Strength and Durability Studies of Hybrid Fiber Reinforced Geopolymer Concrete

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Abstract- *Due to growing environmental concerns of the cement industry, development of materials which are alternatives for cement have become an area of increasing interest. On the other hand, already huge Volumes of fly ash are generated around the world, most of the fly ash is not used effectively, and face serious problems in handling and disposal of the fly ash. Both the above problems are to be solved. An effort in this regard is the development of geo polymer concrete, synthesized from the materials of geological origin or by product materials such as fly ash, which are rich in silicon and aluminum.*

The main objective of this study is to investigate the impact of steel fibers (0.25% by volume) and hybrid polypropylene(0.075% by volume) and steel fibers(0.175%by volume) on the mechanical and durability properties of geo polymer concrete composites The results of the experimental program reveal that mechanical properties of GPC are improved with the addition of fibers .SFRGPC has shown an increase of 11 and 14% in compressive strength and split tensile strength respectively compared to GPC and HFRGPC has shown a significant increase of 25% in flexural strength compared to GPC. Addition of fibers in the GPC mix decreases the water absorption and sorptivity coefficient values. Fiber reinforced geo polymer concrete specimens have shown good resistance to acid, Sulphate and chloride attacks.

I. INTRODUCTION

1.1 GENERAL

Concrete is the most common construction material used in building industry. Cement is a basic component of concrete used for building and civil engineering construction. The production of cement involves the consumption of large quantities of raw materials, energy, and also results in the release of a significant amount of solid waste materials and green house gaseous emissions. The emissions from cement plants which cause greatest concern and which need to be dealt with are dust, carbon dioxide CO2, nitrogen oxides (NOx) and Sulphur dioxide (SO2). Manufacturing of one ton of cement generates about one ton of CO2. 4 to 5% of the global CO2 emissions are caused by cement production.

1.2 GEOPOLYMER DEVELOPMENT

Geo polymer cements develop through a series of several distinct reaction processes from initial pozzolanic activation to final microstructure development. The major processes involved are dissolution of the alumina silicate species within a highly basic, alkaline environment, polymerization of the dissolved minerals into short-lived structural gel, precipitation of formed hydration products similar to natural zeolites and final hardening of the matrix by excess water exclusion and the growth of crystalline structures. Figure 1.1 shows the overall polymerisation process in alkali activated geo polymer concrete.

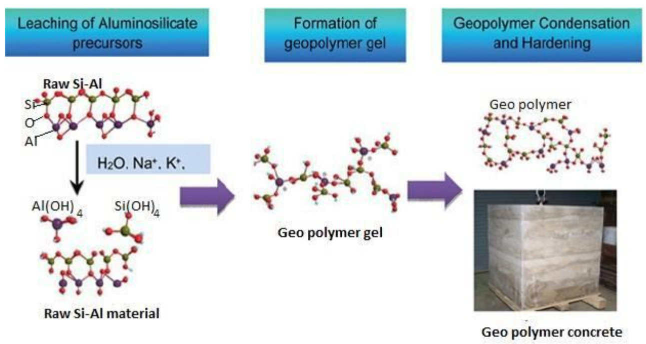

Fig 1.1 Geo polymer concrete development

1.3 HYBRID FIBRE RIENFORCED GEOPOLYMER CONCRETE

The addition more than one type of fibre in concrete is known as hybrid fibre reinforced concrete. A composite can be termed as hybrid, if two or more types of fibres are rationally combined in a common matrix to produce a composite that drives benefits from each of the individual's fibres and exhibits a synergetic response. Steel and polypropylene fibres are used as hybrid fibres in this study.

1.3.1 Advantages of Hybrid Fibre Reinforced Concrete

The advantages of hybrid fibre reinforced concrete are

1) To provide a system in which one type of fibre, this is stronger and stiffer, improves the first cracks stress and ultimate strength, and the second types of fibre, which is more flexible, and ductile leads to improved toughness and stain in the past cracking zone.
2) To provide hybrid reinforcement in which one type of fibre is smaller, so that it bridges the micro cracks of which growth can be controlled. This leads to a higher tensile strength of the composite. The second type of fibre is larger, so that it arrests the propagating micro cracks and can substantially improve the toughness of the composite.
3) 3)To provide a hybrid reinforcement, in which the durability of fibre type is different. The presence of the durable fibre can increase the strength and toughness relation after age while the other type is to guarantee the short term performance during transportation and installation of the composite elements.

1.4 OBJECTIVE OF THE RESEARCH

The primary objective is to study the effect of fibre additions on mechanical and durability characteristics of geo polymer concrete.

To study mechanical characteristics like compressive strength, split tensile strength and flexural strength for the designed geo polymer concrete(GPC), steel fibre reinforced geo polymer concrete(SFRGPC) and hybrid fibre reinforced geo polymer concrete(HFRGPC).

To study durability parameters like water absorption, sorpitivity, resistance to chemical attacks like acid attack, chloride attack and sulphate attack.

II. MATERIAL PROPERTIES

2.1 FLY ASH (ASTM Class F).

Table 2.1 Chemical properties of Fly ash (Class F)

Chemical composition	Percentage by mass
SiO_2	51.98
Al_2O_3	23.04
Fe_2O_3	5.04
CaO	4.50
MgO	0.90
SO_3	0.10
L.O.I	0.85

Table 2.2 Physical properties of Fly ash (Class F)

Property	Values
Specific gravity	2.64
Specific surface area	370 m^2/kg

2.3 GROUND GRANULATED BLAST-FURNACE SLAG ASH

Table 2.3 Chemical properties of GGBFS

Chemical composition	Percentage by mass
SiO_2	29.96
Al_2O_3	12.25
Fe_2O_3	0.52
CaO	45.45
Na_2O	0.31
K_2O	0.38
SO_3	3.62
P_2O_5	0.04
TiO_2	0.46
L.O.I	2.39

2.4 FINE AGGREGATE

Table 2.4 Specific Gravity of Fine Aggregate

Sl. No.	Observations	Trial 1	Trial 2	Trial 3
1.	Weight of the specific gravity bottle, (W_1), g	25	25	25
2.	W_1 + 1/3rd filled aggregate, (W_2), g	54	53.8	53.5
3.	W_2 + water, (W_3), g	93.6	93.5	93.4
4.	Weight of bottle + water ,(W_4), g	75	75	75
5.	Specific Gravity	2.52	2.45	2.82

Average specific gravity of fine aggregate = 2.6

2.5 COARSE AGGREGATE

Table 2.5 Specific Gravity of Coarse Aggregate

Sl. No.	Observations	Trial 1	Trial 2	Trial 3
1.	Weight of the specific gravity pycnometer (W_1), g	619.40	619.40	619.40
2.	Weight of pycnometer + 1/3rd filled aggregate (W_2), g	1109.20	1119.40	1108.40
3.	Weight of pycnometer + 1/3rd filled aggregate + water (W_3), g	1754.20	1754.70	1753.50
4.	Weight of pycnometer + water (W_4), g	1442.80	1442.80	1442.80
5.	Specific gravity	2.75	2.87	2.77

Average specific gravity of coarse aggregate = 2.80

III. MIX DESIGN AND MIX PROPORTIONS

3.1 DESIGN STIPULATIONS:

i. Anticipated strength : 30 MPa
ii. Maximum size of aggregate : 20 mm
iii. Alkaline solution to binder ratio :0.35

3.2 FLY ASH & GGBFS:

Based on the target strength of concrete and the fineness of fly ash, thequantity of fly ash can be found. Hence from the available data, the quantity of binder material is = 400 kg/m^3.

To utilize the ambient temperature conditions, GGBFS is added in equal amount as of fly ash.

Hence, Quantity of GGBFS = 200 kg/m^3
Quantity of fly ash = 200 kg/m^3

3.3 DETERMINATION OF AGGREGATE CONTENT:

Total aggregate content = (wet density of geopolymer concrete) – (fly ash + GGBFS + Alkaline solution + water) = 2400 – (400 + 140 + 77.72) = 1782 kg/m^3
Considering, ratio of fine to total aggregates = 0.35

Fine aggregate required = 623 kg/ m^3
Coarse aggregate required = 1782-623
= 1160 kg/ m^3

3.4 STEEL FIBRE REINFORCED CONCRETE

Steel fibres = 0.25% by volume of concrete
= 0.25*7850/100

= 19.625 Kg/m^3.

3.5 HYBRID FIBRE REINFORCED CONCRETE

Poly propylene fibres = 30% (0.25% by volume of concrete)
= **(**30*0.25*910)/ (100*100**)**
= 682 gm/m^3.
Steel fibres = 70% (0.25% by volume of concrete)
= **(**70*0.25*7850)/ (100*100**)**
= 13.73 kg/m^3.

IV. TESTS PROCEDURE

- WORKABILITY TEST
- COMPRESSIVE STENGTH
- SPLIT TENSILE STENGTH
- FLEXURAL STRENGTH
- WATER ABSORPTION TEST
- SORPTIVITY TEST
- CHEMICAL ATTACKS
  - ACID ATTACK (SULPHURIC ACID - H2SO4)
  - SULPHATE ATTACK (MAGNESIUM SULPHATE – MgSO4)
  - CHLORIDE ATTACK (SODIUM CHLORIDE – NaCl)

V. RESULTS AND DISCUSSIONS

5.1 WORKABILITY

Workability of geo polymer concrete decreases with the addition of fibers. The decrease in workability was higher in SFRGPC compared to GPC and HFRGPC .the reduction in workability due to steel fibres was more compared to poly propylene fibres. The slump values are shown in Table 5.1

Table 5.1 Slump values

Concrete type	Slump(mm)
GPC	105
SFRGPC	80
HFRGPC	90

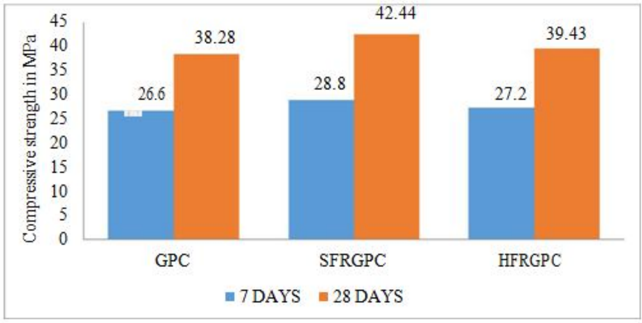

Fig. 5.2 Variation of Compressive Strength at 7th and 28th day

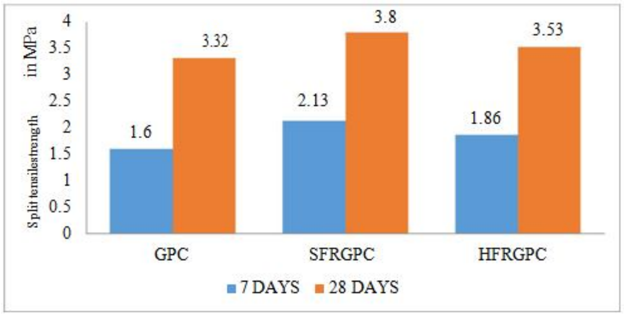

Fig. 5.3 Variation of Split tensile Strength on 7th and 28th day

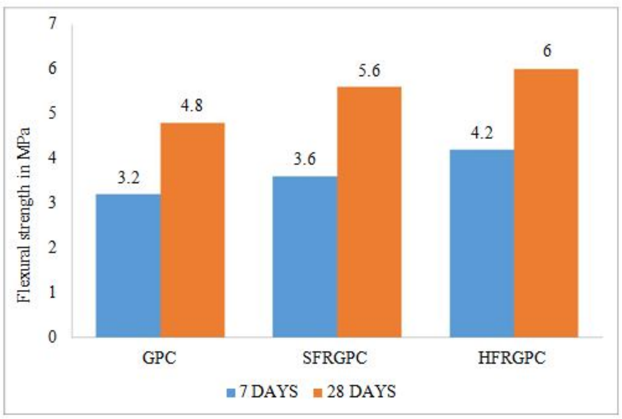

Fig. 5.4 Variation of Flexural Strength at 7th and 28th day

5.3 WATER ABSORPTION TEST

The water absorption values after 24 hours indicated that SFRGPC specimens were having lower absorption rate compared to control GPC and HFRGPC specimens. Addition of fibres to geo polymer concrete had increased the resistance of concrete to water absorption and porosity characteristics. The variation weights of specimens with time is shown in Table 6.3.

Table 5.3 Water absorption test

Concrete type	Initial Weight (kg)	Final Weight (kg)	Percentage increase In Weight (kg)	Percentage increase In Weight (kg)
GPC	8.80	9.03	2.65	2.82
	8.65	8.90	2.83	
	8.45	8.70	2.98	
SFRGPC	8.27	8.45	2.14	2.41
	8.38	8.58	2.45	
	8.12	8.33	2.63	
HFRGPC	8.41	8.64	2.74	2.68
	8.55	8.78	2.68	
	8.60	8.82	2.63	

VI. CONCLUSION

Based on the results, the following are the conclusions

1. When fibres are added to concrete, the mix becomes stiff. So the workability of Geo polymer concrete is decreased with addition of fibres.
2. Addition of fibres improved the mechanical properties of geo polymer concrete.
3. Percentage increase in compressive strength of SFRGPC was 11%when compared to GPC and 5% compared to HFRGPC.
4. Percentage increase in Split tensile strength of SFRGPC was 14.4%when compared to GPC and 6.2% compared to HFRGPC.
5. Percentage increase in Flexural strength of HFRGPC was 25%when compared to GPC and 7.2% compared to HFRGPC
6. HFRGPC did not show any significant improvement in compressive strength, but flexural strengths was improved significantly compared to GPC and SFRGPC.
7. Test results of water absorption shows that SFRGPC has shown lower water absorption of 2.41% compared to GPC and HFRGPC.
8. The Sorptivity curve of HFRGPC was found to be less linear compared to that of GPC and SFRGPC.
9. SFRGPC specimens have shown more weight loss (0.3%) compared to GPC and HFRGPC when immersed in sulphuric acid solution.
10. More weight gain in HFRGPC specimens immersed in MgSO4 was observed when compared to that SFRGPC and GPC specimens. The increase in weight may be due to the absorption of the exposed liquid.

11. More weight gain in HFRGPC specimens immersed in NaCl was observed when compared to that SFRGPC and GPC specimens.

REFERENCES

[1] Ganesan N ,Ruby Abraham and S.Deepa Raj (2015) “Durability characteristics of steel fibre reinforced geopolymer concrete” International journal of Construction and Building Materials, 93, 471–476.

[2] Faiz Uddin Ahmed Shaikh (2013) “Review of mechanical properties of short fibre reinforced geopolymer composites”, International journal of Construction and Building Materials 43, 37–49.

[3] Chunxiang Qian, Piet Stroeven (2010) “Fracture properties of concrete reinforced with steel and polypropylene hybrid fibres”, International journal of Cement and Concrete Composites, 22, 342-351.

[4] N. Banthia, M. Sappakittipakorn (2007) “Toughness enhancement in steel fiber reinforced concrete through fibre hybridization”, International journal of Cement and Concrete Research 37, 1366–1372.

[5] Mark Reed, Weena Lokuge and Warna Karunasena (2014) “Fibre-reinforced geopolymer concrete with ambient curing for in situ applications”, Journal of Material Science 49, 4297–4304.

[6] Wu Yaoa, Jie Lib and Keru Wua (2003) “Mechanical properties of hybrid fiber-reinforced concrete at low fiber volume fraction”, International journal of Cement and Concrete Research 33, 27–30.

[7] Kim hung, Johnson Alengarmam and Mohd Zamin Jumaat (2016) “Structural performance reinforced geopolymer concrete members”, Construction and Building materials, 120, 251-264.

[8] Venkata suresh G. and J.Karthikeyan (2016) “Performance enhancement of Green concrete”, Proceedings of the institution of Civil Engineers-Engineering sustainability, May 2016.

[9] Jalal Rouhl et al (2011) “The effects of polypropylene fibers on the properties of reinforced concrete structures”, International journal of Construction and Building materials, 27, 73-77.

[10] Chunxiang Qian and Piet Stroeven, (2000) “Fracture properties of concrete reinforced with steel and polypropylene hybrid fibres”, “International journal ofCement & Concrete Composites 22 (2000), 343-351”.