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Strength Studies on Geopolymer Mortar for Ferro Geopolymer Water Tank

THANUSH THAMPI, SREEVIDYA V., VENKATASUBRAMANI R.
Department of Civil Engineering, Sri Krishna College of Technology, Coimbatore, Tamil Nadu, India
Email: thanushthampi1988@gmail.com, sreevidya.sankr@gmail.com

Abstract: Geopolymer mortar is an innovative construction material which is produced by the chemical action of inorganic molecules. In Geopolymer mortar, Portland cement is not utilized at all. The recent environmental awareness in construction industry promotes the use of alternative binders to partially or fully replace the cement as its production creates environmental pollution due to release of CO_2 into atmosphere. A great development around the world in new types of inorganic cementitious binders is the "geopolymeric cement". This prompted its use in mortar and concrete, which improves the greenness of ordinary concrete. Fly ash is one of the most normally preferred substitutes for cement because concrete workability and durability are enhanced by fly ash by their small size and round shape. This paper presents the mechanical properties with emphasis on compressive strength and tensile strength of geopolymer mortar at ambient and heat curing for construction of a geopolymer water tank.

Keywords: *Fly Ash, Geopolymer , Sodium hydroxide , Sodium Silicate.*

I. Introduction:

The ordinary portland cement (opc) is widely used material in construction industry as a binder in concrete and cement mortar. The manufacturing of OPC releases large amount of carbon dioxide (CO_2) which significantly contributes to the green house gas emissions. A greener alternative, geopolymer fits into an emerging class of cementitious materials that utilize 'fly ash', one of the most abundant industrial by-products on earth, as a substitute for Portland cement. The development of geopolymer material is an important step towards the production of eco-friendly materials. Fly ash is one of the residues generated from the combustion of coal. Fly ash is generally captured from the chimneys of coal-fired power plants. Consumption of fly ash in the manufacture of geopolymers is an important strategy in making materials more environment friendly. For this reason, fly ash has been chosen as a base material for this project in order to better utilize this industrial waste and reduce the emission of CO_2

II. Fly Ash:

There are two major classes of fly ash on the basis of chemical composition from the types of coal burned are

1. Class F
2. Class C

The composition of fly ash obtained from Mettur power plant is shown in table 1

The color of fly ash is either grey or blackish grey. Fly ash particles are spherical, having small surface area. The size of the fly ash generally varies between manufactured sand and silt clay. Ash is characterized by low specific gravity, uniform gradation and lack of Plasticity. The specific gravity of ash particles depends on chemical composition and generally varies from 2.0 to 2.6 with an average value of about 2.2. The pH of fly ash contacted with water range from 8 to 12.

Table I - Composition of Fly Ash

Constituents	Percentage of content (%)
SiO_2	46.2
Al_2O_3	26.4
Fe_2O_3	10.7
CaO	7.60
SO_2	1.80
LOI	0.20

III. Geopolymer:

Geopolymers are a novel class of materials that are formed by the polymerization of silicon, aluminum, and oxygen species to form an amorphous three-dimensional framework structure. The term geopolymer was termed by Davidovits in1978.

Alkaline dissolution and subsequent polymerization of silicon and aluminium species results in formation of ceramic materials that exhibit excellent fire-and acid-resistance properties. The polymerization reaction of geopolymer mortar is shown in fig 1.

IV. Materials used:

Water: In the present investigation, potable water was used.

Fine Aggregate: The properties of river sand used are shown in Table 2.

Table II - Properties of River Sand

Properties	Values
Specific gravity	2.6
Fineness modulus	2.85

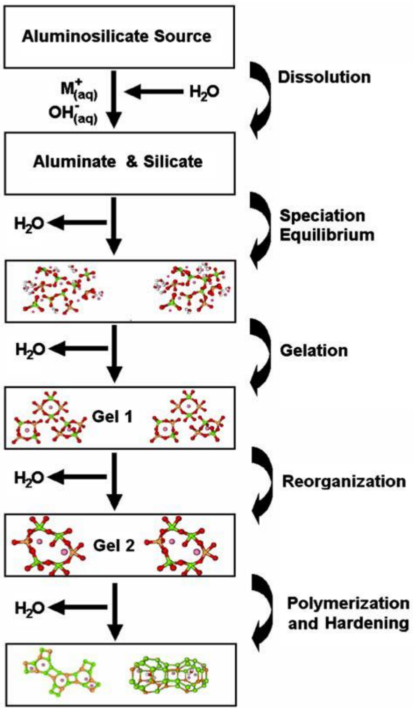

Fig 1 Polymerisation Reaction

Sodium Hydroxide: Generally sodium hydroxides are available in solid state by means of pellets and flakes. The cost of the sodium hydroxide is mainly varied according to the purity of the substance. For an economical geopolymer concrete , it is recommended to use the lowest cost possible i.e. up to 94% to 96% purity.

In this investigation the sodium hydroxide pellets of 16 molar concentrations were used, whose physical property and chemical property are shown in Table 3and 4.

Table III - Physical Properties Sodium hydroxide

Specific Gravity	
Colour	**Colour less**
20%	1.22
30%	1.33
40%	1.43
50%	1.53

Table IV - Chemical Properties Sodium Hydroxide

Assay	97%	Min
Carbonate(Na_2CO_3)	2%	Max
Chloride (Cl)	0.01%	Max
Sulphate (SO_2)	0.05%	Max
Lead (Pb)	0.001%	Max
Iron (Fe)	0.001%	Max
Potassium (K)	0.1%	Max
Zink (Zn)	0.02%	Max

Sodium Silicate: Sodium silicate also known as water glass or liquid glass, available in liquid (gel) form. In present investigation sodium silicate 2.0 is used. The chemical properties and the physical properties of the silicates are given the manufacturer is shown in Table 5.

Table V - Physical and Chemical Properties Sodium Silicate

Chemical Formula	Na_2O x SiO_2 (Colour less)
Na_2O	15.9%
SiO_2	31.4%
H_2O	52.7%
Appearance	Liquid (Gel)
Colour	Light Yellow Liquid (gel)
Boiling Point	102 C for 40% aqueous solution
Molecular Weight	184.04
Specific Gravity	1.6

Geopolymer mortar is a mixture of flyash, sand and fluid (sodium hydroxide, sodium silicate and water). Flyash in its original form cannot function as binder rather it can be used just as filler material in cement mortar as a replacement of cement. Hence to activate flyash a strong alkali solution of sodium hydroxide and sodium silicate is used. The activated flyash which is rich in silica and aluminium can function as a binder like OPC.

V. Mix Proportion:

The geopolymer mortar is prepared in F/B ratio of 0.416 with flyash: sand ratio as 1:2. The molar concentration of NaOH is 16M. Ratio of NaOH: Na_2SiO_3 is taken as 2.5.

Preparation of Liquids:

The sodium hydroxide (NaOH) solids were dissolved in water to make the solution. The mass of NaOH solids in a solution varied depending on the concentration of the solution expressed in terms of molar, M. For instance, NaOH solution with a concentration of 16M consisted of 16x40 = 640 grams of NaOH solids (in flake or pellet form) per litre of the solution, where 40 is the molecular weight of NaOH. The mass of NaOH solids was measured as 444 grams per kg of NaOH solution of 16M concentration. Similarly, the mass of NaOH solids per kg of the solution for 14M concentration was measured as 404 grams. The sodium silicate solution and the sodium hydroxide solution were mixed together at least one day prior to use to prepare the alkaline liquid. On the day of casting of the specimens, the alkaline liquid was mixed together with the super plasticizer and the extra water (if any) to prepare the liquid component of the mixture.

Preparation of Mortar:

The fly ash and the fine sand were first mixed together in for about 3 minutes. The liquid component of the mixture was then added to the dry material sand the mixing continued for further about 4 minutes to manufacture the fresh mortar. The fresh mortar was cast into the moulds immediately after mixing and compacted by vibrating the moulds for 20 seconds on a vibrating table. Cubes and cylinders were cast for study of compressive strength and split tensile strength respectively.

VI. Curing:

Curing for the specimens adopted is of two types.

i. *Ambient curing*

In ambient curing the specimens are cured in ambient conditions i.e. at room temperature in laboratory conditions.

ii. *Heat curing*

There are two types of heat curing viz. are steam curing and dry curing. Dry curing was adopted. In heat curing the specimens are heat cured at 60^0C for 24hrs in laboratory oven and then left in ambient conditions.

Mortar cubes of 5 x 5x 5cm and 5 cm diameter with 10 cm height cylinders were cast with a ratio of fly ash to sand (1:2). After casting the specimen were cured by ambient as well as heat curing. The compressive and tensile strength test was performed at 7, 14 & 28 days.

VII. Strength Tests:

Compressive Strength Test

Compressive strength test is a mechanical test measuring the maximum amount of compressive load a material can bear before fracturing. Due to compression load, the cube or cylinder undergoes lateral expansion owing to poisons ratio effect.

$$CompressiveStrength = \frac{Maximum\ load}{C/S\ Area\ of\ the\ cube} N/mm$$

Splitting Tensile Test

The splitting test is simple to perform and gives more uniform results than other tension tests. Strength determined in the splitting test is believed to be closer to the true tensile strength. Splitting strength gives about 5 -12% higher value than the direct tensile strength.

$$\text{Split Tensile Strength} = \frac{2P}{\pi LD}$$

where

P = Compressive Load in kN

L =Length in mm, D=Diameter in mm

VIII. Results and Discussions:

The variation of load and compressive strength for heat and ambient cured samples at 7, 14 and 28 days respectively are shown in Table 6 and 7.

Table VI - Load at Failure for Compressive Strength

	Load at Failure (kN)					
	Ambient curing			Heat curing		
Days of curing	7	14	28	7	14	28
Cube (5cm x 5cm x 5cm)	52	63	100	75	88	140

Table VII - Compressive Strength for Ferro-Geopolymer Mortar

	Compressive strength (MPa)					
	Ambient curing			Heat curing		
Days of curing	7	14	28	7	14	28
Cube (5cm x 5cm x 5cm	20.8	25.2	37	30	35	56

The variation of split tensile strength for heat and ambient cured samples at 7, 14 and 28 days respectively are shown in Table 8 and 9.

Table VIII - Split Tensile Load at Failure

	Load at Failure (kN)					
	Ambient curing			Heat curing		
Days of curing	7	14	28	7	14	28
Cylinder (5cm diameter and 10 cm height)	13	16	25	19	22	35

Table IX - Split Tensile Strength for Ferro-Geopolymer Mortar

	Split tensile strength (MPa)					
	Ambient curing			Heat curing		
Days of curing	7	14	28	7	14	28
Cylinder (5cm diameter and 10 cm height)	1.7	2.1	3.2	2.4	2.8	4.5

For a constant F/B ratio of 0.416 the compressive strength and split tensile strength variation of heat and ambient cured specimen for different fiber dosage at 7, 14 and 28 days were arrived. Heat curing was found to be more effective as the 28 days strength developed was 30% more that of ambient cured specimens.

IX. Conclusion:

i. Geo-polymerization is a slow process, so the initial strength gain in ambient condition is very less.

ii. Heat cured specimen showed improved result than ambient cured, the possible reason for this may be that the geo-polymerization process takes place at higher rate in heat cured specimen.

X. Scope for Future Work

i. Durability of Ferro-geopolymer mortar.
ii. Study on setting time of Ferro-geopolymer mortar.

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