

Experimental Investigation and Strength Characteristics of Low Calcium Fly Ash Based Geopolymer Concrete (GPC)



Engineering

KEYWORDS : Geopolymer, Fly ash ,Alkaline Solutions, Steam Curing, Polymerization, Sodium Hydroxide, Sodium silicate

R.SUBHAJA

Assistant professor, E.S.Engineering College, Villupuram. Department of Civil Engineering

ABSTRACT

Carbon-di-Oxide emission from Cement production is the second most pollution next to automobile industry which pollutes the atmosphere. Concrete is the second most used material next to water. Hence, it is inevitable to find an alternative material to the existing most expensive, most resource consuming Portland Cement. Global warming, is one of the greatest environmental issues and has become a major concern during the last decade. The global warming is caused by the emission of greenhouse gases such as CO₂, Methane, Chlorofluorocarbon (CFC) etc. Geopolymer concrete is a 'new' material that does not need the utilization of Portland cement as a binder. Instead, activating the source materials such as fly ash that are rich in Silicon (Si) and Aluminum (Al) using high alkaline liquids produces the binder required to manufacture the concrete. Hence, Greener concrete can be achieved. Aggregate ratio have been varied with six mix ratios and 14 M molarity of alkaline solution is used. In this study the strength of Geopolymer Concrete trial mixes are compared and this paper depicts about fly ash-based geopolymer concrete, aqueous solutions used mixture proportions, the manufacturing process, and the strength parameters etc.

1.0 INTRODUCTION

In GPC, Low-calcium (ASTM Class F) fly ash-based geopolymer is used as the binder, instead of Portland or other hydraulic cement paste, to produce concrete. The fly ash-based geopolymer paste binds the loose coarse aggregates, fine aggregates and other un-reacted materials together to form the geopolymer concrete. Geopolymer concrete can be manufactured by using the low-calcium (Class F) fly ash obtained from coal-burning power stations. Most of the fly ash available globally is low-calcium fly ash formed as a by-product of burning anthracite or bituminous coal. The annual generations of fly ash has increased from about 1 million tonne in 1947 to 112 1 million tonne in 2005, and is expected to reach 225 1 million tonne in 2027. Although coal burning power plants are considered to be environmentally unfriendly. Fly ash, which is rich in silica and alumina reacts with alkaline solution during hydration process and forms alumina - silicate gel. As far as possible, the technology and the equipment currently used to manufacture ordinary Portland cement concrete were used to make the geopolymer concrete.

2.0 GEOPOLYMER

Geopolymer concrete is a type of amorphous alumino-silicate cementitious material. Davidovits (1988) proposed that an alkaline liquid could be used to react with the silicon (Si) and the aluminum (Al) in a source material of geological origin. Because the chemical reaction that takes place in this case is a polymerization process.

Water is released during the chemical reaction that occurs in the formation of geopolymers. This water is expelled from the geopolymer matrix during the curing and further drying periods. The water in a geopolymer mixture, therefore, plays no role in the chemical reaction that takes place; it merely provides the workability to the mixture during handling. For the current study the combination of sodium hydroxide (NaOH) and sodium silicate is used.

2.1 ALKALINE LIQUIDS

The flakes of sodium hydroxide solution is prepared by dissolving it in water. The alkaline liquid is prepared by mixing both the solutions together at least 24 hours prior to use. The concentration of sodium hydroxide solution used is 12 Molar. The mass of NaOH solids was measured as 480 grams per kg of NaOH solution with a concentration of 1.

3.0 TRAIL MIX DESIGN

Trial mix design procedure is done to cast the specimens by varying the aggregate ratio from 70% to 78 % with molarity 14. There is no particular mix design procedure for GPC. Based on Code

Book reverse mix design is done and quantities are calculated.

Sl No	Materials	Mix A 70%	Mix-B 72%	Mix C 74%	Mix D 76%	Mix-E 78%	Mix-E 78%
1.	CA	1176	1209.6	1243.2	1276.8	1310.4	1344
2.	FA	504	518.4	532.8	547.2	561.6	576
3.	Fly ash	533.3	497.7	462.2	426.6	391.1	355.5
4.	Na ₂ SiO ₃	133.28	124.42	115.47	106.72	97.68	88.84
5.	NaOH	53.31	49.7	46.2	42.68	39.11	35.5

Table 1. Mix design Procedure

3.1 Trail Mix design Procedure for Trial mix -B

Unit weight of concrete = 2400 kg/m³

Mass of combined aggregate = 72%

Mass of concrete = 0.72 X 2400

$$= 1728 \text{ kg/m}^3$$

10 mm coarse aggregate - 70%

$$= 70/100 \times 1728$$

$$= 1209.6 \text{ kg/m}^3$$

4.75 mm fine sand - 30%

$$= 30/100 \times 1728$$

$$= 518.4 \text{ kg/m}^3$$

Mass of low calcium fly ash

and alkaline liquid

$$= 2400 - 1728$$

$$= 672 \text{ kg/m}^3$$

Take liquid-To-Fly ash ratio = 0.35

$$\text{Mass of fly ash} = 672 / (1+0.35) = 497.7 \text{ kg/m}^3$$

$$\begin{aligned} \text{Mass of alkaline liquid} &= 672 - 497.7 \\ &= 174.2 \text{ kg/m}^3 \end{aligned}$$

Take sodium silicate-to-sodium hydroxide ratio = 2.5

$$\begin{aligned} \text{Mass of sodium hydroxide solution} &= 174.2 / (1+2.5) \\ &= 49.7 \text{ kg/m}^3 \end{aligned}$$

$$\begin{aligned} \text{Mass of sodium silicate solution} &= 174.2 - 49.7 \\ &= 124.42 \text{ kg/m}^3 \end{aligned}$$

4. EXPERIMENTAL PROGRAMME

4.1 Mixing

The fly ash and the aggregates were first mixed together dry for about three minutes. The aim of this action was to ease the promotion of this 'new' material to the concrete. The liquid component of the mixture was then added to the dry materials and the mixing continued usually for another four minutes. Sodium hydroxide solution and sodium silicate solution is mixed together at least one day prior to adding the liquid to the dry materials .

4.2 Casting:

The geopolymer concrete are cured at 60°C in oven for 24 hrs. After the cubes, cylinders, prisms are taken out from oven, the following tests are conducted.



Figure 1.Specimens in Hot Curing Chamber

5.0 RESULT AND DISCUSSIONS

5.1 COMPRESSIVE STRENGTH TEST

The compressive strength tests were conducted in cube size 150 mm x 150 mm 150 mm. The specimens were cured at temperature 60°C for 24 hours and tested at 7, 14 and 28 days.

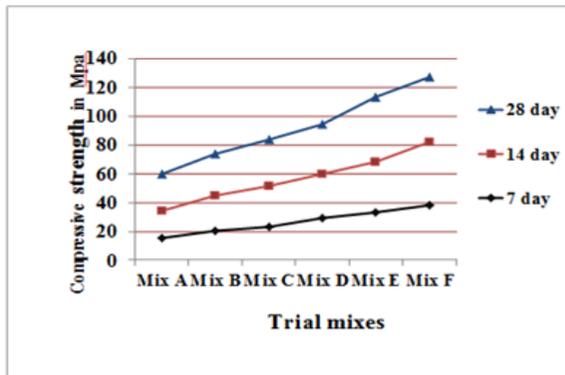


Figure 2.Compressive Strength results of 14M

5.2 SPLIT TENSILE STRENGTH TEST

The Split Tensile strength tests were conducted accordingly with cylinder size 150 mm x 300 mm. The load is applied till the failure of the cylinder specimens. The split tensile strength concrete is determined at the age of 7,14 and 28days

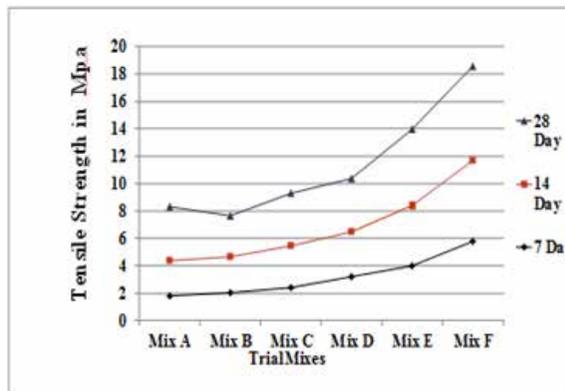


Figure 3.Split Tensile Strength results of 14M

5.3 FLEXURAL STRENGTH TEST

The Flexural strength of concrete is determined at the day of 7,14 & 28. The test was carried out on 100 mm x100 mm x 200 mm size of prisms. The load was applied till the failure of the prism specimens. UTM is used to determine the flexural rigidity of flexural member.

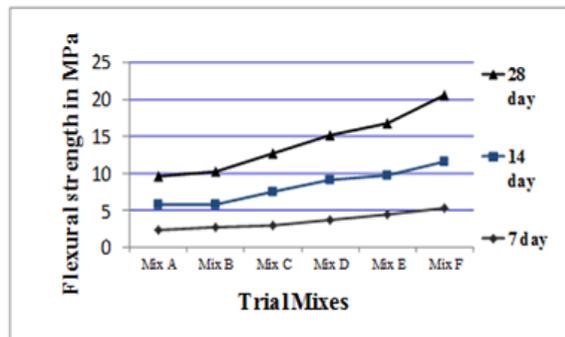


Figure 4.Flexural Strength results of 14M

5.4 DURABILITY TEST

Durability of concrete is the ability of concrete to resist weathering action, chemical attack, and abrasion while maintaining its desired engineering properties. Deterioration of concrete due to acid attack in aggressive environment are one of the main factors . The cubes were cast at the size of 150x150x150 mm and

tested according to IS 445:2000

5.4.1 Hydrochloric acid Resistance Test

HCL attack is important among durability test because it causes corrosion of reinforcement. The BIS specifies that the allowable chloride content in cement to be 0.1%. After 28 days of curing the cubes were immersed in a 5% concentric Hydrochloric acid (HCL) and tested after 14, 28, 56 and 90th days. weight measurement and the compressive strength of cubes and calculation of durability factors were completed. The Hydrochloric acid test results are disclosed below in table 2

Average weight reduction in % due to HCL acid				
Day	14	28	56	90
GPC	0.38	0.46	0.59	0.68

Table 2. Durability test result of HCL acid

5.4.2. Sulphuric Acid Resistance Test

The specimens are immersed in 3% solution of sulphuric acid after curing of 28 days. Test is carried out at regular intervals after 14 days for a period of 90 days. After 90th day specimens are taken from solutions and cleaned to remove loose material from the surface. Then it is allowed to dry and measurements are taken. Then the loss or gain of the weight are studied. The sulphuric acid resistance test results are disclosed below in table 3

Average weight reduction in % due to H ₂ SO ₄ acid				
Day	14	28	56	90
GPC	0.99	1.27	1.38	1.41

Table 3. Durability test result of H₂SO₄ acid

6. DISCUSSION

v The fresh fly ash-based geopolymer concrete is easily handled up to 120 minutes without any sign of setting and without any degradation in the compressive strength.

v As the H₂O-to-Na₂O molar ratio increases, when the compressive strength decreases.

v As the ratio of water-to-geopolymer solids by mass increases, the compressive strength of fly ash-based geopolymer concrete decreases.

v The mass reduction of GPC block due to sulphuric acid resistance at the end of 90 days is found to be 0.68%.

v The mass reduction of GPC block due to hydrochloric acid resistance at the end of 90 days is found to be 1.41%.

7. CONCLUSION

The study has proved that the Replacement of Cement with hundred percent of Fly Ash content shows that the 7th day strength of ambient-cured specimens depends on the average ambient temperature during the first week after casting higher the average ambient temperature higher is the strength. Split Tensile Strength of GPC increases over controlled concrete by 1.45 times. Flexural Strength of GPC increases over controlled concrete by 1.6 times. Fly ash-based Geopolymer concrete cured in the laboratory ambient conditions gains compressive strength with age. Effective use of Fly Ash can reduce pollution, energy consumption and saves the Environment. The Main drawback is need of steam curing, Cost of aqueous solutions. Hence GPC can be mentioned as "Greener Concrete" with sustainability to save our Earth

REFERENCE

- Benny Joseph and George mathew, "Influence of aggregate content on the behavior of fly ash based geopolymer concrete", Scientia Iranica, Transactions A: Civil Engineering, 2012. | 2. Davidovits J., "Geopolymers: inorganic polymeric new materials", Journal of thermal analysis
- Iranica, Transactions A: Civil Engineering, 2012. | 3. Davidovits, J. (1994) "High-Alkali Cements for 21st Century Concretes. In concrete Technology, Past, Present and Future", Proceedings of V. Mohan Malhotra Symposium, Editor: P. Kumar Metha, ACI SP- 144, 383-397. | 4. Hardjito, D. and Rangan, B. V. (2005) Development and Properties of Low-Calcium Fly Ash-based Geopolymer Concrete, Research Report GCI, Faculty of Engineering, Curtin University of Technology, Perth, available at espace@curtin. | 5. Hardjito, S E Wallah D M J Sumajouw, B.V. Rangan, "Introducing fly ash-based geopolymer concrete: Manufacture and engineering properties", 30th Conference on our world in concrete & structures: 23 - 24 August 2005, Singapore | 6. Kiatsuda Somna, Chai Jaturapitakkul, Puangrat Kajitvichyanukul, Prinya Chindaprasit "NaOH-activated ground fly ash geopolymer cured at ambient temperature", Fuel 90 (2011) 2118-2124. | 7. M. I. Abdul Aleem I, P. D. Arumairaj, "geopolymer concrete- a review", IJESIT International Journal of Engineering Sciences & Emerging Technologies, 2012, Volume 1 (1), pp: 118-122. | 8. Mohd Mustafa Al Bakri, H. Mohammed, H. Kamarudin, I. Khairul Niza and Y. Zarina " Review on fly ash-based geopolymer concrete without Portland Cement", Journal of Engineering and Technology Research Vol. 3(1) pp. 1-4, 2011 | 9. Prof.M.A.Bhosale, Prof.N.N.Shinde " Geopolymer Concrete by Using Fly Ash in Construction" IOSR Journal of Mechanical and Civil Engineering, Vol 1, 2012, PP 25-30. | 10. Ramachandra murthy D.S. " Flyash based Geopolymer Concrete bricks for Building construction" Journal of Indian Concrete institute, Vol 15, No.3, Page 29-33, 2014. | 11. Ramachandra murthy D.S. and Parbeen .P., "Studies on Geopolymer Concrete", Sixth Structural Engineering Convention, Chennai, Dec 18-20, 2008. | 12. Rangan B.V. Sumajouw D., Wallah W., Hardjito D., " Heat Cured Low Calcium Fly ash based Reinforced Geopolymer Concrete Beams and Columns", 5th Asian symposium on Polymers in Concrete, Chennai, 2006, 79-85 | 13. Rajiwala D.B., H S Patil, I U Kundan, " Effect of alkaline activator on the strength and durability of geopolymer concrete", "Journal of Engineering Research and Studies. | 14. Sathia R, Babu KG, Santhanam M." Durability study of low calcium fly ash geopolymer concrete". The 3rd ACF International Conference -ACF/VCA, 2008. | 15. Siva Konda Reddy B, J. Varaprasad and K.Naveen Kumar Reddy, "Strength and workability of low lime fly-ash based GPC" Indian Journal of Science and Technology, Vol. 3 No. 12 2010. |