another form of cementations' materials using silicon and aluminum activated in a high alkali solution was developed This material is usually based on fly ash as a source material and is termed geopolymer or alkali-activated fly ash cement . Geopolymers was first developed by Davidovits, consist of SiO_4 and AlO_4 tetrahedral networks [1-3]. The prepared mixture can be subjected to curing at room temperature or at a given temperature. Alumina silicate reactive materials dissolve in strong alkaline solutions and free SiO_4 and AlO_4 tetrahedral structure forms. However, the reaction of the fly ash in the production of geopolymers is low at ambient temperatures [4]. It is also well known that geopolymers possess excellent mechanical properties [5]. Class C fly ash had higher compressive strength than that with Class F fly ash. The mixture of fly ash with 10 molarity(M) of NaOH is suitable for the geopolymer synthesis [6-8]. The strength of the fly ash-based geopolymer increased after exposure to elevated temperatures (800 °C). However, the strength of the corresponding metakaolin-based geopolymer decreased after similar exposure[9]. Geopolymer suffers strength loss after sulphate attack exposure but gains strength with increasing replacement level of fly ash by metakaolin from 5% to 20% and obvious increasing in compressive strength could be observed when the replacement percentage exceeds 15% [10]. The annual output of lignite fly ash from Neyveli Lignite Corporation station 28.5 million tons per annum at Neyveli and one open cast lignite mine of capacity 2.1 million tonnes per annum. This fly ash contains a high percentage of calcium and is being used quite extensively for construction in Tamilnadu. The knowledge of the use of high calcium lignite fly ash in producing geopolymer would be beneficial to the understanding and to the future applications of this material. Therefore, this study focuses on the use of a geopolymer binder for making high calcium concrete which comprises lignite fly ash, sodium silicate and sodium hydroxide solution, and coarse aggregate with partial replacement of metakaolin blend.

II. Experimental details

A. Materials

Class C fly ash used in this work was collected from Neyveli Lignite Corporation in Cuddalore district of Tamilnadu. Metakaolin was collected from jeetmull jaichandlall Pvt Ltd. The chemical composition of high calcium fly ash, metakaolin is shown in Table 1. Other materials like alkaline solution, coarse aggregate of size 12 mm and 6 mm and fine aggregate were used in making of geopolymer concrete. The physical properties of fine and coarse aggregate are shown in Table 2. Alkaline solution comprises of sodium hydroxide and sodium silicates were used.

Chemical composition	SiO2	Al2O3	Fe2O3	MgO	CaO	Na2O	K2O	LOI
FlyAsh	63.11%	19.58%	5.03%	0.24%	17.13%	0.29%	0.84%	1.55 %
Metakaolin	52.22%	40.35%	2.13%	0.79%	0.21%	0.59%	0.61%	2.08%

Table 1: Chemical Composition of High Calcium Fly Ash

Description	Fine aggregate	Coarse aggregate
Specific gravity	2.55	2.70
Bulk density	1791.1kg/m^3	1689.32 kg/m^3
Fineness modules	2.6	6.50

Table 2: Physical Properties of fine and coarse aggregate

B. Mix design and mixing

All geopolymer mortars were made with fly ash to sand ratio of 1:3. The NaOH of three concentrations viz., 8, 10, 12 and 14 M, liquid to binder ratio of 0.5 and the sodium silicate to NaOH ratios by mass of 2.5 and metakaolin replacement percentage by the weight of flyash from 0%,25%, 50%, 75% &100% were attempted. The mixing was done at room temperature. The mixing procedure started with mixing of NaOH solution and sodium silicate solution. This was followed by the addition of fly ash for 5 min in a pan mixer. Sand was then added and mixed for 5 min.

C. Experimental Work

1) Compressive strength of mortar

Mortar cube of size 70.6 mm x 70.6 mm x 70.6 mm were casted with different NaOH concentrations, five various percentage replacement of metakaolin blend with flyash. Compressive strength of geopolymer fly ash mortar was measured by uniaxial compressive strength tests after 3, 7, and 28 days. The geopolymer mortars were cured under kept in room temperature up to the date of testing. The casted specimens were shown in Fig.1. the compressive strength test of mortar specimen shown in Fig.2.

Fig. 1: Casted Mortar Cube Specimens

Fig. 2: Compressive strength Test

2) compressive strength of concrete cube:

The high calcium fly ash geopolymer concrete with NaOH concrete 8, 10,12 and 14M with metakaolin blend replacement of 0%, 25%, 50%, 75% and 100% were tested for 3, 7,and 28days of curing for mortar cube. 75% replacement gives the higher compressive strength, so concrete cubes are casted on that replacement. These cubes were loaded on their sides during compression testing such that the load was exerted perpendicularly to the direction of casting .The average value of the three cubes was taken as the compressive strength. The Fig.3 shows the compressive strength test of geopolymer concrete specimen.

Compressive strength in N/mm2 = P/A

Where,

P = Maximum load at failure in N.

A = Average net area under compression in mm2.

Fig. 3: compressive strength Test

Fig. 4: split tensile strength Test

Fig. 5: Flexural Strength Test

3) Split Tensile Strength of Concrete Specimen:

Three cylinders of concrete specimens of size 150 mm dia and 300 mm height the specimens were tested at the age of 7 days and 28 days in the compressive testing machine .Apply the load horizontally, till failure (or) crack occurs and note the maximum load at failure .The load at failure shall be the maximum load at which the specimen fails to procedure any future increase in the indicator reading on the testing machine. The Fig.4 shows the split tensile strength test of geopolymer concrete specimen.

Split tensile strength in N/mm2 = 2P/πld

Where,

P = Maximum load at failure in N.

l = Height of the specimen in mm.

d = Diameter of the specimen in mm.

4) flexural strength of concrete specimen:

Flexural strength is the ability of a beam or slab resist failure in bending .It is measured by loading un-reinforced concrete beam of size 500x100x100mm. Hydraulic flexural testing machine was used for the test and with a capacity of 10 tonne. The bearing surfaces of the supporting, loading rollers are wiped clean and make contact with the rollers. The specimen is then placed in the machine is such a manner that the load is applied to the upper most surfaces as cast in the mould, along two lines spaced 20 cm apart. The load was applied gradually until the specimen fails and the maximum load applied to the modulus of rupture fb and formula used to calculate the flexural strength depends on the distance between the line of fracture and nearer support , measured on the center line of the tensile side of the specimen. The Fig.5 shows the flextural strength test of geopolymer concrete specimen. Since the failure distance „a" is greater than 13.3 cm formula used shown below. When,

1) a ≥ 133 mm , Fcr = Pl/bd2
2) a ≥ 110 mm , Fcr = 3Pa/bd2
3) If a < 110 mm, the beam fails

Where,

P = Maximum load at failure in N.

L = Length of the beam in mm.

b = Breadth of the beam in mm.

d = Depth of the beam in mm.

III. Results and Discussion

A. Compressive Strength of Mortar Specimens

The compressive strength at 3, 7, and 28 days for NaOH concentration 8, 10, 12 and 14M, liquid to binder ratio 0.5 with $NaOH/Na_2SiO_3$ ratio 2.5 was tested. From the results the mortar mix with NaOH concentration 12M, liquid to binder ratio 0.5 and sodium silicate to NaOH ratio 2.5, metakaolin replacement percentage 75% with high calcium flyash was attained mariginally higher compressive strength (21.69 MPa) than the other mixes. The graphical representations of geopolymer mortar specimen's compressive strength test results of were shown in Fig.6.

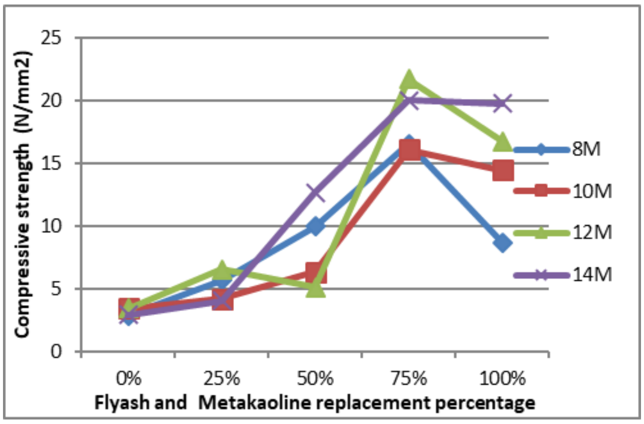

Fig. 6: Compressive strength Test results

B. Compressive strength of geopolymer concrete specimens

The compressive strength of ambient cured geopolymer concrete with 75% replacement of metakaolin blend with high calcium fly ash was determined by using 150x150x150mm cubes. The test results of 7& 28 days of compressive strength of geopolymer concrete are shown in table. From the results it is found that compressive strength of 12M geopolymer concrete attained 11.2% higher compressive strength of 8M at the age of 28 days. The graphical representations of geopolymer concrete specimen's compressive strength test results of were shown in Fig.6.

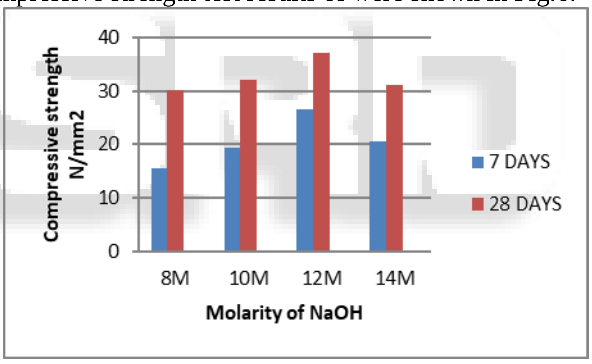

Fig. 9: Flexural strength test results of concrete specimens

IV. Conclusion

The following conclusions were drawn from the study on HCFA GPC.

Higher compressive strength of 21.69 MPa was attained in 12M NaOH and Na2SiO3 to NaOH ratio 2.5 with 75% of metakaolin replacement with flyash and liquid to binder ratio 0.5 in HCFA geopolymer mortar specimens. Hence, this combination mix was considered as optimum mix for study on HCFA geopolymer concrete. When the higher compressive strength concrete mix is to attained in 12M NaOH with compared to 8M NaOH. Split tensile and flexural strength of concrete mix also to be attained in higher value by 12M NaOH at 75% replacement of metakaolin by the weight of HCFA.

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