

Feasibility Study of High Strength with Fly-Ash Based Geopolymer Concrete

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Received on: 26 April, 2021

Revised on: May 29, 2021

Published on: 31 May 2021

Abstract –Concrete being the core element used for the construction across the world has a main ingredient in it called 'cement'. Production of cement leads to larger amount of carbon dioxide in the environment with a staggering amount 8% of carbon dioxide annually, on the other hand there is still increase in significant number of construction projects day after day which leads to more demand of cement. Keeping the fact protection of environment into consideration there is an immediate need of an alternative material to cement which will have same properties of cement and of course which can help to achieve environmentally friendly construction. One material is geopolymer concrete. Geopolymer concrete uses alumina silicate rich sources as binder instead of ordinary cement. It also uses different additives like industrial by-products which has encouraged an increase in workability, compressive strength, durability and minimization of effects of temperature variation. Geopolymer concrete is an innovative material which is 100% cement free. Geopolymer concrete is necessity for the future of construction industry and for a sustainable environment.

Keywords- Geopolymer, Alumina Silicate, environment friendly, compressive strength, durability.

1- INTRODUCTION

There is an increase in manufacturing, and transportation sectors due to population growth and urbanization. Natural landscapes are transformed by

humans in large proportions across the earth. Result of this continuous development has led to construction industry being one of the largest across the world. Concrete being one of the most abundantly used material across the construction industry possess cement as the core ingredient in its mixture. Studies have indicated cement manufacturing alone accounts for about 8% of the carbon dioxide emissions across the world, there is a need to protect the environment from being affected further by the emissions from the construction industry. As such there is an immediate need to resort to alternative materials to achieve environment friendly construction. One such material that has been in use for more than a decade is geopolymer concrete. The geopolymer concrete technology proposed by Joseph Davidovits ensures efficient application of By-products as an alternative material to the Portland cement.

The aim of the project is to study the influence of parameters such as alkaline solution to binder ratio, curing condition on compressive strength of fly ash based geopolymer concrete at various ages. The objective of this project can be paraphrased as a normal cement contains high amount of (silica and alumina), the usage of cement is increasing day to day worldwide. Hence, alternative innovative material should be used which is fly ash. Fly ash constitutes of high number of Si-Al materials. Since fly ash is a waste material and can be reused. So, this paper focuses on the effect of alkaline solution to binder ratio, concentration of sodium

hydroxide solution and curing conditions on fly ash based geopolymer concrete and to determine the compressive strength of fly ash based geopolymer concrete at various ages such as 7 days, 14 days and 28 day.

II- OBJECTIVES

- To develop mixture proportioning process to prepare Geopolymer concrete using Fly ash, Alkaline liquids, coarse aggregate and fine aggregate.
- To identify and study the effect of salient parameters such as;
 1. Ratio of sodium hydroxide to sodium silicate solution.
 2. Alkaline liquid to fly ash ratio.
 3. Molarity of sodium hydroxide.
 4. Water to Geopolymer solids.
- To study effects of water on Geopolymer concrete and its Durability

III- MATERIALS AND TESTS

For current project work various materials like Coarse aggregate and fine aggregate are collected. We conducted various tests on the above-mentioned materials in laboratory.

3.1 Fly Ash (Class- F)

For this project work the obtained fly ash is from Adani Thermal Power Station, Dahanu through Sai Yash RMC plant- Wada, Palghar.

Table 1. Chemical composition of fly ash

Sr. No	Name of The Chemical	% by weight
1	Sulfate (SO ₄) % by mass	1.24%
2	Magnesium Oxide (MgO) % by mass	0.91%
3	Titanium Dioxide (TiO ₂) % by mass	0.42%
4	Ferric Oxide (Fe ₂ O ₃ + Fe ₃ O ₄) % by mass	4.17%
5	Calcium Oxide (CaO) % by mass	6.20%
6	Alumina (Al ₂ O ₃) % by mass	20.21%
7	Silica (SiO ₂) % by mass	64.80%
8	Loss on Ignition (L01) % by mass	1.70%

3.2 Coarse Aggregate

Coarse aggregate having nominal size 20 mm were used and different tests were performed and the result are tabulated as below.

Properties	Value obtained
Specific gravity	2.83
Fineness modulus	7.1
Water absorption	1.94

3.3 Fine Aggregate

Good quality zone-I fine aggregate were used. The different tests for physical properties of fine aggregate are carried out in the laboratory and results are tabulated below.

Properties	Value Obtained
Specific gravity	2.69
Fineness modulus	3.5
Water absorption	3.04

3.4 Alkaline Liquids Activators

The alkaline activator used in geopolymerisation is a combination of sodium hydroxide (NaOH) to prepare 10M and 14M solution and sodium silicate (Na₂SiO₃) which is directly available in liquid form was considered for this study.

3.5 Super Plasticizer

Dispa-Ret SPR 485 is a strong slump retaining super Plasticiser based on Naphthalene Sulphonates with selected polymer. Amount used was 2% of total quantity of Fly ash in Kg.

IV- MIX DESIGN

Sr no	Material	10M(kg/m ³)	14M(kg/m ³)
1	Fly ash	408.89	408.89
2	Activator Solution	143.11	143.11
3	Sodium Hydroxide	40.89	40.89
4	Sodium Silicate	102.22	102.22
5	Fine Aggregate	554	554
6	Coarse Aggregate	1293.6	1293.6
7	Super Plasticizer	7.61	7.61

V- METHODOLOGY

5.1 Mixing

The fly ash and the aggregates are first mixed together for 3 minutes. The aggregates are prepared in saturated surface dry condition. The alkaline solution is then added to the dry materials and the mixing continued for further about 4 minutes to manufacture the fresh

concrete. The required quantity of super plasticizer was added as 2% by mass of fly ash.

5.2 Casting

Standard concrete specimen cubes 150mm x 150mm x 150mm was casted and demoulded after 48 hours.

5.3 Curing

Two types of curing were used for geopolymer concrete, i.e. Oven curing and Ambient curing. In oven curing, the specimens are oven-cured within 60°C - 100°C for 24 hours in the oven. Ambient curing of low calcium fly ash based geopolymer concrete is generally recommended. Ambient curing substantially assists the chemical reaction that occurs in the geopolymer paste. Both curing time and curing temperature influence the compressive strength of geopolymer concrete. The curing time varied from 12 to 24 hours. Longer curing time improved the polymerization process resulting in higher compressive strength.

5.4 Testing

The compressive strength test on hardened fly ash based geopolymer concrete was performed on standard compression testing machine of 2000kN Capacity. Totally 44 number of cubical specimens of size 150mm x 150mm x 150mm was casted and tested for the compressive strength at the age of 7 days, 14days and 28days.

VI- RESULTS & DISCUSSION

The different molarity of NaOH (10M,14M) at alkaline liquid to fly ash ratio 0.35 have been selected for testing. The tables 6.1(A) show the compressive strength of geopolymer concrete cubes for different molarities of NaOH at duration of 7 days, 14 days and 28 days.

Table 6.1- Compressive strength of 10M specimen

Sr. No	Molarity	Curing			Comp strength N/mm
		Type	Days	Temp (°C)	
1	14M	Sun Dry	7	33°C	41.68
2	14M	Sun Dry	7	33°C	41.03
3	14M	Oven Dry	7	75°C	44.34
4	14M	Oven Dry	7	75°C	45.11
5	14M	Sun Dry	14	33°C	58.5
6	14M	Sun Dry	14	33°C	59.55
7	14M	Sun Dry	14	33°C	59.91
8	14M	Oven	14	75°C	61.54

		Dry			
9	14M	Oven Dry	14	75°C	60.87
10	14M	Oven Dry	14	75°C	60.23
11	14M	Sun Dry	28	33°C	59.80
12	14M	Sun Dry	28	33°C	61.20
13	14M	Oven Dry	28	75°C	62.97
14	14M	Oven Dry	82	75°C	66.17

Table 6.2 Compressive strength of 14M specimen

Sr. No	Molarity	Curing			Comp strength N/mm
		Type	Days	Temp (°C)	
1	10M	Sun Dry	7	33°C	33.89
2	10M	Sun Dry	7	33°C	30.77
3	10M	Oven Dry	7	75°C	34.94
4	10M	Oven Dry	7	75°C	34.41
5	10M	Sun Dry	14	33°C	46.45
6	10M	Sun Dry	14	33°C	47.50
7	10M	Sun Dry	14	33°C	44.88
8	10M	Oven Dry	14	75°C	47.97
9	10M	Oven Dry	14	75°C	48.07
10	10M	Oven Dry	14	75°C	48.53
11	10M	Sun Dry	28	33°C	44.23
12	10M	Sun Dry	28	33°C	45.7
13	10M	Oven Dry	28	75°C	52.15
14	10M	Oven Dry	82	75°C	48

Table 6.3 Compressive Strength N/mm² after 14 days with additional water added

Sr. No	Molarity	Compressive Strength N/mm ² after 14 days	
		% of additional water added in specimen	
		50% added water	100% added water
1	10M	11.11	2
2	10M	9.51	2.1
3	10M	9.96	2.24

4	10M	6.98	1.83
5	14M	22.13	7.2
6	14M	21.6	7.91
7	14M	19.07	8.8
8	14M	18.44	4.53

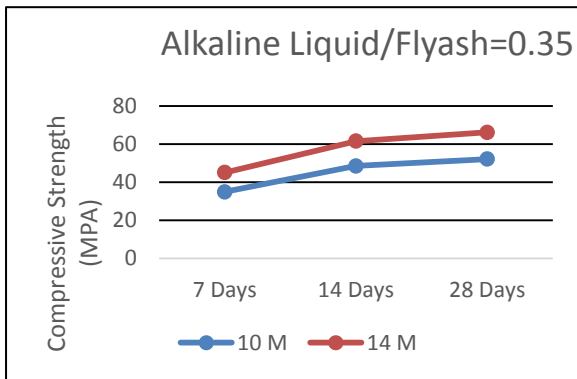


Fig.1- Compressive strength of 10M and 14M Specimens.

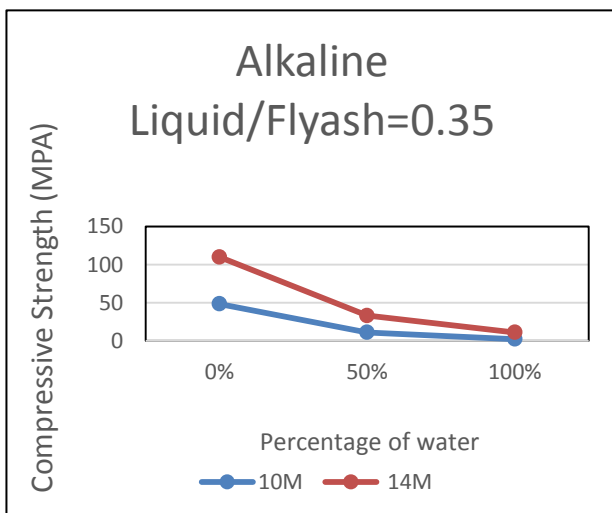


Fig. 2 -Compressive strength Vs water to geopolymer solids ratio.

- As the molarity of NaOH solution increases, compressive strength also increases, because as the molarity of NaOH solution increases water to Geopolymer solids ratio decreases.
- The concrete casted was very stiff because of which it was very hard to compact it so the use of vibrator was done which helped to compact the specimen effectively.
- The experiment performed gave us the results of high strength concrete.
- Effect of water on geopolymer concrete by additional extra water in specimen showed decline in compressive strength of the specimen.

VII-CONCLUSIONS

1. The Na₂SiO₃ to NaOH by mass equal to 1:2.5 has resulted into the higher strength geopolymer concrete.
2. The maximum compressive strength obtained for 10M Oven dry sample was 52.15 N/mm², for Sun dry sample was 45.17 N/mm².
3. The maximum compressive strength obtained for 14M Oven dry sample was 66.17 N/mm², for Sun dry sample was 59.80 N/mm².
4. The experiment results stated that as the Molarity of Geopolymer Concrete increases there is increase in compressive strength.
5. As the Molarity increases the water to Geopolymer solids ratio decreases.
6. The workability of the geopolymer concrete in fresh state increases with the increase of extra water added to the mix but decreases the compressive strength by 20-30% overall.
7. Geopolymer concrete tend to show no significant physical change in its properties at normal operating room temperature which is observed in case of normal variety. The complete setting of Geopolymer concrete specimens will take up to 72 hours without any reminiscences on the surface on which it is hardened.
8. The use of by-products like Fly ash has gained significant importance because of the requirement of environmental protection and sustainable construction in future.
9. Fly ash, Sodium Hydroxide and Sodium Silicate helps in increasing the mechanical properties on Geopolymer concrete.

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