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EXPERIMENTAL STUDIES ON MECHANICAL PROPERTIES OF GEOPOLYMER CONCRETE

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Abstract

Ordinary Portland cement (OPC) is the important material used to prepare concrete. The amount of carbon dioxide released to manufacture each ton of cement is hazardous to environment. To overcome this Geopolymer concrete is used instead of conventional concrete. Geopolymer concrete has many advantages and also is environmentally friendly. The current research is to know variation in strength for different molarities, as well as durability of geo polymer specimens. The specimens were tested for both compressive and tensile strength test. The experimental study shows that strength increases with increasing molarity from 8M, 10M, 12M and 14M after which it the strength decreases around 16M. The compressive strength increases for 8M to 14M by 21.79% for 7 days and by 31.99% for 28 days. But compressive strength decreases for 14M to 16M by 10.56% for 7 days and by 6.46% for 28 days. The tensile strength increases for 8M to 14M by 38.15% for 7 days and by 32.19% for 28 days. However, there is decreasing trend in tensile strength for 14M to 16M by 16.66% for 7 days and by 2.88% for 28 days testing. Water absorption test results show decrease in in mass up to 14M and increases for 16M. Outcome of the overall investigation shows high value for strength parameters at 14M.

Keywords

Fly-ash, GGBS, Sodium silicate, Sodium hydroxide, Compression test, Split tensile test and Water absorption test.

1 Introduction

Ordinary Portland cement is used worldwide for construction. While manufacturing cement which leads to release of carbon-di-oxide in huge amount, to overcome this we can use the other cementations material which is environmental friendly and gives good strength as that of cement. Geo- polymer is one of the replacements. It prepared by using the materials GGBS and fly ash as replacement to cement. To overcome

the effect of weathering action, chemical attack, and abrasion it is required to test the durability of concrete. Geopolymers are a type of inert polymers that are developed at chamber temperature by using industrial waste materials to form a solid binder which possess similar properties that of ordinary Portland cement. The fly ash is mixed with alkaline solution to produce binder. Geopolymer paste binds the loose finer aggregates, coarse aggregates, and some unreacted materials together to form the Geopolymer concrete. Fly ash is available worldwide easily as a substitute and alternative for Ordinary Portland cement to manufacture concrete. When fly ash is used as replacement for Ordinary Portland cement, it reacts with calcium hydroxide during the hydration of cement to form calcium silicate hydrate gel. This helps to know the variation in strength for different molarities, also in durability by testing specimens for water absorption.

2 Literature Review

Research was carried out to know the properties of Geo- polymer concrete with M-Sand, here the materials used were fine aggregates, fly ash, coarse aggregates, sodium silicate and sodium hydroxide [1]. Concrete cubes of size 100mmx100mmx100mm, cylindrical specimens of dia 150mm and of height 300 mm and beams of size 100mmx100mmx400mm were prepared using geopolymer concrete with m-sand as well as conventional concrete, for same mix. Compressive strength, split tensile strength and flexure tests were conducted for 7days, 14days, 21days and 28 days. The strength of geopolymer concrete (GPC) with m-sand has high compressive strength up to 52N/mm² when compared to conventional concrete. The compressive strength of the specimens with geopolymer concrete for 7,14,21 and 28 days is increased by 144%, 160%,176% and 136% respectively when compared to ordinary Portland cement concrete (OPCC). Tensile strength of geopolymer concrete for 7, 14 and 28 days is increased by 10%, 10% and 50% respectively when compared to OPCC. Flexural strength of GPC for 7, 14 and 28 days the strength of gpcm is 20%, 50% and 100% more than OPCC.

Fly ash, bottom ash, silica fume and different types of cement (Normal Portland cement and Rapid-hardening Portland cement) [2] are mixed and strength is investigated. The tests conducted are Compressive strength, Split tensile strength. A simple power function is proposed to evaluate the ratio of the tensile to compressive strength as a function of the cylinder compressive strength. On the basis of error analysis tested for 4 to 120 MPa, irrespective of proportion of mixture, the nature of the cementitious materials, temperature and time of curing. The level of concrete strength influences the ratio of tensile strength to compressive strength. At low compressive strength, the splitting tensile strength is as high as 10 per cent of the cylinder compressive strength.

The authors carried out the experiments to know the strength properties of Geo-polymer Concrete [3]. The materials like Fly Ash, coarse aggregate, M- sand and sodium hydroxide in flake form were used. After the preparation of the alkaline activator, the specimens were casted in 100x200mm cylinder and were oven

cured. It was observed that, the compressive strength of geo-polymer concrete does not depend on the age of concrete. But increase in curing time improves the polymerization process resulting in higher compressive strength up-to 80MPa. Increasing the curing temperature increases the concrete compressive strength (70MPa), especially up-to 75^0C.

An investigation was done to find out the Effect of molarity in geo-polymer concrete. For comparison 8 to 18M of NaOH were taken to prepare geo-polymer concrete [4]. In this the cubes of size 150X150X150mm were casted (3 cubes each for 7 and 28 days of 8 to 18M NaOH). The concrete mix was designed to get 15 to 52MPa. Concrete was prepared by with 1M NaOH solution the specimens were prepared and tested for 7- and 28-days strength in CTM. The Change in compressive strength for different molarities was observed. The highest strength was observed for 14M cubes. In this investigation oven curing method is adopted for 24 hrs at 80^0C and tested.

3 Materials and Methodology

3.1 Fly Ash

Class F fly ash is used, the properties of which are found as per IS: 3812-2003 and are tabulated in the table 1.

Table 1: Properties of fly ash

Sl. No.	Nature of the test	Test Results
1	Fineness	6%
2.	Specific Gravity	2.28

3.2 Ground granulated Blast Furnace Slag

The properties of Ground Granulated Blast Furnace Slag are tabulated as in the table 2

Table 2: Properties of Slag

Sl. No.	Nature of the test	Test Results
1	Fineness	2.45%
2.	Specific Gravity	2.786

3.3 Sodium Hydroxide

Sodium hydroxide commercially called as caustic soda, generally available in the form of pellets, flakes or granular form. It is highly soluble in water and gives rise to exothermic reaction liberating large amounts of heat. The basic tests done in laboratory and are tabulated in the table 3

Table 3: Properties of Sodium Hydroxide

Sl. No.	Nature of the test	Test Results
1	Specific Gravity	2.13
2.	Purity	97%

3.4 Sodium Silicate

Sodium silicate also called as liquid glass or water glass and is available in the form of aqueous solution or in solid form. The composition of sodium silicate consists of sodium oxide, silicon dioxide and water. Sodium silicate is added to increase the rate of polymerization. The results of the basic tests done in laboratory are tabulated in the table 4.

Table 4: Properties of Sodium Silicate

Sl. No.	Nature of the test	Test Results
1	Specific Gravity	1.39
2.	Composition Sodium Oxide Na_2O Silicon dioxide SiO_2 Water	Mass (%) 14.7 29.4 55.9

3.5 Manufactured Sand (M Sand)

In the current research work the manufactured sand (M sand) passing through IS sieve 4.75mm was used as fine aggregates. The tests are conducted as per IS: 383-1970 (Reaffirmed 2007)

3.6 Coarse Aggregate

Coarse aggregates are sieved and those passing through 20mm sieve are used for the research work. The tests conducted are based on IS 383-1970 standards.

4 Experimental Program

The optimum mix is prepared using pre-treated M-sand in concrete as per IS specifications. The specimens were tested for compressive strength and split tensile strength for 7 and 28 days respectively by conducting, water absorption test for GPC is carried out to study the durability of geo-polymer concrete.

4.1 Concrete mix design

Due to non-availability of any standard specification on GPC mix design, the methods and techniques employed in the past to design the GPC mixes have been studied and adopted in the study. The density of GPC is 2350 kg/m³, total mass of combined aggregate was considered as 70% of the mass of concrete, and alkaline solutions were taken as 30% of mass of concrete. Mix proportions of Geopolymer concrete are tabulated in table 4

Table 5: Geopolymer Concrete mix design

Sl. No.	Specimen	Geopolymer Mortar
1	Volume	1 *m*3
2.	Fly ash	352 Kg
3	GGBS	151 Kg
4	Sodium Silicate	144 Kg
5	Sodium Hydroxide	58 Kg
6	Coarse Aggregate	1069.25 Kg
7	M Sand	575.57 Kg
8	Water	50.3 Kg

4.2 Experimental Procedure

1. Alkaline solution is prepared by mixing NaOH, sodium silicate and distilled water. Sodium silicate will be in semi liquid state and sodium hydroxide will be in flakes or in granular form. The amount of distilled water taken from literature review and sodium hydroxide pellets are added and stirred completely until all the pellets are dissolved. The solution was used 24 hours after preparation.

2. Cubes of 100mm dia and 50mm height for Rapid chloride penetration test were made by cutting 100mm dia PVC pipes (15 moulds), for sportively test moulds of 75mm dia and 75mm height were made by 75mm dia PVC pipes (15 moulds). The top and bottom faces of the moulds were covered using steel plates.

3. For the research work cubes and cylinders were casted. Cubes of 150mmX150mmX150mm for 8M, 10M, 12M,14M and 16M (6 cubes for each molarity) were casted for compressive strength test.

4. Cylinders of 150mm dia and 300mm height for 8M, 10M, 12M,14M and 16M (6 cylinders for each molarity) were casted for tensile strength test.

5. 3 cubes for each molarity were casted of size 150x150x150mm for Water absorption test

5 Results & Discussions

5.1 Compressive strength

The compressive strength is obtained by testing the cubes of size 150mmX150mmX150mm for 7 and 28 days respectively in CTM. The test results are tabulated in the table 6 and table 7 and the plot for variation in compressive strength as shown in figure 1 and figure 2

Table 6: 7- Days Compressive strength results

Molarity	Load(kN)			Average Load (kN)	7 days compressive strength
	Cube 1	Cube 2	Cube 3		
8M	879.5	871.5	887.5	879.5	39
10 M	927.7	927.5	926.9	927.37	41.2
12 M	891.2	939.9	1010.9	947.33	42.1
14 M	1068.6	1065	1061	1064.87	47.1
16 M	959.4	961	958.1	959.5	42.6

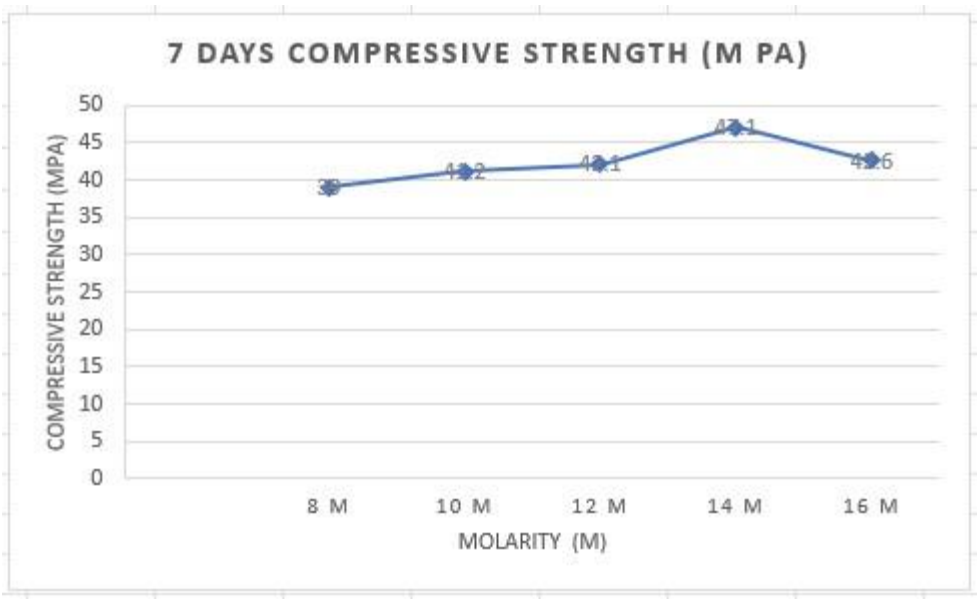

Figure 1: 7- Days compressive strength (MPa)

From figure 1 it is observed that the variation in compressive strength is almost similar for both 7 and 28 days. The compressive strength increases for 8M to 14M by 21.79% and decreases for 14M to 16M by 10.56% for 7 days.

Table 7: 28 -Days Compressive strength results

Molarity	Load(kN)			Average Load (kN)	28 days compressive strength
	Cube 1	Cube 2	Cube 3		
8M	1233.9	1230.6	1232	1232.17	54.7
10 M	1354.8	1384	1386	1374.93	55.7
12 M	1484.7	1493.9	1482.1	1486.90	62.1
14 M	1691.8	1584.6	1650.2	1642.20	72.75
16 M	1532.7	1499	1528	1519.90	68.1

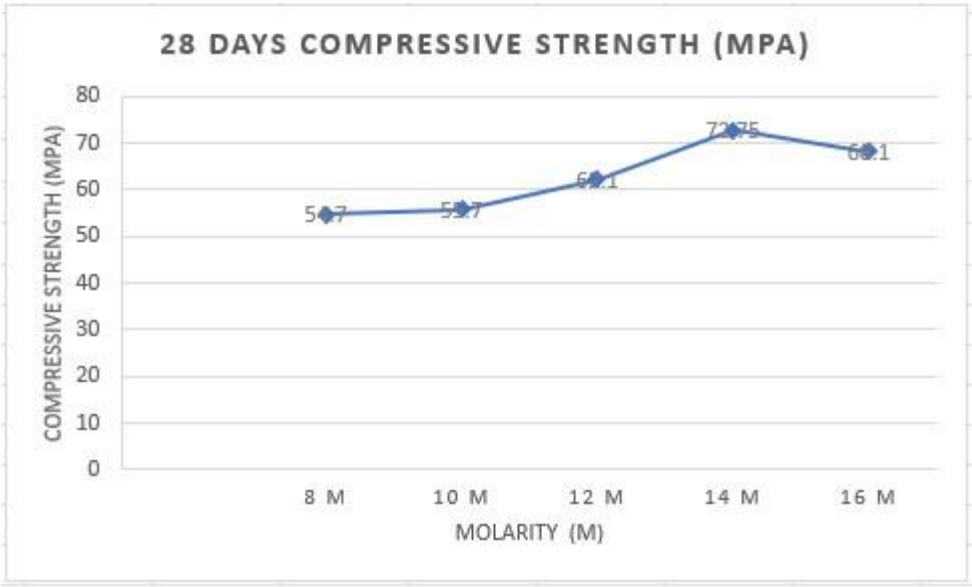

Figure 2: 28- Days compressive strength (MPa)

From figure 2 it is observed that the variation of compressive strength is almost similar for both 7 and 28 days. The compressive strength increases by 31.99% for 8M to 14M and decreases for 14M to 16M by 6.46% for 28 days.

5.2 Tensile strength

The split tensile strength test was conducted on specimens (cylinders) of size 150mm diameter and 300mm length were casted and tested for 7 and 28 days respectively. Test results are tabulated in thetable 8 and table 9 and the plot of split tensile strength vs molarity are shown in the figure 3 and figure 4.

Table 8: 7- Days Split tensile strength results

Molarity	Load(kN)			Average Load (kN)	7 days split tensile strength
	Cyl 1	Cyl 2	Cyl 3		
8M	164.4	157.7	160.2	160.8	2.3
10 M	193.0	193.6	194.4	193.7	2.7
12 M	210.9	206.5	207.2	208.2	2.9
14 M	220.9	225.0	220.6	222.3	3.1
16 M	190.0	192.0	191.0	191.0	2.7

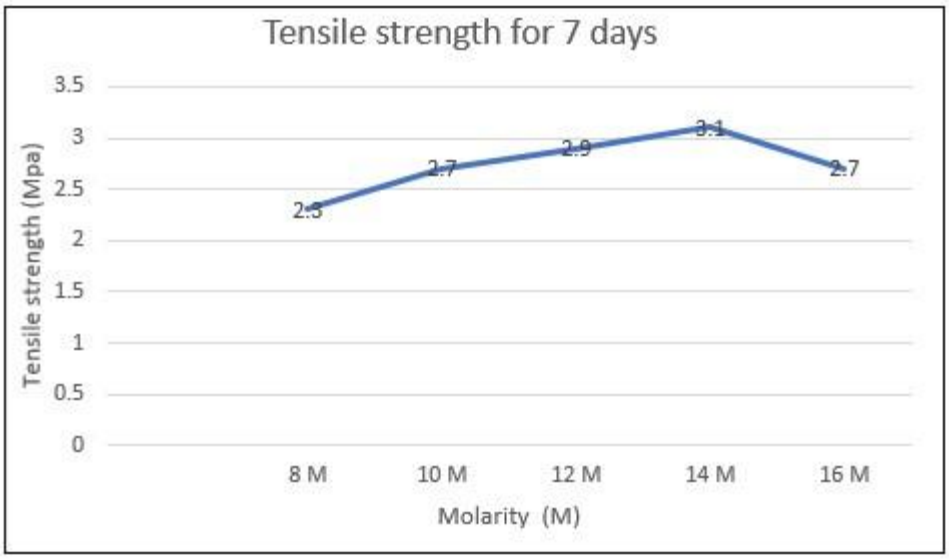

Figure 3: 7- Days split tensile strength

From the figure 3 it can be observed that increase in tensile strength for 8M to 14M by 38.15% and decreases for 14M to 16M by 16.66% for 7 days.

Table 9: 28 -Days Split tensile strength results

Molarity	Load(kN)			Average Load (kN)	7 days split tensile strength
	Cyl 1	Cyl 2	Cyl 3		
8M	252.9	246.5	245.6	248.33	3.56
10 M	301.3	296.3	298.6	298.7	4.23
12 M	324.5	317.7	317.9	320.03	4.54
14 M	344.7	307.7	332	328	4.64
16 M	308	325	324	319	4.51

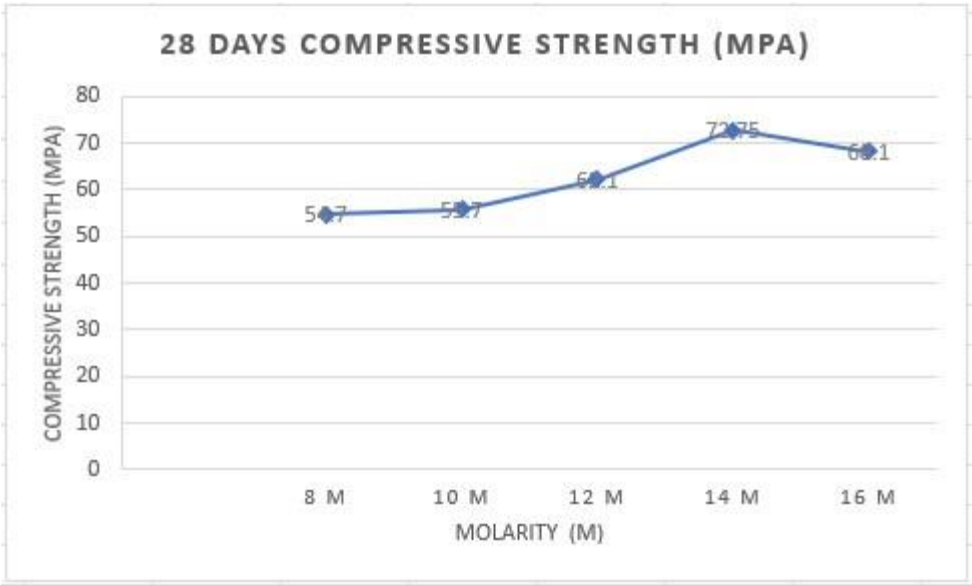

Figure 4: 28 -Days split tensile strength

From the figure 4it is seen that the variation of split tensile strength is almost similar for both 7 and 28 days. The tensile strength increases for 8M

5.3 Water absorption test

The 3 cubes of 150mmX150mmX150mm were tested for water absorption and Percentage of change in mass of specimens of different molarities test for water absorption test were tabulated in the table 10 and plot for the same shown in the figure 5

Table 10: Water absorption test

Molarity	Mass of oven dried specimen in kg (m1)	Mass of wet specimen in kg (m2)	Percentage of Change in Mass(%) [(m2 -m1)/ m1]X100
8M	8.1	8.19	1.11
10 M	8.05	8.126	0.94
12 M	8.01	8.083	0.91
14 M	8.035	8.09	0.68
16 M	8.08	8.15	0.87

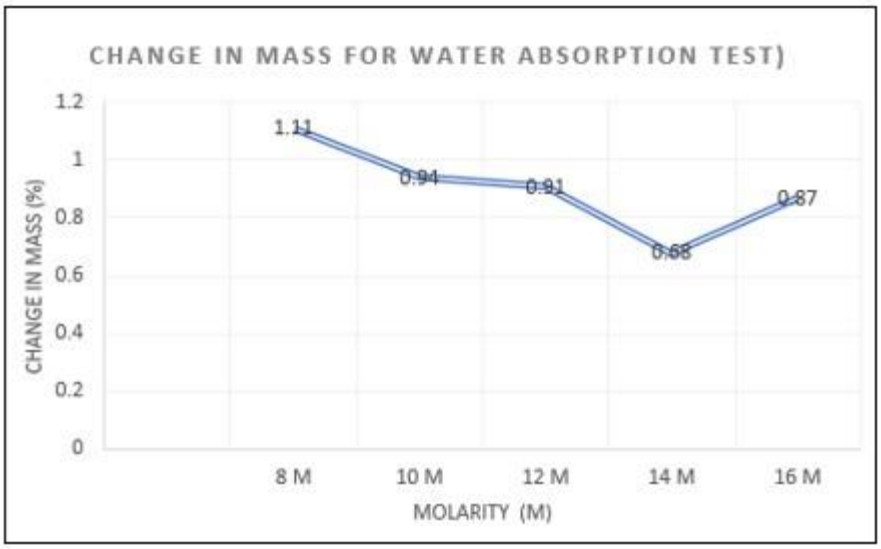

Figure 5: Water absorption test results

From figure 5 percentage of change in mass decreases with increase in molarity. Hence, as the molarity increases water absorption of geo-polymer concrete decreases.

6 Conclusions

Following are the conclusions made from the results obtained due to the tests conducted and are as follows:

1. From the test results it is observed that the compressive strength experiment test showed the similar results for both 7 and 28 days. The compressive strength increases from 8M to 14M by 21.79% at the age of 7 days and by 31.99% at the age ofg28 days. But plot for variation of compressive strength showed decrease in strength from 14MPa to 16MPa by 10.56% at age of 7 days and by 6.46% at age of 28 days.

2. From the tensile strength experiment test showed the similar results for both 7 and 28 days. The tensile strength increases from 8M to 14M by 38.15% at the age of 7 days and by 32.19% at the age of 28 days. However, there is decreasing trend in tensile strength from 14MPa to 16MPa by 16.66% at age of 7 days and by 2.88% at age of 28 days.

3. The water absorption test on geo-polymer concrete results with maximum value for 8M (1.1%), least for 14M (0.8%) and aga0in increases for 16MPa (0.87%) from these results we can conclude that the percentage of change in weight decreases up to 14MPa and increases for 16MPa.

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