Study on Strength and Durability Characteristics of Geopolymer Concrete

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ABSTRACT

The use of Ordinary Portland cement in concrete construction is under critical review due to high amount of carbon dioxide gas released to the atmosphere during the production of cement. Geopolymer concrete is a 'new' material that does not need Portland cement as a binder. Instead, the source of materials such as fly ash and slag, that are rich in Silicon(Si) and Aluminium(Al) are activated by alkaline liquids to produce the binder. To activate the Silicon and Aluminium content in fly ash and slag, a combination of sodium hydroxide solution and sodium silicate solution was used. The geopolymer concretes (GPCs) have alumino-silicates as binder and do not generally have free lime. Therefore, GPCs have potential to be more durable as compared to conventional concretes (CCs) with respect to exposure to acids. Sulphuric acidic solutions of 2%, 4% and 6% were chosen as acidic media. Three GPCs were made with different proportions of Ground Granulated Blast Furnace Slag (GGBS) and Fly Ash (FA) as geopolymeric materials. The reference mix prepared using OPCC had a water-binder ratio of 0.44 and 28 day compressive strength of more than 25 MPa. The results indicate that compressive strength of GPC prepared using FA and GGBS in equal proportions was comparable to the reference mix at 28 days. Results also indicate that for an exposure period of 30 days, the percentage loss in compressive strength of test specimens of OPCC were more as compared to GPCs. Thus, GPCs were found to be more resistant to acids than OPCC.

Keywords: Durability Test, Compressive Strength Test, Geopolymers.

1. INTRODUCTION

Concrete is conventionally produced by using the Ordinary Portland Cement(OPC) as the binder material. The amount of CO_2 released during the manufacture of OPC due to the calcination of limestone and combustion of fossil fuel is in the order of one tonne for every one tonne of OPC produced. The abundance of fly ash and ground granulated blast furnace slag create opportunity to utilize this by-product of burning coal and iron manufacturing as partial replacement to OPC. Fly ash in itself does not possess the binding properties but in presence of water, it reacts with calcium hydroxide during the hydration of OPC to form calcium silicate hydrate(CSH) gel when it is added to OPC as an admixture.

In the present study, Geopolymer concrete was developed using FA and GGBS in different percentages and the strength and durability characteristics of this new concrete were investigated in order to explain its utilization potential. The first mix GPC1had geopolymeric binder synthesized from a mixture of 25% GGBS and 75% FA. The second mix GPC2 had geopolymeric binder synthesized from a mixture of 50% FA and 50% GGBS and third mix GPC3 of 75% GGBS and 25% FA.

1.1 Fly Ash (FA): In this present work, Low calcium (class F) dry fly ash obtained from the silos of Guru Gobind Singh Super Thermal Power Plant (GGSTPP), Ropar (Punjab) was used as the base material.

Ground Granulated Blast Furnace Slag (GGBS): *GGBS was obtained from Amba Shakti factory, Kala Amb (Himachal Pradesh). Specific gravity of the GGBS was 2.91 and water absorption was 1.4%.*

1.3 Fine Aggregates: Locally available Ghaggar river sand from Zirakpur was used as fine aggregate. The sand was sieved through IS sieve 10mm, washed to remove the dust and then dried. Sieve analysis and other tests were performed in the laboratory. The results conformed to grading zone II as per IS 383-1970[2].

Cement: OPC 43 grade of Birla make confirming to IS:8112-1989 [3] was used.

1.5 Coarse Aggregates: *The crushed coarse aggregate of 20mm and 10mm size were obtained from Zirakpur.* Sieve analysis and tests were performed in the lab.

2. DESIGN OF CONCRETE MIX

The mix was designed as per code IS:10262-1982[4], the content proportions of different types of materials was studied. For the reference mix of 25 grade, the mix proportions was found to be 1:1.24:2.65:0.44(cement:sand:aggregates:water) and for that of Geopolymer concretes (GPs) prepared by using admixtures was found out to be 1:1.3:2.5:0.45.

3. MIXING

The fresh fly ash and slag based geopolymer concrete was dark in color(due to the dark color of the fly ash and slag), and was cohesive. The amount of water in the mixture played an important role on the behavior of fresh concrete. Davidovits[1](2002) suggested in his articles that it is preferable to mix the sodium silicate solution and sodium hydroxide solution before adding it to the solid constituents. When this suggestion was followed, it was found that the occurrence of bleeding and segregation ceased.

4. TESTING OF SPECIMENS

4.1 Compressive Strength Test: Compressive strength tests were conducted on concrete cubes of size 150mm×150mm×150mm. To check the quality of concrete, these tests were carried on a 2000 KN compression testing machine at 28 days age. The load was applied at the rate of 14 N/mm^2/minute. The maximum compressive load on the specimen was recorded as the load at which the specimen failed to take any further increase in load.

4.2 Tensile Strength of Concrete: These tests were carried out on cylindrical specimens 150mm in diameter and 300mm in height. The specimen was placed with its longitudinal axis in the horizontal position between the two plates of CTM, with plywood strips 3mm thick, 12mm wide and 300mm long sandwiched between the plates and the cylindrical surface. The load was applied at a uniform rate of 1.5N/mm^2/minute till failure of the test specimen. It was calculated by the expression:

$$T_{SP} = \frac{2P}{\Pi D_{\O} L_{\O}}$$

Where, P = Failure load in N.
$D_{\O}$= Diameter of the cylindrical specimen in mm
$L_{\O}$= Length of the cylindrical specimen in mm.

5. RESULTS

5.1 Compressive Strength

Table 1: Compressive Strength of mixes.

Mix Designation	Curing (days)	Compressive Strength (N/mm^2)	Average Compressive Strength (N/mm^2)
RM	7	24.00 22.20 23.50	23.23
RM	28	33.24 37.16 33.74	34.72

GPC1(25% GGBS+75% FA)	7	15.74 13.62 14.78	14.79
GPC1(25% GGBS+75% FA)	28	31.40 32.15 30.10	31.21
GPC2(50% GGBS+50% FA)	7	17.00 15.20 16.40	16.21
GPC2(50% GGBS+50% FA)	28	32.30 36.19 32.77	33.78
GPC3(75% GGBS+25% FA)	7	14.29 12.56 13.68	13.52
GPC2(75% GGBS+25% FA)	28	30.90 29.06 30.38	30.11

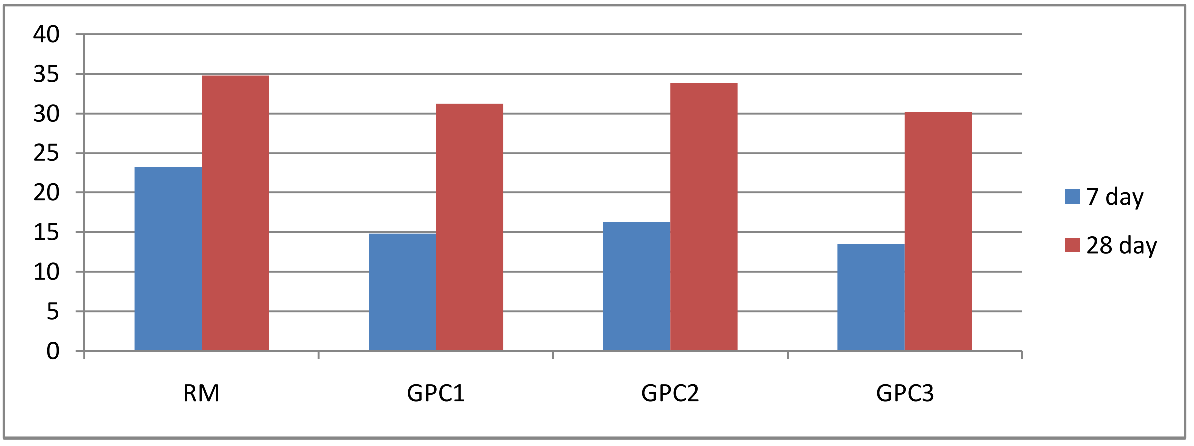

Fig 1: Comparison of Average Compressive Strength of mixes.

It is clear that the compressive strength of GPC2 mix is almost equal to the reference mix but the 7 days compressive strength of GPC2 is less than that of reference mix by 33%. Therefore, the 1:1 proportioning of GGBS and FA mix gives higher compressive strength as compared to other proportions.

5.2 TENSILE STRENGTH

Table 2:- Tensile Strength of mixes.

Mix Designation	Curing (days)	Tensile Strength (N/mm^2)	Average Tensile Strength (N/mm^2)
RM	7	2.66 2.87 3.18	2.90
RM	28	3.71 4.64 4.23	4.20
GPC1(25% GGBS+75% FA)	7	1.48 1.70 1.99	1.72
GPC1(25% GGBS+75% FA)	28	3.21 4.14 3.73	3.70
GPC2(50% GGBS+50% FA)	7	2.86 1.08 2.37	2.10
GPC2(50% GGBS+50% FA)	28	3.41 4.34 3.93	3.9
GPC3(75% GGBS+25% FA)	7	2.36 1.05 1.33	1.59
GPC2(75% GGBS+25% FA)	28	3.03 3.92 3.53	3.5

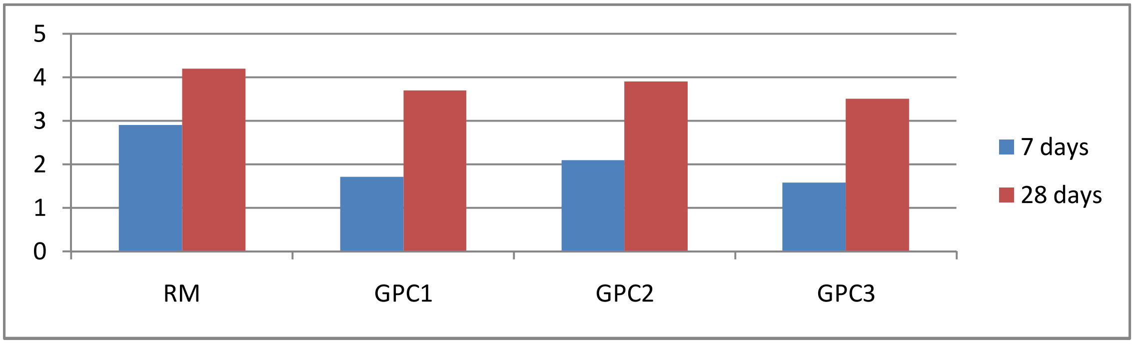

Fig 2: Comparison of Average tensile Strength of mixes.

5.3 DURABILITY TEST

5.3.1 Sulphuric Acid Solution: Concentrated sulphuric acid of 98% concentration and density 1.84g/cc was taken and was used to prepare the diluted sulphuric acids of 2%, 4% and 6% concentrations.

5.3.2 Acid Attack Test on specimens: Specimens were submerged in sulphuric acid solution such that there was a min. of 30mm depth of acid over the top surface of specimens. The specimens were taken out at end of 30 days and observed visually for deteriorations, were washed in tap water and then allowed to dry before doing tests.

Table 3:- Compressive Strength of mixes after 30 days immersion.

Mix Designation	Concentration of Sulphuric acid solution	Compressive Strength (N/mm^2)	Average Compressive Strength(N/mm^2)
RM	2%	32.45 30.63	31.54
RM	4%	30.07 28.28	29.18
RM	6%	27.89 26.08	26.99
GPC1	2%	28.73 28.95	28.84
GPC1	4%	28.85 27.04	27.95
GPC1	6%	27.79 25.97	26.88
GPC2	2%	32.20 30.39	31.30
GPC2	4%	31.40 29.58	30.49
GPC2	6%	30.65 28.86	29.76
GPC3	2%	30.64 28.87	29.76
GPC3	4%	29.05 27.22	28.14
GPC3	6%	28.75 26.93	27.84

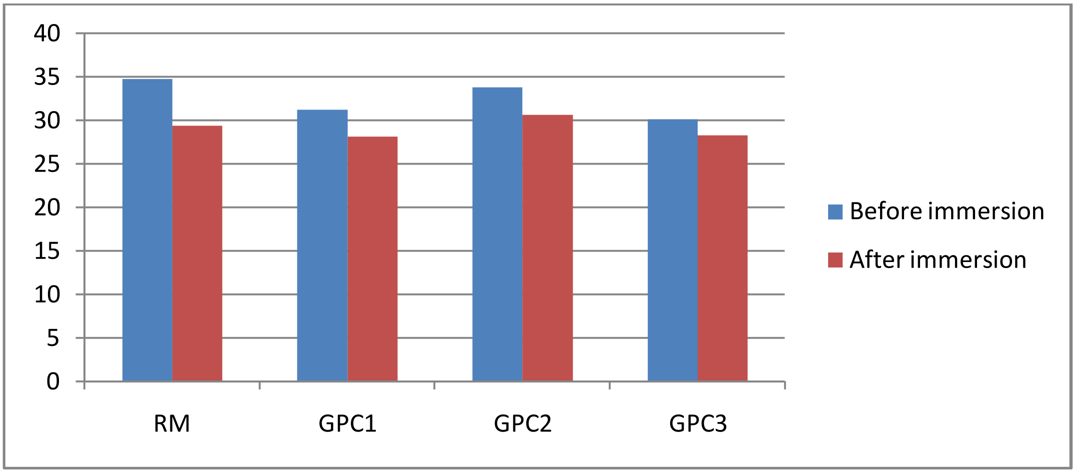

Fig 3:- Compression strength comparison of concretes after 30 days immersion in 4% sulphuric acid solution.

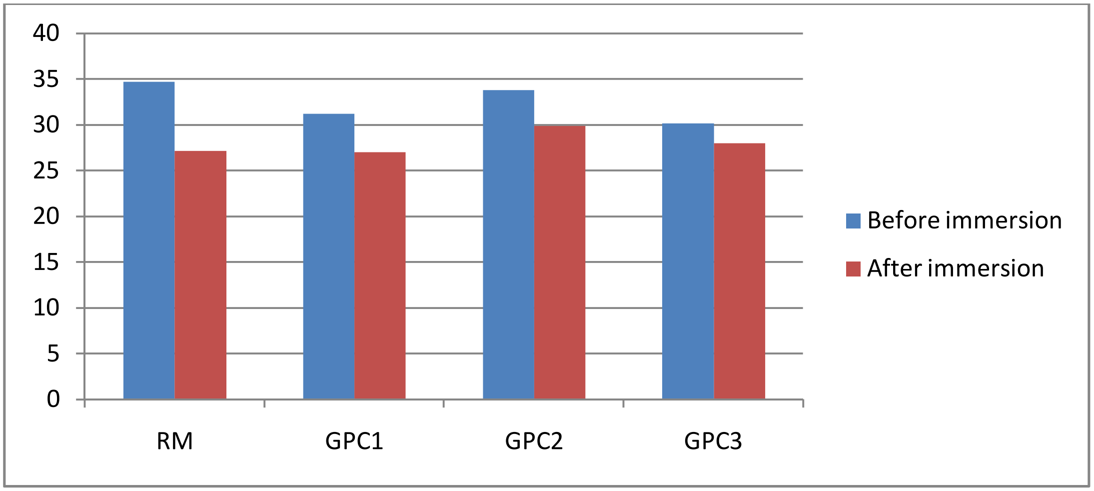

Fig 4:- Compression strength comparison of concretes after 30 days immersion in 6% sulphuric acid solution.

The results shows that at the exposure to sulphuric acid, the loss in compressive strength in cement concrete is 8%, 15.6% and 24% at 2%, 4% and 6% acid respectively but in GPC2 mix, the loss in compressive strength is 7.5%, 10% and 11.6%.

6. CONCLUSIONS

Fly Ash and GGBS can be used as base materials to produce geopolymer reaction using alkali hydroxide-silicate based activator solution. GPCs do not require Portland cement and hence can be considered as less energy intensive since Portland cement is a highly energy intensive material. GPCs are highly acid resistant even after 30 days of immersion without any significant change in mass and shape as compared to OPCCs. Hence, it can be concluded that GPCs are good materials of construction from both strength and durability considerations.

REFERENCES

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[3] IS 8112-1989: Specifications for OPC 43 grade.

[4] IS 10262-1982: Recommended guidelines for concrete mix design.