Evaluating Structural Performance and Mix Optimization in Geopolymer Concrete

Dr N V N PRABATH[1], A SAITHEJA[2], G MADHULATHA[3], A ALEKHYA[4] , E DEEPIKA[5]
[1]Associate Professor, Department of Civil Engineering, AnuBose Institute of Technology, KSP Road, New Paloncha, Bhadradri Kothagudem District, Telangana (TS), 507115
[2,3,4,5]Assistant Professor, Department of Civil Engineering, AnuBose Institute of Technology, KSP Road, New Paloncha, Bhadradri Kothagudem District, Telangana (TS), 507115

Abstract
Concrete is among the most widely consumed materials worldwide. As global attention to environmental issues—including climate change, sustainable development, and recycling—increases, researchers are exploring alternatives to conventional concrete, including geopolymer concrete. This material replaces the cement-based binder with an alternative that contains no Portland cement. One type of geopolymer binder uses fly ash activated by an alkaline solution of sodium silicate and sodium hydroxide.This study evaluates the workability, compressive strength, and split tensile strength of geopolymer concrete at alkaline liquid-to-fly ash ratios of 0.35, 0.40, and 0.45. Strength is measured after curing for 7 and 28 days.

Key words: geo polymer concrete, workability, strength, alkaline liquid to fly ash ratios

This is an open access article under the creative commons license https://creativecommons.org/licenses/by-nc-nd/4.0/
CC BY-NC-ND 4.0

I. INTRODUCTION

Now a day's concrete plays a major role in the human life. It has become in such a Way that the usage of concrete became second only to water around the world. In the last two decades environmental issues in the concrete industry have been paid a lot of attention, aiming at reducing the total environmental impact of concrete structures to a minimum, without compromising on their performance. A lot of different tools have been developed in order to reduce the environmental impact of concrete.

Ordinary Portland cement (OPC) is the primary binding material used in the preparation of concrete. As we know cement is the backbone for global infrastructural development. It was estimated that 7% of the world's carbon dioxide is attributable to Portland cement industry. Because of the significant contribution to the environmental pollution & to the high consumption of natural resources like limestone etc., we can't go producing more and more cement.

Amount of the carbon dioxide released during the manufacture of OPC due to the calcination of limestone and combustion of fossil fuel is in the order of one ton for every ton of OPC produced. In addition, the extent of energy required to produce OPC is only next to steel and aluminium. To solve this problems the geo polymer concrete is one of the advanced method for alternative of cement

1.1Low-calcium fly ash-based geopolymer concrete

In this work, 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 aggregate sand other un-reacted materials together to form the geopolymer concrete, with or without the presence of admixtures. The manufacture of geopolymer concrete is carried out using the usual concrete technology methods.

As in the case of OPC concrete, the aggregates occupy about 75-80 % by mass, in geopolymer concrete. The silicon and the aluminium in the low-calcium (ASTM Class F) fly ash react with an alkaline liquid that is a combination of sodium silicate and sodium hydroxide solutions to form the geopolymer paste that binds the aggregates and other un-reacted materials.

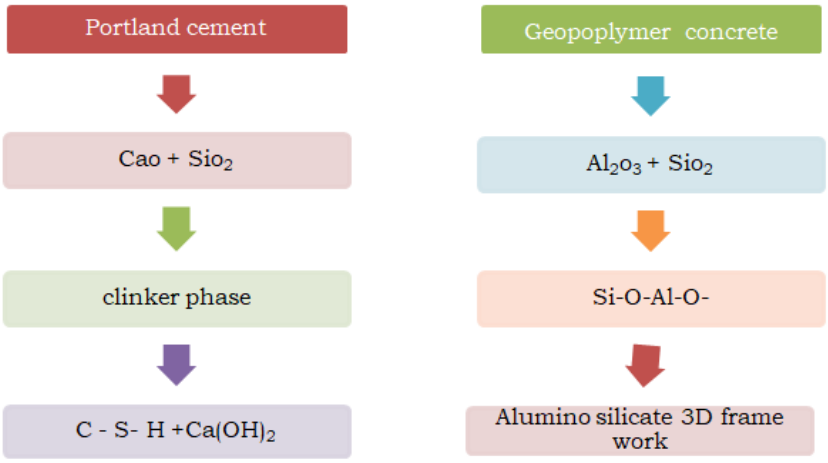


Figure 1: Comparison of OPC and GPC concrete

1.2 Aim of the study

The aims of this study were:

1. To develop a mixture proportion to manufacture low-calcium fly ash-based geopolymer concrete.
2. To identify and study the effect of replacing fly ash with other supplementary cementatious materials like G.G.B.S and metakaolin that affects the properties of low-calcium fly ash-based geopolymer concrete.
3. To study the compressive strength hardened low-calcium fly ash-based geopolymer concrete.
4. To study the tensile strength hardened low-calcium fly ash-based geopolymer concrete. In this project we have utilized low-calcium (ASTM Class F) fly ash as the base material for making geopolymer concrete

II. LITERATURE SURVEY

***Palomo* (1999)** concluded that the type of alkaline liquid plays an important role in the polymerisation process. Reactions occur at a high rate when the alkaline liquid contains soluble silicate, either sodium or potassium silicate, compared to the use of only alkaline hydroxides.

***Xu and van Deventer* (2000)** confirmed that the addition of sodium silicate solution to the sodium hydroxide solution as the alkaline liquid enhanced the reaction between the source material and the solution. Further more,after a study of the geopolymerisation of sixteen natural Al-Si minerals, they found that generally the NaOH solution caused a higher extent of dissolution of minerals than the KOH solution.

Xu and van Deventer (2000) reported that the proportion of alkaline solution to alumino-silicate powder by mass should be approximately 0.33 to allow the geopolymeric reactions to occur. Alkaline solutions formed a thick gel instantaneously upon mixing with the alumino-silicate powder. The specimen size in their study was 20x20x20 mm, and the maximum compressive strength achieved was 19 MPa after 72 hours of curing at 35°C with stilbite as the source material.

III. MATERIALS USED MIX RATIO

3.1 Fly ash

In the present experimental work, low calcium, Class F (American Society for Testing and Materials 2001) dry fly ash obtained from the silos of Vijayawada thermal power station (VTPS), Vijayawada, Andhra Pradesh was used as the base material.

3.2 Super plasticiser

To improve the workability of the fresh geopolymer concrete, a naphthalene sulphonate super plasticiser, supplied by national scientific Vijayawada,Andhra Pradesh. Another type of super plasticiser, a polycarboxylic ether hyperplasticiser, under thebrand name of Glenium 27, this type of super plasticiser was not used due tothe cost. Super plasticiser should be within the limit 1.5 to 2.5% of fly ash content. Exceeding this limit compressive strength of the geo polymer concrete will be decreased

3.3 Alkaline liquids

In the present study we have used a combination of sodium hydroxide (NaOH) and sodium silicate (Na_2SiO_3) solutions. The sodium hydroxide solids were either a technical grade in flakes form (3 mm), 98% purity, and obtained from National scientific company, Vijayawada, or a commercial grade in pellets form with 97% purity, obtained from National Scientific, Vijayawada.



Figure 2: Mixing of liquid

3.4 Aggregates

In the present study aggregates were obtained from the locally available. Coarse aggregates were obtained in crushed form and majority of the particles were of granite-type. The fine aggregate was obtained from the sand dunes in uncrushed form.

Three different combinations were used in the present study. They are 20mm, 12.5mm, 6.5mm aggregates were used. In total coarse aggregate

1. 6 mm aggregate consists of 50% ,
2. 12mm aggregates consists of 27.5%,
3. 20mm aggregates consists of 22.5%,

The coarse aggregates are taken in saturated surface dry condition (SSD).

3.5 Mix design for different (alkaline liquid/fly ash) ratios.

Table 1: mix ratios used

Mixture No	Alkaline liquid/fly ash	Mix proportion
1	0.35	1 : 1.01 : 1.88
2	0.4	1 : 1.20 : 2.24
3	0.45	1: 1.40 :2.60

3.6 Test to be conducted on concrete

The following are the tests to be conducted on GPC with different alkaline liquid to fly ash ratios

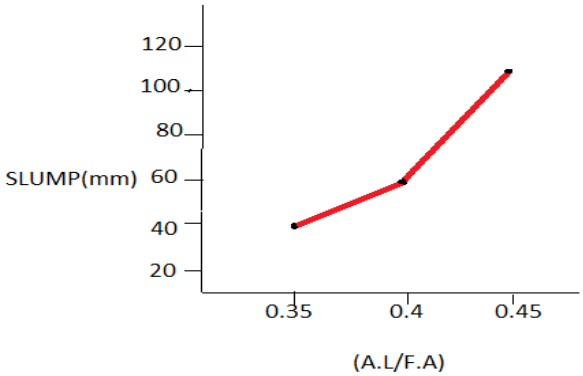
1. Slump cone test
2. Compressive strength test
3. Split tensile strength

IV RESULTS AND ANALYSIS

4.1 Slump cone test

Table 2: Slump cone test results

S.NO	Mix proportion	$\frac{Alkaline\ liquid}{fly\ ash}$	Slump(mm)
1	1:1.013:1.88	0.35	42
2	1:1.2:2.24	0.4	50
3	1:1.2:2.6	0.45	110

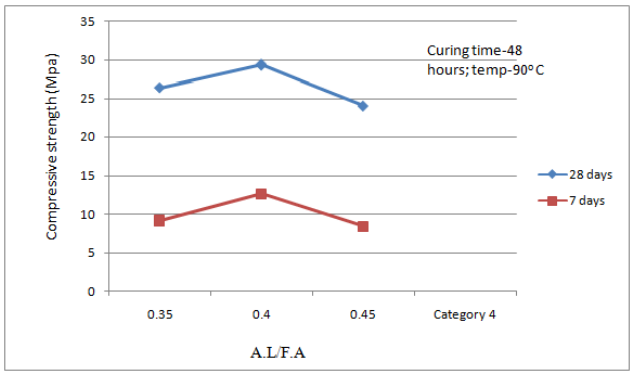


Graph 1: Comparison of slump cone test

4.2 Compressive strength

Table 3: Compressive strength test results

S. No.	Mix proportion	$\frac{A.L}{F.A}$	$\frac{sodiumhydroxide}{sodiummeta\ silicate}$	Compressive strength(Mpa)	
				7 days	28 days
1	1:1.013:1.882	0.35	1:2.5	9.5	26.45
2	1:1.20:2.24	0.4	1:2.5	12.61	29.41
3	1:1.402:2.60	0.45	1:2.5	8.4	24.08

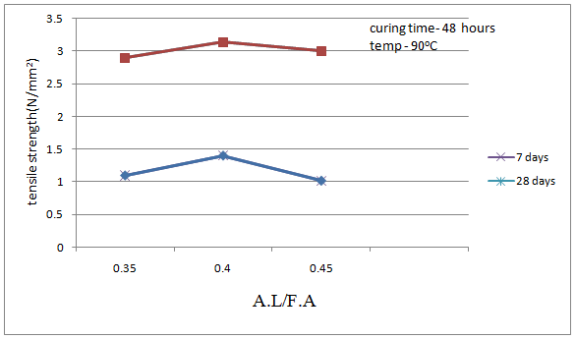


Graph 2: Comparison of compressive strength

4.3 Split Tensile strength

Table 4: Split tensile strength test results

S. No	Mix proportion	$\frac{A.L}{F.A}$	$\frac{NaoH}{Na203Si9H2O}$	Tensile strength(Mpa)	
				7 days	28 days
1	1:1.013:1.882	0.35	1:2.5	1.1	2.9
2	1:1.20:2.24	0.4	1:2.5	1.4	3.14
3	1:1.402:2.60	0.45	1:2.5	1.02	3.01



Graph 3: Comparison of split tensile strength

V CONCLUSIONS

1. From our test results we observed that $\frac{Alkalineliquid}{flyash} = 0.4$ ratio mix proportion specimens will have maximum compressive and tensile strengths.
2. Workability of geopolymer concrete increases while increase in the $\frac{Alkalineliquid}{flyash}$ ratio.
3. with our preliminary laboratory work we observed that ,rest Period of geopolymer concrete influences the strength of the concrete.
   Rest period for moulded specimens should be 2 days for better strengths.
4. Addition of super plasticiser to fresh concrete is not sufficient for increase in the workability of concrete.$\frac{Alkalineliquid}{flyash}$ ratio highly influences the workability of geopolymer concrete.

REFERENCES

[1]. ACAA (2003). Fly Ash Facts for Highway Engineers. Aurora, USA, American Coal Ash Association**:** 74.
[2]. ACI Committee 232 (2004). Use of Fly Ash in Concrete. Farmington Hills, Michigan, USA, American Concrete Institute**:** 41.
[3]. ACI Committee 363 (1992). State of the Art Report on High-Strength Concrete, American Concrete Institute, Detroit, USA.
[4]. Aitcin, P. C. and P. K. Mehta (1990). "Effect of Coarse-Aggregate Characteristics on Mechanical Properties of High-Strength Concrete." ACI Materials Journal **87**(2): 103-107.
[5]. American Society for Testing and Materials (2001). Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use as a Mineral Admixture in Concrete. Philadelphia, USA**:** 4.
[6]. Balaguru, P. (1998). Geopolymer for Protective Coating of Transportation Infrastructures, CAIT/Rutgers**:** 23.
[7]. Balaguru, P., S. Kurtz, J. Rudolph. (1997). Geopolymer for Repair and Rehabilitation of Reinforced Concrete Beams. St Quentin, France, Geopolymer Institute**:** 5.
[8]. Cheng, T. W. and J. P. Chiu (2003). "Fire-resistant Geopolymer Produced by Granulated Blast Furnace Slag." Minerals Engineering **16**(3): 205-210.
[9]. Collins, M. P., D. Mitchell, J.G MacGregor (1993). "Structural Design Considerations for High Strength Concrete." ACI Concrete International **15**(5): 27-34.
[10]. Davidovits, J. (1982). Mineral Polymers and Methods of Making Them. United States Patent: 4,349,386. USA.
[11]. Davidovits, J. (1991). "Geopolymers: Inorganic Polymeric New Materials." Journal of Thermal Analysis **37**: 1633-1656.
[12]. Davidovits, J. (1994). High-alkali Cements for 21st Century Concretes. Concrete Technology: Past, Present and Future. P. K. Mehta, ACI, Detroit, USA. **SP 144-19:** 383-397.