LONG - TERM STRENGTH OF GEOPOLYMER CONCRETE

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ABSTRACT

The production of Ordinary Portland Cement causes atmospheric pollution due to the emission of CO_2. An alternative material is tried to replace OPC in the concrete. Low calcium Fly ash, a by-product from the coal industry, which is widely available in the world contains silicate and alumina. Fly ash with alkaline solution produces alumina silicate gel that binds the aggregate to produce a good concrete called Geopolymer concrete. The compressive strength increases with the increase of fly ash fineness and thus the reduction in porosity can be obtained. The nominal mix required for M 20 grade is tried in this study. The Geopolymer concrete cubes of size 100×100×100 mm were casted and tested. The long term compressive strength of Geopolymer concrete was obtained. The Geopolymer concrete exhibits higher compressive strength with respect to age.

Keywords: Fly ash, Alkaline solution, Alumina silicate, Compressive strength.

I. INTRODUCTION

Concrete is widely used as a construction material. Portland cement is the main component of making concrete. The cement industry emits more CO_2 the production of one ton Portland cement releases approximately one ton of CO_2 to the atmosphere (Davidovits, J 1994, Malhotra VM 1999). Many efforts in taken were order to reduce Portland cement in concrete by means of finding alternative cementing materials such as fly ash, silica fume, ground granulated blast furnace slag, rise husk ash and metakaolin (Davidovits, J 1998) proposed an alkaline liquid that could be used to react with the silicon (Si) and aluminium (Al) to produce binders. Because the chemical reaction that takes place is a polymerization process, Davidovits coined the term "Geopolymer" to represent these binders. The Geopolymer technology shows considerable promise for application in concrete industry as an alternative binder to the Portland cement (Duxson, 2007).

II. GEOPOLYMER CONCRETE

The main constituents of geopolymers are the source materials and the alkaline liquids Patankar SV et al (2013). The source materials for geopolymers are rich in silicon and aluminium. By product materials such as fly ash, silica fume, slag, rice husk ash, red mud, can be used as source material. The alkaline liquids are formed from soluble alkali metals that are sodium or potassium based. The combination of sodium hydroxide with sodium silicate is used on alkaline liquids since it is cheap when compared to potassium. The type of alkaline liquids used as acts significant factor which affect the mechanical strength and the combination of sodium silicate and sodium hydroxide. It also affects the highest compressive strength.

III. RESEARCH METHODOLOGY

3.1 Fly ash

Low-calcium (Class F) fly ash obtained from the Mettur Thermal Power Station, (Tamil Nadu) is used.

3.2 Aggregates

Coarse and fine aggregates are used by the concrete industry to manufacture geopolymer concrete. The aggregate grading curves currently used in concrete practice are applicable in the case of geopolymer concrete (Hardjito and Rangan, 2005). The properties of aggregate used are listed below:

Specific gravity of fine aggregate and coarse aggregate used are 2.65 & 2.72 respectively.

Fineness modulus of fine aggregate and coarse aggregate used are 2.41 & 7.22 respectively.

3.3 Alkaline liquid

It is recommended that the alkaline liquid is prepared by mixing sodium silicate and sodium hydroxide solutions allowing the mix to remain undisturbed for a minimum period of 24 hours for the reaction of polymerization to take place (Wallah and Rangan, 2006). The sodium silicate solution is commercially available in different grades. The sodium silicate solution (Na_2SiO_3) with Sodium Hydroxide (NaOH) ratio by mass of 2.5 is used. The sodium hydroxide with 97 - 98% purity in pellet form is commercially available. The solids dissolved in water to make a solution of required concentration of 8 M. Since the molecular weight of Sodium Hydroxide is 40 and in order to prepare 8 molar solution, sodium Hydroxide is dissolved in 1000 ml of water. The mass of NaOH solids in a solution varies depending on the concentration of the solution. The materials as shown in Figure 1, required the preparation of geopolymer concrete.

3.4 GPC Concrete

The minimum strength of concrete to be used for construction is M 20 grade as per I.S: 456- 2000. Hence the nominal mix required for M 20 grade 1:1.5:3.0 is tried in this study(Kumaravel, 2014). The same ratio of mix is tried in the geopolymer concrete also. The constituents of Geopolymer concrete of 8 Molarity Sodium Hydroxide for M 20 grade concrete shown in Table 1.

Table 1 Constituents of Geopolymer Concrete

DESCRIPTION	QUANTITY
Flyash	436 kg / m^3
Na_2SiO_3 / NaOH	2.5
(Na_2SiO_3 + NaOH) / Flyash	0.45
NaOH Solid	17.94 kg / m^3
WATER (Added With NaOH Solid)	38.12 kg / m^3
Na_2SiO_3 Solution	140.14 kg / m^3
Coarse Aggregate	1308 kg / m^3
Fine Aggregate	654 kg / m^3
24 Hours (Steam) Curing	60° C

3.5 Mixing, Casting and Curing

The geopolymer concrete can be manufactured by adopting the conventional techniques used in the manufacture of Portland cement concrete. In the laboratory, the fly ash and the fine aggregates are first dry mixed in 50-litre capacity pan mixer (Figure 2) for about three minutes. The course aggregates are prepared in Saturated-Surface-Dry (SSD) condition. The alkaline liquid and the liquid component of the mixture added to the dry materials and the mixing continued usually for another four minutes. The fresh concrete could be handled up to 120 minutes without any sign of setting and without any degradation in the compressive strength.

The geopolymer concrete is used to cast cubes of size 100x100x100mm to determine its compressive strength. It is observed that a geopolymer concrete stick hard to the mould so oiling the moulds is very important to release each cube specimen. While casting, add in three layers within the mould and compact it manually. Each layer received 25 strokes of compaction by standard compaction rod for concrete. Fresh fly ash-based geopolymer concrete is usually cohesive. The workability of fresh concrete is measured by means of the conventional slump test. The slump measured is 130mm (Figure 3).

After casting the specimens (Figure 4), they are kept for 1 day in rest period at room temperature. The term 'Rest Period' is coined to indicate the time taken from the completion of casting of test specimen to the start of curing at an elevated temperature. After casting, the specimens are covered using vacuum bagging film. A steam boiler is used to generate the steam, (Kumaravel et al., 2013) at a specified temperature of 60º C (Figure 5). The curing at 60º C was done in the steam convert by the channel in steam curing chamber for 24 hours (Figure 6). The geopolymerconcrete is de-moulded and then placed in an autoclave for steam curing in 24 hours at a temperature of 60ºC.

Figure 1 Materials for GPC

Figure 2 Pan Mixer

Figure 3 Slump Test

Figure 4 Casting of Specimens

Figure 5 Steam Boilar

Figure 6 Steam Curing Chamber

IV. RESULTS AND DISCUSSION

4.1 Compressive Strength of GPC

The compressive strength testing machine - 1000 kN capacity is used to apply the axial force of compression. The 7 and 28 days compressive strength of geopolymer concrete cubes are given in Table 2 and shown in Figure 7. The steam cured geopolymer concrete cubes are kept in room temperature for three years. These cubes are tested at 90, 180, 365, 730, and 1095 days. The compressive strength of cube are given Table 3 and shown in Figure 8.

Table 2 Compressive Strength of GPC in 7 and 28 days

Type of Specimen	Weight (g)	7 Days Strength (N/mm^2)	7 Days Average Strength (N/mm^2)	28 Days Strength (N/mm^2)	28 Days Average Strength (N/mm^2)
Cube 1	2335	22.30		28.80	
Cube 2	2329	21.60		27.30	
Cube 3	2343	22.40	**22.37**	28.20	**27.85**
Cube 4	2338	22.65		27.10	
Cube 5	2327	22.90		27.85	

Table 3 Compressive Strength of Geopolymer Concrete at Deferent Days

Type of Specimen	Compressive Strength of Geopolymer Concrete (N/mm^2)				
	90 Days	180 Days	365 Days	730 Days	1095 Days
Cube -1	29.60	32.40	34.30	36.50	38.40
Cube -2	29.40	31.70	33.85	35.80	37.90
Cube -3	30.10	33.10	34.60	36.30	38.80
Average Strength	**29.70**	**32.40**	**34.25**	**36.20**	**38.37**

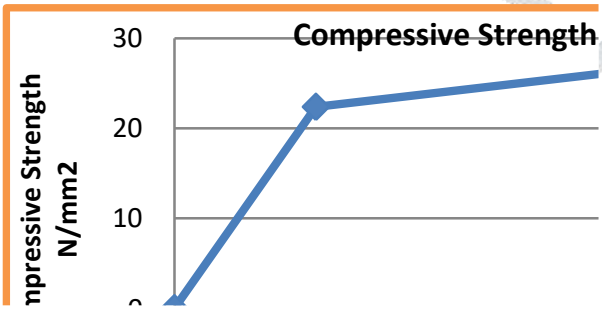

Figure 7 Compressive Strength of GPC

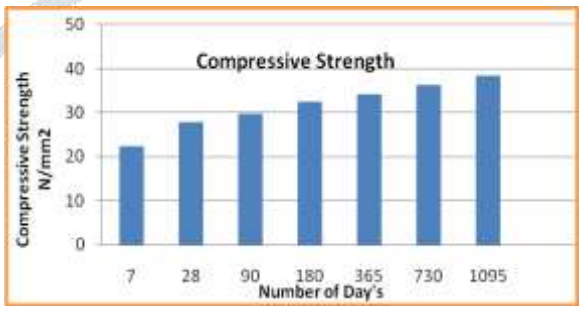

Figure 8 Compressive Strength in GPC in Different Days

Geopolymer concrete of nominal mix ratio of 1:1.5:3.0 (M 20) is used with alkaline solution and the compressive strength of concrete is obtained. The density of geopolymer concrete is found as 2350 kg/m^3 which is less to that of cement concrete. The 7 days and 28 days average compressive strength of geopolymer concrete cubes gives 22.37 N/mm^2 and 27.85 N/mm^2 respectively. The average compressive strength of geopolymer concrete cubes at 90, 180, 365, 730 and 1095 days obtained as 29.70, 32.40, 34.25, 36.20 and 38.37 N/mm^2 respectively. The rate of increase in strength is found to be 23%, 31%, and 40%, at 1, 2 and 3 years with respect to 28 days compressive strength. These results obtained in geopolymer concrete are suited for structural applications with a minimum concrete strength of 20 MPa.

V. CONCLUSIONS

1. The steam cured geopolymer concrete of nominal strength 28 days result of 27.85 N/mm^2 is developed.

2. The steam cured low-calcium fly ash-based geopolymer concrete offers higher strength of 23%, 31%, and 40%, at 1, 2 and 3 years respectively, when it is kept in room temperature.

3. The Geopolymer concrete possesses good compressive strength and well-suited in the manufacture of precast concrete products.

4. It is evident from the obtained results that the geopolymer concrete is encouraging. It can be increased by properly selecting the influencing parameters such as to make a concrete for different days. Low calcium fly ash-based Geopolymer concrete has excellent compressive strength and is suitable for structural applications.

REFERENCES

[1] Davidovits J. (1994) "High -Alkali Cements for 21st Century Concretes in Concrete Technology, Past, Present and Future", Proceedings of V.Mohan Malotra Symposium, Editor: P.Kumar Metha, ACIP-144, 383-397.
[2] Malhotra VM (1999) Making concrete greener with fly ash. ACI Conc. Int. 21(5): 61 – 66.
[3] Davidovits J. (1998) "Soft mineralogy and Geopolymers". In proceeding of Geopolymer 88 International conference, the Universite de Technologie, Compiegne, France.
[4] Duxson P, Provis J L, Lukey G C and van Deventer J S J (2007), " The role of inorganic polymer technology in the development of green concrete", Cement and Concrete Research, 37 (12), 1590-1597.
[5] Hardjito. D and Rangan B.V, (2005),"Development and properties of low calcium fly ash based geopolymer concrete", Research Report GC1, Curtin University of Technology, Perth, Australia.
[6] Wallah S.E and Rangan B.V, (2006), "Low calcium fly ash based geopolymer concrete: long term properties", Research Report GC2, Curtin University of Technology, Perth, Australia.
[7] IS 456-2000 Plain and reinforces concrete-code of practice (forth revision). Bureau of Indian Standards, New Delhi.
[8] Kumaravel S (2014), Development of various curing effect of nominal strength Geopolymer concrete, Journal of Engineering Science and Technology, 7 (1), 116 – 119.
[9] Patankar SV, Jamkar SS, Ghugal YM (2013) Effect of water-to-geopolymer binder ratio on the production of fly ash based geopolymer concrete. Int. J Adv Technol Civil Engg. 2(1):79–83.
[10] Kumaravel S and S.Thirugnanasambandam, (2013), Flexural behaviour of geopolymer concrete beams, International Journal of Advanced Engineering Research and Studies, 3(1), 04 - 06.