Available online at http://www.journalijdr.com

IJDR

ISSN: 2230-9926

International Journal of Development Research
Vol. 08, Issue, 05, pp.20245-20252, May, 2018

ORIGINAL RESEARCH ARTICLE   OPEN ACCESS

STRENGTH PROPERTIES OF FIBRE AND HYBRID FIBRE REINFORCED GEOPOLYMER CONCRETE MADE WITH LOW CALCIUM FLYASH

***[1]Eliza Edison and [2]Alester Joseph Vanreyk**

[1]M.Tech Scholar, Toc-H Institute of Science and Technology
[2]Asst. Prof, Civil Engineering Department, Toc-H Institute of Science and Technology

ARTICLE INFO

Article History:
Received 18th February, 2018
Received in revised form
10th March, 2018
Accepted 27th April, 2018
Published online 28th May, 2018

Key Words:
Plain Geopolymer Concrete, Fibreand Hybrid Reinforced Geopolymer Concrete, Low Calcium Flyash, Polypropylene Fibre, Glass Fibre, Strength Parametres.

ABSTRACT

This paper presents an experimental study on the strength properties of plain geopolymer concrete, fibre reinforced geopolymer concrete and hybrid fibre reinforced geopolymer concrete made with low calcium flyash. The strength parameters considered in this study are compressive strength, split tensile strength and flexural strength. The polypropylene fibre incorporation in 8M alkali activated geopolymer was performed by 0.5, 1, 1.5 and 2% of total volume of concrete. A maximum of 4.41%, 7.57% and 20.12% increase in compressive strength, split tensile strength and flexural strength, respectively were noticed corresponding to the addition of 2% PP fibre in GPC. The optimum was taken as 1% since the specimen had already attained a compressive strength more than the target strength and further increasing the fibre content won't be advisable considering the various limitation of excess fibres in concrete. Keeping the optimum dosage of polypropylene fibre as constant, glass fibres are added to the concrete in different proportions of this optimum dosage viz. 5%, 10%, 20%, 30% and 40% of 1% of PP fibre and the effect of these hybrids in compression, tension and flexural strength is experimentally investigated. Based on the test results, it was observed that a maximum of 11.38 %, 7.87 % and 10.67 % increase in compressive strength, split tensile strength and flexural strength respectively by 10% replacement of optimum PP fibre with glass fibre with respect to the geopolymer concrete without fibres.

Citation: Eliza Edison and Alester Joseph Vanreyk, 2018. "Strength properties of fibre and hybrid fibre reinforced geopolymer concrete made with low calcium flyash", *International Journal of Development Research*, 8, (05), 20245-20252.

INTRODUCTION

THE basic materials required for cement manufacturing are non-renewable and reducing at a rapid rate. At the same time, large amount of industrial and agro wastes with distinctive cementitious properties are produced plentifully but mostly discharged into dumps. The use of such by-products as replacement for cement has collective betterments containing environmental conservation, resource sustainability and clear up the disposal problem (PrasannaVenkatesan and Pazhani, 2015). Davidovits (1978) gave introduction to a concrete by utilizing industrial by products and alkali activatatorcalled geo polymer concrete. In geo polymer concrete hardening property is governed by condensation polymerization of binder and alkali activator. In this study low calcium flyash was used as industrial by product. Through the action of hydroxide ions from alkali activator, the dissolution of Si and Al atoms of flyash has occurred, as a result transportation and condensation of precursor ions are transformed into monomers. Then setting and poly condensation of monomers are then transformed into polymeric (Aswani and Lathi Karthi, 2017). The end product of this reaction is a three dimensional polymeric ring structure consisting of Si – O – Al – O bonds, termed as silicon oxo aluminates. The general formula describing the chemical composition of the geo polymer is given by Mn (-(SiO2)z – AlO2)n. wH2O, Where M is the alkali component (like sodium or potassium), the symbol '–' represents the presence of bond , n is the degree of polymerisation and z is the number 1, 2, 3 etc. up to 32 (Singh *et al*., 2015). Geo polymer concrete support low creep and very little drying shrinkage. Young's modulus, Poisson's ratio and Tensile strength of low calcium fly ash based geo polymer concretes acquires the characteristics similar to Portland cement concrete (DivyaKhale and Rubina Chaudhary, 2007). In geopolymer concrete fibres play a vital role in strength characteristics. In this study, two fibres are used polypropylene fibre and glass

****Corresponding author:* Eliza Edison,**
M.Tech Scholar, Toc-H Instituite of Science and Technology

fibre. This study compares the influence of variable dosages of fibres i.e. polypropylene fibre in fibre reinforced concrete and hybrid fibres (polypropylene + glass fibre) in hybrid fibre reinforced geo polymer concrete. Slump value, Compressive strength, split tensile strength and flexural strength were measured to investigate the characterization of fresh and hardened concrete.

MATERIALS AND METHODS

Flyash

Low calcium Flyash and its chemical composition was obtained from Hindustan Newsprint Limited, Velloor, Kottayam.

below with a specific gravity of 2.8 and fineness modulus of 3.02 was used and it is. confirming to IS 383.

Chemicals: A mixture of sodium hydroxide and sodium silicate was used as the alkaline solution. Sodium hydroxide in pellets form (97% purity) and sodium silicate solution having 15.9%Na_2O, 52.7% H_2O and 31.4% SiO_2 by mass were used. The molar concentration of sodium hydroxide was kept as 8M and the ratio of sodium silicate to sodium hydroxide was taken as 2.5. A naphthalene based super plasiticizer was used to improve the workability of concrete in fresh state.

Fibres: In this investigation polypropylene fibre and glass fibre are used.

Table 1. Chemical composition of flyash

Parameters	Results
Acid insoluble(%)	50.5
Al_2O_3(%)	26.53
Ash (%)	88.8
Bulk density (Kg/m^3)	4
CaO (%)	2.1
Fe_2O_3 (%)	13.2
Fineness (m^2/ Kg)	252
Loss on ignition (%)	0.60
MgO(%)	1.54
Moisture (%)	0.1
silica(%)	50
SO_3 (%)	0.41
Specific gravity	2.62

Table 2. Physical and mechanical properties of polypropylene and glass fibre

Parametres	Polypropylene Fibre	Glass Fibre
Length (mm)	12	12
Diameter (mm)	0.14	0.014
Specific gravity(g/cm^3)	0.92	1.9
Tensile strength(MPa)	400-600	1700
Youngsmodulas(GPa)	3.5-5	73

Table 3. Mix designation

ID Mix	Explanation
GC	Geopolymer Concrete
GC + 0.5%	GC+ 0.75% Polypropylene Fibre
GC + 1%	GC+ 1% Polypropylene Fibre
GC + 1.5%	GC+ 0.75% Polypropylene Fibre
GC + 2%	GC+ 0.75% Polypropylene Fibre
HGC1	1% Polypropylene fibre and glass fibre in 5% of Polypropylene fibre
HGC2	1% Polypropylene fibre and glass fibre in 10% of Polypropylene fibre
HGC3	1% Polypropylene fibre and glass fibre in 20% of Polypropylene fibre
HGC4	1% Polypropylene fibre and glass fibre in 30% of Polypropylene fibre
HGC5	1% Polypropylene fibre and glass fibre in 40% of Polypropylene fibre

Table 4. Mix proportion of geopolymer concrete with or without fibres

ID Mix	Fly ash (Kg/m^3)	Fine aggregate (Kg/m^3)	Coarse aggregate (Kg/m^3)	NaOH (Kg/m^3)	Na_2SiO_3 (Kg/m^3)	PolyPropylene Fibre (Kg/m^3)
GC	412	601.92	1222	47	117	-
GC + 0.5%	412	601.92	1222	47	117	4.6
GC + 1%	412	601.92	1222	47	117	9.2
GC+ 1.5%	412	601.92	1222	47	117	13.8
GC+ 2%	412	601.92	1222	47	117	18.4

Aggregates

M sand conforming to Zone II as per IS 383 with fineness of modulus 2.91 and specific gravity of 2.6 was used as fine aggregate. Crushed granite coarse aggregate of size 20mm and

The polypropylene fibre was collected from Bison shelter system Pvt. Ltd, Edappally and glass fibre from Shree Building Solution Pvt. Ltd, Goa. The physical and mechanical properties of both fibres are given in Table 2.

Mix proportions

Since there are no codal provisions available for the mix design of geopolymer concrete, the density of geopolymer concrete was assumed as 2400 kg/ m^3 and other calculations were based on the density of concrete as per the design given by Lloyd and Rangan (2010). The combined total volume occupied by the coarse and fine aggregate was 76%. The alkaline liquid to binder ratio was taken as 0.4. target strength of 30MPa was fixed considering as a regular strength concrete. Mix proportion was calculated based on relevant literature and is shown in Table 4. To prepare 8 molarity concentration of sodium hydroxide solution 320gm of sodium hydroxide pellets was dissolved in water and made up to one litre. The sodium hydroxide solution was prepared 24 hours prior to use, because after dissolving pellets of NaOH in water the temperature of solution goes up. Hence it is necessary to cool it at room temperature. The sodium hydroxide solution thus prepared was mixed together with sodium silicate solution to get desired alkaline solution. Then the other ingredients used for preparing geopolymer concrete are flyash, fine and coarse aggregate and were dry mixed for about 2 minutes. For fibre and hybrid fibre reinforced geopolymer concrete one more constituent was added i.e. polypropylene fibre and hybrid fibres (polypropylene + glass fibre) in relevant proportion and mixing was continued for 2 more minutes. After this the alkaline solution and superplasticizers were added to the dry materials and mixed for 4 to 5 minutes. After mixing slump of fresh concrete were determined. After that the concrete was placed in steel mould by giving proper compaction. Two types of curing were adopted. Cubes and cylinders were oven cured (75℃ for 8hrs) after demoulding and after 8hrs they were allowed to cure in the room temperature till the required day of testing. For ambient curing, the beams were kept in room temperature after casting and demoulded after 2 days and further cured in room temperature till the day of testing. The specimens were tested at 7 and 28 days from the day of casting.

Test conducted

Workability test- slump cone test

The workability of geopolymer concrete, fibre reinforced geopolymer concrete and hybrid reinforced geopolymer concrete was conducted using slump cone test. The method of test was confirming to IS 1199: 1959 (reaffirmed 2013). The apparatus used for doing slump test are slump cone and tamping rod. In slump test, fresh concrete was filled in layers and tamped using tamping rod. The slump was measured in millimetres.

Compressive strength test

The compressive strength of geopolymer, fibre reinforced, and hybrid fibre reinforced geopolymer concrete was tested as per IS 516 : 1959. Cube specimens of size 150mm were cast for each proportion and tested for their compressive strength at the ages of 7 and 28 days. All the oven cured specimens (75 degree Celsius for 8 hours) were tested using compression testing machine (CTM) of 2000 KN capacity under a uniform rate of loading of 140 kg/cm^2/min until failure and the ultimate load at the failure was taken to calculate the compressive strength.

Split tensile strength test

The split tensile strength test of geopolymer, fibre reinforced and hybrid fibre reinforced geopolymer concrete was carried out as per IS 5816: 1999. Cylindrical concrete specimens of size 150 mm diameter and 300 mm height were cast. The oven cured (75 degree Celsius for 8 hours) specimens were then tested for their splitting tensile strength using compression testing machine (CTM) of 2000 KN capacity at the ages of 7 and 28 days

Flexural strength test

The flexural strength of of geopolymer, fibre reinforced and hybrid fibre reinforced geopolymer concrete was carried out as per IS 516: 1959. Beams of size 100 mm x 100 mm x 500 mm size were cast and ambient cured for 28 days. Then it was subjected to flexural strength test using Universal Testing Machine

RESULT AND DISCUSSION

Fibre Reinforced Geopolymer Concrete

Workability

The slump test on polypropylene fibre reinforced concrete was performed as per IS 1199 -1959 which is similar to conventional concrete. The slump test is used to characterize the workability of fresh fibre reinforced geopolymer concrete.

Table 5. Mix proportion of hybrid fibre reinforced geopolymer concrete

ID Mix	Fly ash (Kg/m^3)	Fine aggregate (Kg/m^3)	Coarse aggregate (Kg/m^3)	NaOH (Kg/m^3)	Na_2SiO_3 (Kg/m^3)	PolypropyleneFibre (Kg/m^3)	Glass fibre (Kg/m^3)
HGC1	412	601.92	1222	47	117	8.74	0.46
HGC2	412	601.92	1222	47	117	8.28	0.92
HGC3	412	601.92	1222	47	117	7.36	1.84
HGC4	412	601.92	1222	47	117	6.44	2.76
HGC5	412	601.92	1222	47	117	5.52	3.68

The slump of the mix varied depending upon the molar strength of sodium hydroxide solution, ratio of silicate to hydroxide solution workability aids and extra water added to the mix. The rheological parameters such as yield stress and plastic viscosity were attempted over slump test of concrete to assess its workability loss and flow behaviour. yield stress gives initial resistance to flow arose from friction among the solid particles while plastic viscosity governs the flow after it is initiated resulting from viscous dissipation due to the movement of water in sheared material. (Singh *et al*., 2015).

By adding fibre to GPC concrete slump value decreases. Addition of 1% of PP fibre in GPC decreases the slump value to 62mm. The slump value was decreased to 60mm and 58mm corresponding to the fibre content of 1.5% and 2%. The increase in fibre content results in significant reduction in flow ability of fresh matrices it may be due to the higher shear resistance to flow, hydrophobic characteristics of PP Fibre lead to weak contact with the binder in fresh state.

Table 6. Slump value of fibre reinforced geopolymer concrete

Sl No	Mix Designation	Slump Value (mm)
1	GC	69
3	GC + 0.5%	65
4	GC + 1%	62
5	GC + 1.5%	60
6	GC + 2%	58

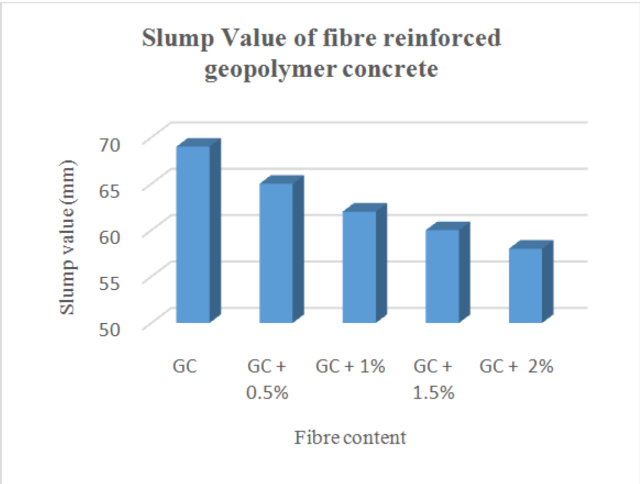

Fig. 1. Slump value of fibre reinforced geopolymer concrete

Compressive Strength

The compressive strength test was conducted as per IS 516-1959 (reaffirmed in 1999). Oven cured cube specimens are tested in compression testing machine (200 tonne capacity). The compressive strength results of concrete specimens which were activated using 8M alkaline solution and polypropylene fibre reinforced geopolymer concrete was given in table VI .The compressive strength of low calcium fly ash based geopolymer concrete at 7day and 28day were 33.44 MPa and 35.85 MPa respectively The maximum improvement was obtained by 2% inclusion of polypropylene fibre, which led to produce a composite having 38.4MPaand 40.56MPa compressive strength at the age of 7th and 28 days respectively. A maximum of 13.13% increase in compressive strength was noticed corresponding to the addition of 2% PP fibre in GPC. But the optimum was taken as 1% since the specimen had already attained a compressive strength more than the target strength and further increasing the fibre content wont be advisable considering the various limitation of excess fibres in concrete. The percentage increase in compressive strength of 1% pp fibre addition in geopolymer concrete was 9.34% as compared to normal geopolymer concrete. The increase in strength of GPC may be due to the crack arresting effect of fibres. The compressive strength corresponding to 0.5%, 1% and 1.5% PP fibre reinforced geopolymer concrete at 28 days are 36.77, 39.2 and 40.29 MPa respectively.

Split Tensile Strength

The split tensile strength test was conducted as per IS 5816-1999. Oven cured cylindrical specimens were tested in compression testing machine (200 tonne capacity).The split tensile strength of geopolymer concrete and polypropylene fibre reinforced concrete are shown in table VII. As seen in the compressive strength results, the split tensile strength also increased with the curing age. The split tensile strength of low calcium based fly ash geopolymer concrete obtained a strength of 3.09 MPa and 3.30 MPa at 7day and 28day respectively. The 7 day and 28 day cured specimen of 1% PP fibre reinforced geopolymer concrete gained a strength of 3.25 MPa and 3.48 MPa respectively. The addition of 2% volume fraction of PP Fibre shows maximum increase in split tensile strength i.e. 15.15% with respect to geopolymer mix. Increase in split tensile strength may be due to the bridging action of the fibres across the cracks.

Table 7. Compressive strength of fibre reinforced concrete

Compressive Strength (MPa)			
Sl No	Mix Designation	7th day	28th day
1	GC	33.44	35.85
2	GC + 0.5%	34.16	36.77
3	GC + 1%	36.04	39.20
4	GC + 1.5%	37.72	40.29
5	GC + 2%	38.40	40.56

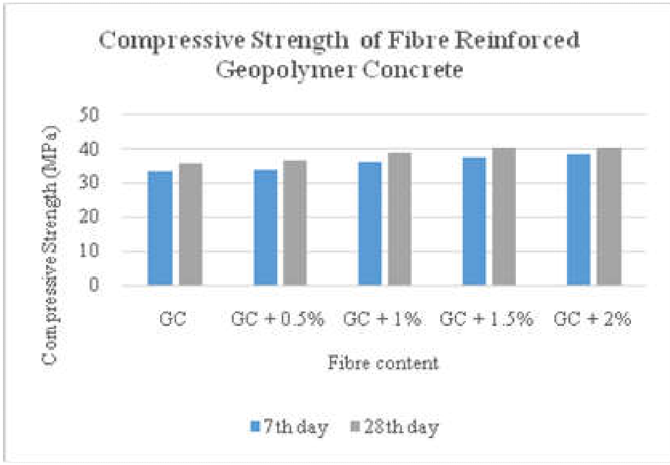

Fig. 2. Compressive strength of fibre reinforced concrete

Table 7. Split tensile strength of fibre reinforced concrete

SPLIT TENSILE STRENGTH (MPa)			
Sl No	Mix Designation	7th Day	28th day
2	GC	3.09	3.30
3	GC + 0.5%	3.11	3.33
4	GC + 1%	3.25	3.48
5	GC + 1.5%	3.31	3.55
6	GC + 2%	3.48	3.8

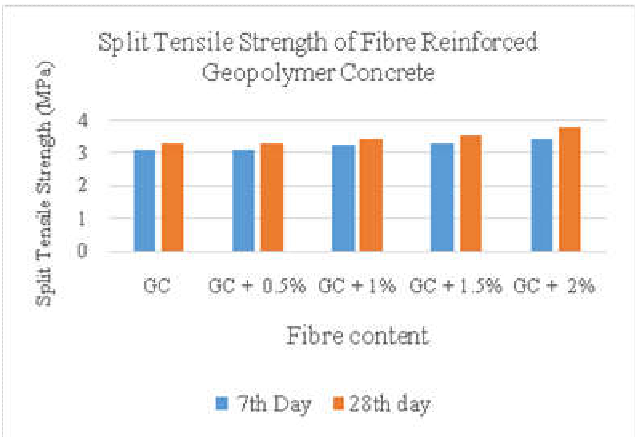

Fig. 3. Split tensile strength of fibre reinforced geopolymer concrete

Flexural Strength

The flexural strength test was conducted as per IS 516-1959 (reaffirmed in 1999). Ambient cured beams are tested in UTM (100 KN capacity) with two point loading setups. The flexural strength of normal geopolymer concrete obtained was 3.28 MPa. From the result it can be observed that the flexural strength of geopolymer concrete was increased as the volume fraction upto 2%. The addition of 1% PP fibre increased flexural strength by 9.14 % with respect to normal GPC mix without fibres. Flexural strength of fibre reinforced geopolymer concrete are shown in Table 8.

Table 8. Flexural strength of fibre reinforced geopolymer concrete

Flexural Strength (MPA)		
SL NO	Mix Designation	28^{th} day
1	G	3.28
2	GC + 0.5%	3.46
3	GC +1%	3.58
4	GC + 1.5%	3.66
5	GC + 2%	3.94

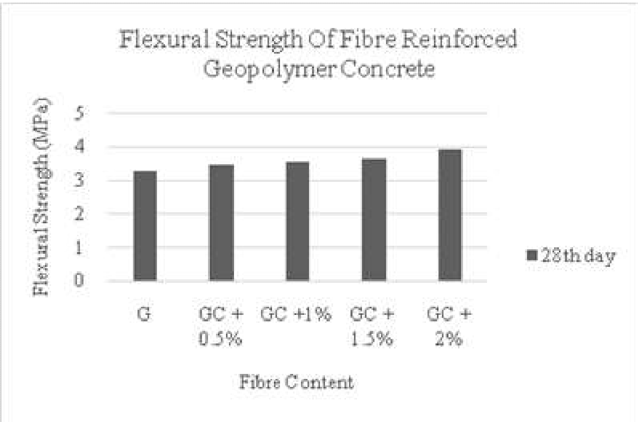

Fig. 4. flexural strength of fibre reinforced geopolymer concrete

Hybrid Fibre Reinforced Concrete

From the result of polypropylene fibre reinforced concrete it was clear that addition of 2% of polypropylene fibre to 8M alkali activated geopolymer composite gives high strength in compressive, split tensile and flexural tests. . But the optimum was taken as 1% since the specimen had already attained a compressive strength more than the target strength and further increasing the fibre content wont be advisable considering the various limitation of excess fibres in concrete and attained a compressive strength of 39. 20 MPa at 28day curing age.

Workability

Workability of hybrid fibre reinforced geopolymer concrete was characterised using slump cone test and shown in table IX. By replacing 1% PP Fibre with 10% of glass fibre by weight had a slump value of 60 mm. The slump value was decreased to 59mm, 57mm and 54mm corresponding to glass fibre weight at 20%, 30% and 40% of optimum.

Compressive Strength

The compressive strength test on hybrid fibre reinforced geopolymer concrete was conducted as per IS 516-1959 (reaffirmed in 1999) and shown in table X . Oven cured cube specimens are tested in compression testing machine (200 tonne capacity). By replacing 1% of PP fibre with 10 % of glass fibre by weight gained a compressive strength of 37.63 MPa and 39.93 at 7 day and 28 day curing age. The replacement of 1% PP fibre with 10% glass fibre increased compressive strength by 11.38% with respect to normal GPC mix without fibres and 1.86% with respect to the optimum of polypropylene fibre. Then the 28day compressive strength was decreased to 38.74MPa, 38.45 MPa and 38.12 MPa corresponding to glass fibre weight at 20%, 30% and 40% of optimum PP fibre respectively.

Table 9. Slump value of hybrid fibre reinforced geopolymer concrete

Sl No	Mix designation	Slump value (mm)
1	HGC1	63
2	HGC2	60
3	HGC3	59
4	HGC4	57
5	HGC5	54

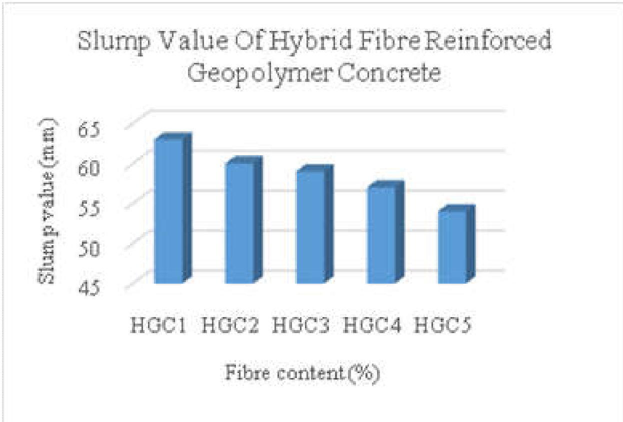

Fig. 5. slump value of hybrid fibre reinforced geopolymer concrete

Table 10. Compressive strength of hybrid fibre reinforced geopolymer concrete

COMPRESSIVE STRENGTH (MPa)			
Sl no	Mix designation	7^{th} day	28^{th} day
1	HGC1	36.96	37.92
2	HGC2	37.63	39.93
3	HGC3	37.56	38.74
4	HGC4	37.34	38.45
5	HGC5	36.98	38.12

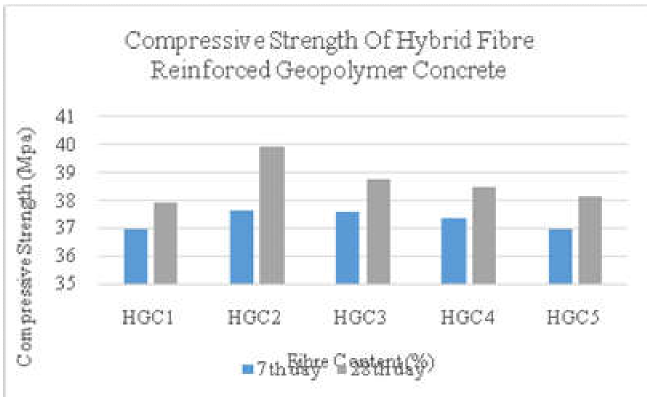

Fig. 6. Compressive strength of hybrid fibre reinforced geopolymer concrete

Split Tensile Strength

The split tensile strength test was conducted as per IS 516-1959 (reaffirmed in 1999) and shown in table XI. Oven cured cylinderical specimens are tested in compression testing machine (200 tonne capacity). By replacing 1% PP fibre with 10% of glass fibre by weight gained a tensile strength of 3.42 MPa and 3.56 at 7 day and 28 day curing age. The replacement of 1% PP fibre with 10% glass fibre increased split tensile strength by 7.87%with respect to normal GPC mix without fibres. Then the 28day compressive strength was decreased to 3.47 MPa, 3.44MPa and 3.39MPa corresponding to glass fibre weight at 20%, 30% and 40% of optimum PP fibre respectively.

Table 11. Split tensile strength of hybrid fibre reinforced geopolymer concrete

Split tensile strength (MPa)			
Sl no	Mix designation	7th day	28th day
1	HGC1	3.34	3.43
2	HGC2	3.42	3.56
3	HGC3	3.38	3.47
4	HGC4	3.35	3.44
5	HGC5	3.32	3.39

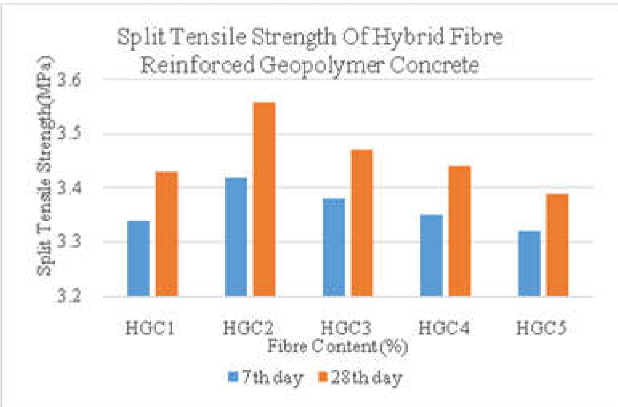

Fig. 7. Split tensile strength of hybrid fibre reinforced geopolymer concrete

Table 12. Flexural strength of hybrid fibre reinforced geopolymer concrete

Sl no	Mix designation	28th day strength (MPa)
1	HGC1	3.42
2	HGC2	3.63
3	HGC3	3.59
4	HGC4	3.57
5	HGC5	3.54

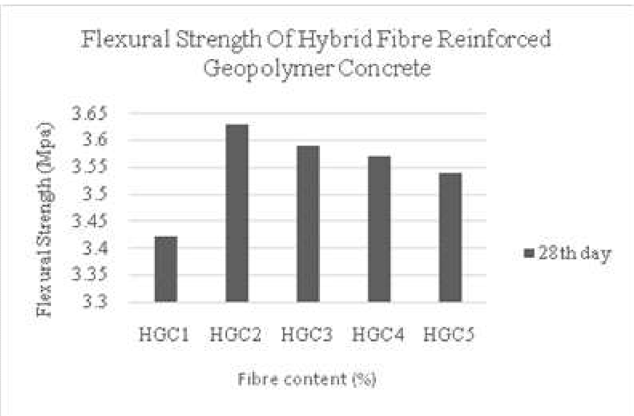

Fig. 8. Flexural strength of hybrid fibre reinforced geopolymer concrete

Flexural Strength

The flexural strength test on hybrid fibre reinforced geopolymer concrete was conducted as per IS 516-1959 (reaffirmed in 1999) and shown in table XII. Ambient cured beam specimens were tested in UTM (100 KN capacity) with two point loading setups. By replacing 1% PP fibre with 10% of glass fibre by weight gained a flexural strength of 3.63 MPa at 28 day curing age. The replacement of 1% PP fibre with 10% glass fibre increased flexural strength by 10.67% with respect to normal GPC mix without fibres. Then the 28day compressive strength decreased to 3.59 MPa, 3.57 MPa and 3.54MPa corresponding to glass fibre weight at 20%, 30% and 40% of optimum PP fibre respectively.

Conclusion

- The addition of PP fibre in GPC shows an increase in strength parameters with respect to GPC without fibres.
- A maximum of 13.13 %, 7.57 % and 20.12% increase in compressive strength, split tensile strength and flexural strength respectively were noticed by the addition of 2% PP fibre with respect to 8 molar alkali activated GPC. The optimum was taken as 1% since the specimen had already attained a compressive strength more than the target strength and further increasing the fibre content won't be advisable considering the various limitation of excess fibres in concrete.
- 10% replacement of 1% PP fibre with glass fibre shows maximum increase in strength parameters.
- A maximum of 11.38 %, 7.87 % and 10.67 % increase in compressive strength, split tensile strength and flexural strength respectively were noticed in Hybrid fibre reinforced geopolymer concrete with respect to the geopolymer concrete without fibres.

REFERENCES

Arunakanthi, E. and Chaitanya Kumar. J.D. 2016. Experimental Studies On Fibre Reinforced Concrete, *International Journal Of Civil Engineering*, 7, pp. 329-336.

Aswani, E. and Lathi Karthi, 2017. A literature review on fibre reinforced geopolymer concrete, *International Journal of Scientific and Engineering Research*, 8, pp. 408-411.

Behazadnemattollahi, Jay sanjayan and Faiz Uddin Ahmed Shaikh, 2014. comparative deflection hardening behaviour of short fibre reinforced geopolymer composites, *Construction And Building Materials*, 70, pp. 54-64.

Bhalchandra S. A., Bhosle A. Y. 2013. Properties of glass fibre reinforced geopolymer concrete, *International Journal of Modern Engineering Research*, 3, pp. 2007-2010.

Damu, J T. Thaarini, S.B. and Venkatasubramani, R. 2015. strength studies on geopolymer concrete using steel and polypyopylene fibres, *International Journal Of Applied Engineering Research*, 10, pp. 14088-14092.

Divya Khale and Rubina Chaudhary, 2007. Mechanism Of Geopolymerization And Factors Influencing Its Development A Review, *Journal Of Material Science*, 42, pp. 729-746.

Dylmar Penteado Dias and ClelioThaumaturgo, 2005. Fracture toughness of geopolymeric concretes reinforced with basalt fibres DylmarPenteado Dias, ClelioThaumaturgo, *Cement and Concrete Composites*, 27, pp. 49–54

Enther Thanon Dawood and Mahynddin Ramli, 2011. contribution of hybrid fibres on the properties of high strength concrete having high workability, *procedia engineering,* 14, pp. 814-820.

Eswaramoorthi P. and Arunkumar G.E. 2014. Fibres Study On Properties Of Geopolymer concrete With Polypropylene, *International Refereed Journal of Engineering and Science*, 3, pp. 60-75.

Gao. Q. L. Yu. R. Yu. and Brouwers, H. J. H. 2017. Evaluation of hybrid steel fibre reinforcement in high performance geopolymer composites, *Materials and Structures*, 50, pp. 1-14.

Harini, B.R. and Elangovan, P. 2015. Experimental Study on Flexural behaviour of Hybrid Fibre Reinforced Concrete with Elastomeric Pads, *Bonfring International Journal of Industrial Engineering and Management Science*, 5, pp. 67-72.

Ilakya Lakshmi, T. 2016. Experimental studies on flexural behaviour of reinforced concrete beams with glass fibre, *International conference on current research in engineering science and technology*, pp. 28-33.

Indian Standard Methods of sampling and analysis, IS 1199:1959 (Reaffirmed 1999) of concrete, Bureau of Indian standards, New Delhi

Indian Standard Methods of test for aggregates for concrete: Part I particle size and shape, Bureau of Indian standards, New Delhi, IS 2386 (part I):1963 (Reaffirmed 2011)

Indian Standard Methods of test for aggregates for concrete: Part III specific gravity, density, voids, absorption and bulking,Bureau of Indian standards, New Delhi, IS 2386 (part III):1963 (Reaffirmed 2011)

Indian Standard Methods of test splitting tensile strength of concrete, Bureau of Indian standards, New Delhi, IS 5816:1999 (Reaffirmed 2004)

Indian Standard Methods of tests for strength of concrete, Bureau of Indian standards, New Delhi, IS 516:1959 (Reaffirmed 1999)

Indian Standard Plain and reinforced concrete code of practice (Fourth), IS 456:2000 Revision), Bureau of Indian standards, New Delhi.

Indian Standard Specification for coarse and fine aggregates from natural source for concrete, Bureau of Indian standards, New Delhi, IS 383:1970 (Reaffirmed 2016)

Joshua Daniela, A., Sivakamasundaria, S. and Abhilasha, D. 2017. Comparative Study on the Behaviour of Geopolymer Concrete with Hybrid Fibres under Static Cyclic Loading, *Procedia Engineering*, 173, pp. 417 - 423

Kolli Ramujee and Potharaju, M. 2013. Development of mix design for low calcium based geopolymer concrete in low, medium and higher grades-Indian scenario, *J. Civil engineering and technology*, 1, pp. 15-25.

Korniejenko, K., Fraczek, E., Pytlak, E. and Adamski, M. 2016. Mechanical properties of geopolymer composites reinforced with natural fibres, *Procedia Engineering* ,151 ,pp. 388 -393.

Lloyd, N A. and Rangan, B V. 2010. Geopolymer concrete with fly ash, *International Conference on sustainable construction materials and technologies*.

Mahyuddin Ramli and Eether Thanam Dawood, 2011. Study The Hybridation Of Different Fibres On The Mechanical Properties Of Concrete: A Mini Review, *Asian Journal Of Applied Science*, 4, pp. 489-492.

NavidRanjbar, Sepepr Talebian, Mehdi Mehrali, Carsten kuenzel, Hendrik Simon Cornelis Metsel and MohdZamin Jumaat, 2016. mechanisms of interface bond in steel and polypropylene fibre reinforced geopolymer composites, *Composites Science and Technology*, 122, pp. 73-81.

Nisha Khamar and Resmi V Kumar, 2013. Properties of Hybrid Fibre Reinforced Geopolymer Concrete under Ambient Curing, *International Journal of Science and Research*, 4, pp. 729-734.

Patil, S. S. and Patil A. A. 2015. Properties of Polypropylene Fibre Reinforced Geopolymer Concrete, *International Journal of Current Engineering and Technology*, 5, pp. 2909-2912.

Prasanna Venkatesan, R. and Pazhani, K. C. 2015. Strength and durability properties of geopolymer concrete made with ground granulated blast furnace slag and black rice husk ash, *journal of civil engineering,* pp. 1-8

Ragthi, V.R., ghogure, A.V. and Nawale, S.R. 2014. Experimental study on glass fibre reinforced concrete moderate deep beam, *International Journal Of innovative Engineering Sciences and Research Technology*, 3, pp. 10639-10645.

Santosh, P., Sai Kumar, AVS. and Gangadhar, VVRLS. 2016. Flexural Response Of Hybrid Fibre Reinforced Geo Polymer Concrete, *International Journal Of Engineering Sciences and Research Technology*, 5, pp. 759-767.

Sathish Kumar, BlessenSkariah Thomas and Alex Christopher 2012. An Experimental Study on the Properties of Glass Fibre Reinforced Geopolymer Concrete , *International Journal of Engineering Research and Applications* , 2, pp. 722-726.

Selina Ruby, G., Geethanjali, C., Jaison Varghese and Muthupriya, P. (2014), Influence Of Hybrid Fibre On Reinforced Concrete, *International Journal Of Advanced Structures And Geotechnical Engineering*, 3, pp. 40-43.

Shaikh, F.U.A. 2013. Deflection hardening behaviour of short fibre reinforced fly ash based geopolymer composites, *Materials and Design*, 50, pp. 674-682.

Shrikant M Harle and Sarang M Dhawade, 2014. Geopolymer Concrete With Glass Fibre Reinforcement And Its Properties, *International Journal Of Scientific And Engineering Research And Technology,* pp.1294-1296.

Singh, B., Ishwarya, G. and Bhattacharya, S. K. 2015. Geopolymer Concrete A Review Of Some Recent Developments, *Construction And Building Materials*, 85, pp. 78-90

Sofi, A. and Phanikumar, B.R. 2015. An Experimental Investigation On Flexural Behaviour Of Fibre Reinforced Pond Ash Modified Concrete, *Ains shams engineering journals*, 6, pp. 1133-1142.

SubbiahIlamvazhuthi, S. and Dr. Gopalakrishna, G.V T. 2013. Performance of geopolymer concrete with polypropylene fibres, *International journal of innovations in engineering and technology*, 3, pp. 148-156.

Sundar, R., Saravana, G. and sagthesh, V.S. 2017. Flexural behaviour of Polypropylene Fibre Reinforced concrete, *International Journal of Engineering Science and computing*, pp. 5507-5511.

Thamer Alomayri, 2017. Effect of Glass Microfibre Addition On The Mechanical Performance Of Flyash Based Geopolymer Composites, *Journal Of Asian Ceramic Societies*, pp. 1-8

Venugopal, V. and Arthanareswaran, R. 2015. Experimental Study on Strength Properties of Polypropylene Fibre Reinforced Geopolymer Concrete, *International Journal of Innovative Research in Science Engineering and Technology*, 4, pp. 32-40

Vijai, K, R., Kumuthaa and Vishnuramb, B.G. 2012. Properties Of Glass Fibre Reinforced Geopolymer Concrete Composites, *Asian Journal Of Civil Engineering Building And Housing*, 13, pp. 511-520.

Yaowa, 2000. Flexural strength and behaviour of polypropylene fibre reinforced concrete beams, *journal of wahan university*, 17, pp. 54-57.

Yuwaraj, M. Ghugal and Santhose B Deshmukh, 2006. Performance of Alkali-resistant Glass Fibre Reinforced Concrete, *Journal of Reinforced Plastics And Composites*, 25, pp. 617- 630.

****