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Influence of Steel Fibre in Geopolymer Concrete

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ABSTRACT: Ordinary Portland Cement (OPC) production produces substantial CO₂ emission. which is a greenhouse gas causing global warming. To address the environmental constraints due to cement production, strength properties of high-calcium fly ash based geopolymer concrete (GPC) has been explored in this paper. For, Alkalineliquid combination, ratio of Sodium Silicate to Sodium Hydroxide solution was fixed as 2.5. Attention was paid upon the durability and flexural behaviour of steel fibre geopolymer concrete specimen. The specimen were designed for the grade G30 with Sodium hydroxide concentration of 12M. Steel fibre added to the concrete mix as 0.5%, 1% and 1.5% to the volume of concrete. Cube, cylinder and prism were cast with and without fibre and cured in 10% concentration of sulphuric acid attack for the period of 28, 60 and 90 days for the strength and durability of concrete.

KEYWORDS: high-calcium fly ash, durability, steel fibre, sulfuric acid, flexural strength fibre used geopolymer concrete.

I. INTRODUCTION

Utilisation of concrete as a major construction material is a worldwide phenomenon and the concrete industry is the largest user of natural resources in the world. Massive use of concrete is driving the massive global production of cement, estimated as about 2.8 billion tonnes. Associated with this is the inevitable carbon-di-oxide emission of about 7% of total global production. Geo Polymer Concrete is one of the green alternatives to Portland cement concrete. Geo polymers are a relatively new group of materials which were developed by Joseph Davidovits in 1970's. Fly ash based geo polymer are one of the branch in the geo polymer family and these have attracted more attention since 1990's. The physical and chemical characteristics of fly ash mainly depend on coal source and method of production. Fly ash mainly contains the high percentage of silica and alumina. The main difference between class F Fly Ash (FFA) and class C Fly Ash (CFA) is the calcium content. Particle size, calcium content, alkali metal content, amorphous content, morphology and origin of fly ash may affect the properties of geo polymers. Calcium content in fly ash in significant quantities could interfere with polymerisation process and may alter the microstructure. Significant amount of research work has been reported on class F fly ash based Geo Polymer Concrete. Class C fly ash based Geo Polymer Concrete has been subjected to limited amount of analysis.

II. EXPERIMENTAL PROGRAM

In this research work, it was aimed to study the impact of sulfuric acid concentration on compressive strength, split tensile strength and flexural strength of geopolymer concrete determined at 28, 60 and 90 days.

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III. MATERIALS AND MIX PROPORTIONS

Class C Fly Ash obtained from Neyveli Thermal Power Plant was used as source material. The properties of CFA were determined in accordance with IS: 1727-1967 and presented in Table 1. Locally available river sand with fineness modulus of 2.64 and crushed granite stone aggregate of 20-mm (maximum) size was used as fine aggregate and coarse aggregate respectively. The specific gravity of both coarse and fine aggregate was 2.8 and 2.66 respectively and the water absorption was 0.40% and 0.60% respectively.

Table .1 Properties of Class C fly ash

a. Physical properties

S.No	Physical properties	Test Results
1	Specific gravity	2.53
2	Fineness, percentage passing on 75 μ m sieve	84%
3	Colour of fly ash	Grey

b. Chemical properties

S. No	Chemical properties	Test Results
1	SiO ₂	32.62
2	Al ₂ O ₃	31.23
3	Fe ₂ O ₃	8.48
4	TiO ₂	1.65
5	CaO	17.12
6	MgO	3.49
7	Na ₂ O	0.91
8	Na ₂ O	0.10
9	Loss on ignition	0.93

The basic mixtures proportion used for the trial mixtures was based upon previous research on geopolymer mixture proportions because of the absence of its codal provisions. Sodium silicate solution, A53 with SiO₂ to Na₂O ratio by mass approx 2.0 (Na₂O = 14.7%, SiO₂= 29.4% and water = 55.9%) and the sodium hydroxide with 97-98% purity, in pellet form was used. Mix proportions for characteristics strength of 30 Mpa (G30) are describe in Table 2. Alkaline solution to fly ash ratio was 0.46. The concentration of sodium hydroxide solution was 12M.

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Table .2 Mix Proportions for G30Geopolymer Concrete

Mix ID	Flyash kg/m ³	Fine aggregate kg/m ³	Course aggregate kg/m ³	NaOH Solution kg/m ³	Na ₂ SiO ₃ Solution kg/m ³	Super plasticizer kg/m ³	Steel fibres kg/m ³
GPC	378	554	1294	50	124	7.5	0
GPC1	378	554	1294	50	124	7.5	0.5%
GPC2	378	554	1294	50	124	7.5	1%
GPC3	378	554	1294	50	124	7.5	1.5%

IV. CASTING AND CURING

In the laboratory, aggregates (SSD) and fly ash were first mixed together in the pan mixer thoroughly. The alkaline solution was then added to the dry materials and the mixing continued till homogenous mixture was obtained. Steel fibre was added to the wet mix in different proportion such as 0.5%, 1% and 1.5% by the volume of the concrete. Prior to casting, the inner wall of the moulds were coated with lubricating oil to prevent adhesion with the concrete specimens. All specimens were cast horizontally in three layer. Each layer was compacted using a tamping rod. The specimens considered in this study consisted of 150mm x 150mm size cube, 150mm diameter and 300mm long cylinders and 100mm x 100mm x 500mm size prisms. After casting, specimen were placed inside the heat curing chamber and cured at 80°C for 24 hours. After curing, the specimens were removed the chamber and left in the laboratory ambient condition and their after the specimens immersed sulfuric acid solution. The acidity of the solution was checked periodically with the aid of pH meter by titrating with standard alkaline solution and test the specimen to find the durability of concrete.

V. RESULT AND DISCUSSION

This session provides a summary of the experimental results and endeavours to draw some conclusions. The test result covers the workability, mechanical properties and durability properties geopolymer concrete with and without steel fibres.

Workability: The workability was assessed by determine the compacting factor as per the IS 1199:1959. It was observed that the workability values are decreasing gradually from GPC to GPC3. Addition of steel fibres causes decrease in workability. It might be due to viscous nature of geopolymer concrete and uneven distribution of fibres in the mix. An attempt has been made to correlate the decrease in workability of Geopolymer concrete due to the addition of fibres. Fig. 1 represents this variation compacting factor with fibres content.

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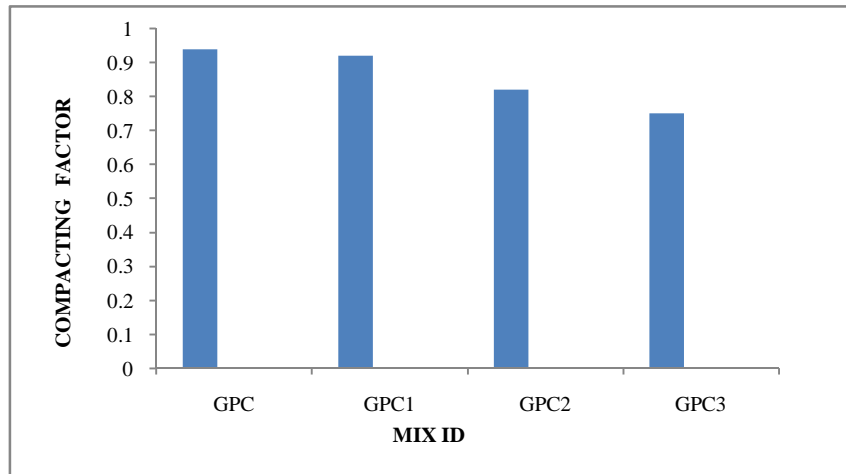


Figure1.compaction factor variation

Compressive strength test: It was noted that as the fibre content increased, the compressive strength also increased. Maximum compressive strength was obtained for GPC2 mix, i.e. the mix with 1% steel fibre. Decrease in compressive strength was about 1.5% GPC3 respectively with respect to GPC2. In GPC, as an average about 98% of strength development was observed within 7 days. Fig.2 shows the variation for compressive strength for all the four mixes. As the volume fraction increases from 0.5 to 1.5%, compressive strength increases with respect to the control mix. So, unlike ordinary concrete, the rate of strength development of geopolymer concrete beyond 28th day is not significant. Because the chemical reaction of the geopolymer gel is due to substantially fast polymerization process, the compressive strength does not vary with the age of concrete. This observation is in contrast to the well-known behaviour of OPC concrete, which undergoes hydration process and hence gains strength over the time. In the present study, compression tests were carried out on 150mm cube specimens at age 7, 28, 56 and 90 days as per IS : 516-1959. The reported strength value are gradually increase the test result. Fig.3 shows the variation of compressive strength with age.

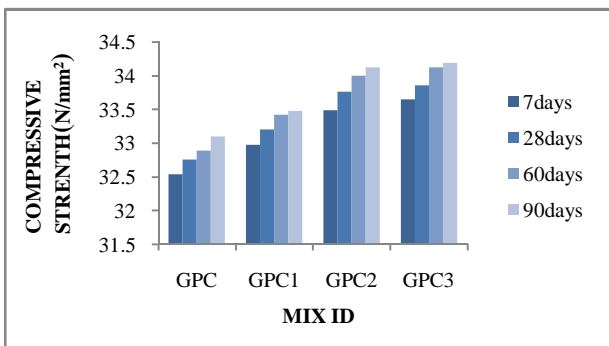


Figure 2.Compressive strength variation for different mixes

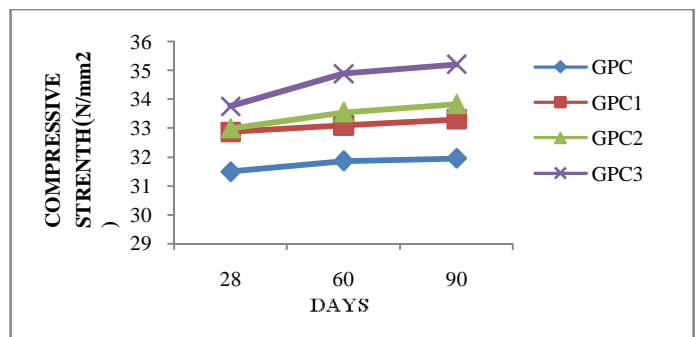


Figure 3. Variation of compressive strength vs days

Split tensile strength: the tensile strength of fly ash based geopolymer concrete was measured by performing the cylinder splitting test on 150 X 300mm concrete cylinders. The average split tensile strength of geopolymer concrete

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with and without fibre used specimen for all the four mix shows fig.4. The increase split tensile strength was about 25.8%, 39.87% and 52.6% for GPC1,GPC2 and GPC3 respectively with respect to Geo polymer concrete mix.

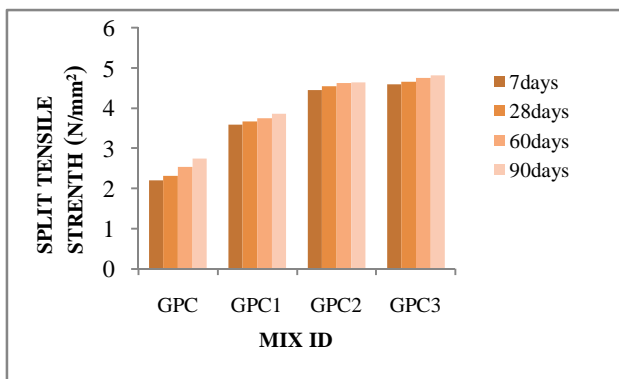


Figure 4. split tensile strength variation for different mixes

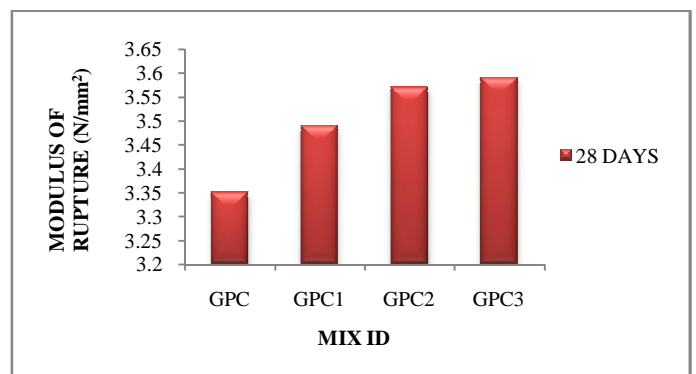


Figure 5. Modulus of rupture for different mixes

Flexural strength test: As the volume fraction increases from 0.5 to 1%, flexural strength increases with respect to the control mix. The increase in modulus of rupture was about 10.1%, 23.6% and 34.2% for GPC1, GPC2 and GPC3 respectively with reference to GPC mix. The increase in flexural strength is due to the effectiveness of the steel fibre in taking up the tension developed in the specimens. The maximum flexural strength was obtained as 5 N/mm² for GPC3. Flexural strength test was conducted as per IS: 516-1959. Fig.5 shows the variation of modulus of rupture of various mixes at 28th day.

Sulfuric acid attack test: The visual appearance of the geopolymer concrete specimens after soaking in sulfuric acid solution shows that GPCs undergoes erosion of the surface. Surface of the specimens get damaged due to the high concentration of acid. But the severity of damage and distortion of specimen was less. From visual appearance it was seen that there was slight reduction in mass of specimen exposed to sulfuric acid. Maximum percentage of mass loss was shown by GPC mix and the value was 1.2% after 90 days of exposure. It was observed that percentage mass loss decreases with increase in fibre content. Overall percentage of mass loss after 56 days of exposure was 0.98% and 90 days of exposure was 1.1%. This mass loss is considerably small. When comparing different mixes percentage mass loss of GPC2 mix was less than that of GPC. Figure 6 presented the variation of compressive strength of specimens exposed to sulfuric acid solution. It was observed that compressive strength of different mixes decrease with exposure period. It can also see that percentage loss of compressive strength decreases with increase in fibre content.

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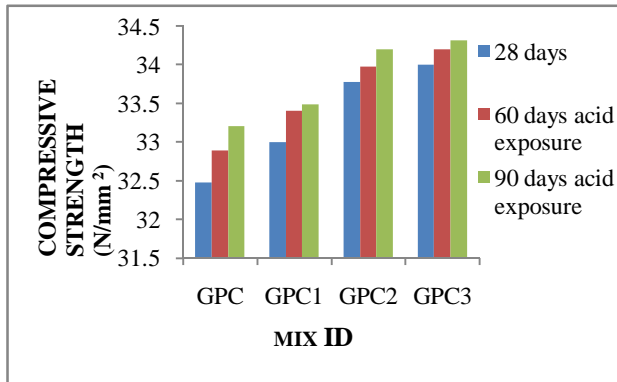


Figure 6. variation of compressive strength of specimen exposed to sulfuric acid solution

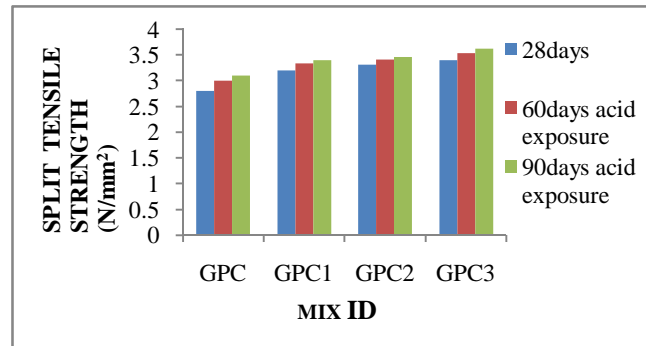


Figure 7. Variation of split tensile strength of specimen exposed to sulfuric acid solution

The degradation in strength is related to depolymerisation of aluminosilicate polymers in acidic media and the formation of zeolites. From the results it was concluded that GPC2 mix have better acid resistance than GPC mix. It's both mass loss and strength loss were lower compared with GPC mix. Figure 7 present the variation of split tensile strength of specimen s exposed to sulfuric acid solution. It was observed that split tensile strength of different mix. From the result it was concluded that GPC2 mix have better acid resistance than GPC mix. It's both mass and strength loss were lower compared with GPC.

VI. CONCLUSION

From the above experimental works following conclusions could be drawn:

- Workability of the geopolymer concrete is decreased with increase of fibre content. Maximum workability was shown by GPC mix, i.e., the mix without fibre.
- Compressive strength is increased with increased fibre content. 7th day strength was 98% of 28th day strength.
- It was observed that compressive strength and split tensile strength did not vary largely with age. It was found that the curing temperature adopted is sufficient for completing the polymerization process and attaining the strength of both test results.
- Flexural strength also increased with increase in percentage of fibre. The increase in modulus of rupture was about 10.1%, 23.6% and 34.2% for GPC1, GPC2 and GPC3 respectively with reference to GPC mix. The maximum flexural strength was obtained as 5N/mm² for GPC3.
- GPC3 mix shows more acid resistant than GPC based on visual appearance, change in mass and change in compressive strength.

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