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Research Article

Properties of Polypropylene Fiber Reinforced Geopolymer Concrete

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Abstract

This paper presents results of an experimental program to determine mechanical properties of Polypropylene Fibre Reinforced Geopolymer Concrete (PFRGPC) which contains fly ash, alkaline liquids, fine & course aggregates & polypropylene fibers. The effects of inclusion of polypropylene fibers on compressive strength, split up tensile strength & flexural strength of hardened geopolymer concrete (GPC) composite was studied. Alkaline liquids to fly ash ratio were fixed as 0.5 with 100% replacement of ordinary portland cement (OPC) by fly ash. Alkaline liquid consists of sodium hydroxide (NaOH) and sodium silicate (Na_2SiO_3) solutions. The ratio of Sodium hydroxide solution to Sodium silicate solution was fixed to 2.50. Polypropylene fibers were added to the mix in two different lengths of 12mm and 20mm and also the hybridization of both polypropylene fibers was mixed in volume of concrete. Based on the test results, it was observed that the PFRGPC have relatively higher strength than GPC & OPC concrete.

Keywords: *Geopolymer, Polypropylene, Workability, Compressive Strength, Flexural Strength, Split Tensile Strength.*

1. Introduction

The worldwide infrastructure development growing, demand for concrete as construction material is increase exponentially, which ultimately increase the demand for cement. Production of Ordinary Portland cement is highly energy intensive, consume significant amount of non renewable natural resources such as lime stone deposition, coal etc. & the production of 1 ton of cement emits 1 ton of CO2 i.e. carbon dioxide which cause that global warming condition (Raijiwala D.B *et al*, 2011). The cement is primary binder material of concrete and other hand there is huge quantity of fly ash generated from thermal power plant, which is used for landfill in low level areas. So the Fly ash is an alternative binder material for OPC that can be used for concreting. The fly ash contains huge quantity of Al and Si material.

Davidovits (1988) proposed that an alkaline liquid could be used to react with the Silicon (Si) & Aluminum (Al) in source material of geological origin or in byproduct material such as Fly ash, there is polymerization process during the reaction so this is named as Geopolymer concrete (N. A. Lloyd *et al*, 2010). High early strength, low shrinkage, freeze thaw resistance, sulphate resistance, & corrosion resistance are the properties of geopolymer concrete (N. A. Lloyd *et al*, 2010). But this geopolymer concrete is required to complete polymerization process by heating process. Low calcium (ASTM class F) fly ash is preferred as source material than high- calcium (ASTM class c) fly ash. The presence of calcium in high amount may interfere with polymerization process and alter the micro structure (Gourley and Johnson 2005). Palomo *et al* (1999) suggested that pozzolans such as blast furnace slag might be activated using alkaline liquids to form a binder and hence totally replace the OPC in concrete by fly ash (P.Eswaramoorthi *et al*, 2004).

2. Experimental Investigations

2.1 Materials

The materials used for making polypropylene fibers reinforced geopolymer concrete are Low calcium dry fly ash as source material, alkaline liquids, course & fine aggregates, polypropylene fibers.

2.1.1 Fly ash

Low calcium, Class F (American Society for Testing and Materials 2001) dry fly ash obtained from the JSW Energy Ltd. Jaigad through Ultratech Cement Limited, Unit: Narmada Cement, Ratnagiri. It can be seen that this fly ash contained a very low percentage of carbon as indicated by the low Loss on Ignition (LOI) values.

2.1.2 Alkaline Liquid

A combination of sodium silicate solution and sodium hydroxide solution was chosen as the alkaline liquid.

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The sodium hydroxide solids were either a technical grade in pellets form (3 mm), with a specific gravity of 2.130, 98% purity. The sodium hydroxide (NaOH) solution was prepared by dissolving either the flakes or the pellets in water. Sodium Silicate was obtained from Amba Industries, Shiroli MIDC Kolhapur Maharashtra. The chemical composition of the sodium silicate solution was Na2O=14.33%, SiO2=33.10%, and water 52.57% by mass.

2.1.3 Fine aggregate

Locally available sand is used. The specific gravity of 2.857 and fineness modulus of 3.895 are used as fine aggregate. The water absorption is of 1%.

2.1.4 Coarse aggregate

20MSA:-Crushed aggregate available from local sources has been used. The coarse aggregates with maximum size of 20mm having the specific gravity value of 3.03. The water absorption is of 0.55 %.

2.1.5 Fiber

In this investigation polypropylene fiber of 12mm and 20mm in length are used.

2.2 Mix design for Polypropylene *fiber reinforced Geopolymer concrete*

The primary difference between Geopolymer concrete and ordinary Portland concrete is the binder. The silica and aluminum oxides in low calcium fly ash with react the alkaline solution to form geopolymer paste that binds the loose coarse aggregate, fine aggregate and other un-reacted material together to form geopolymer concrete. Also as in case of OPC the aggregate occupied 70-80% of the total mass of concrete. The ratio of sodium silicate to sodium hydroxide solution was fixed at 2.5 for all the mixtures because the sodium silicate is cheaper than the sodium hydroxide solution. The molarity of NaOH solution was taken as 10M.

Mix Proportion

Table1: Mix proportions for geopolymer concrete with & without Polypropylene fibers

ID Mix	Fly ash (Kg/m^3)	Fine aggregate (Kg/m^3)	Course aggregate (Kg/m^3)	NaoH Sol^n (Kg/m^3)	Na2SiO3 Sol^n (Kg/m^3)	Polypropylene fibers in (Kg/m^3)
GPC 0% fiber	368.91	581.03	1171.29	52.86	132.14	0.00
GPC1 1.5% Fiber of 12 mm	368.91	581.03	1171.29	52.86	132.14	14.19
GPC2 1.5% fiber of 20mm	368.91	581.03	1171.29	52.86	132.14	14.19
GPC3 0.75% fiber of 12mm + 0.75% fiber of 20mm	368.91	581.03	1171.29	52.86	132.14	7.095+ 7.095

2.3 Preparation of Geopolymer concrete composites

To prepare 10 molarity concentration of Sodium hydroxide solution 400gm of Sodium hydroxide pellets was dissolved in distilled water & make up to one liter. The Sodium hydroxide solution was prepared 24 hours prior to use, because after dissolving flakes of NaOH in water, temperature of solution goes up to 70^0c to 80^0c, hence it is necessary to cool it at room temperature & then it can be used. The Sodium hydroxide solution thus prepared was mixed together with Sodium silicate solution to get desired alkaline solution. The solid constituents of geopolymer concrete mix i.e. fly ash, fine & course aggregates, were dry mixed for about three minutes. Then alkaline solution added to dry mix thoroughly for four minutes to get homogeneous mix. For Polypropylene fibers reinforced geopolymer concrete mixes, fibers were added to dry mix in three different proportions such as 1.5% of 12mm PPF,1.5%of 20mm PPF,0.75%of 12mm ppf + 0.75% of 20mm PPF by volume of concrete. In this experimental work, 150 X 150 X 150mm size cubes, & 100 X 100 X 500mm size beams, and 150 mm dia., 300mm length cylinders were cast for testing of compressive, flexural & Split Tensile strength. After 24 hours of casting all specimens were demoulded & then placed in an oven for thermal curing (heating) at specified temperature of 60^0C for eight hours duration. Then specimens were removed from oven & kept at room temperature. After 28 days, weight of specimens was taken to determine density & tests for compressive strength, Flexural strength & Split tensile Strength were conducted. Workability is carried out by conducting the slump test and compaction factor test as per I.S. 1199-1959 on Fly ash based Geopolymer concrete and Geopolymer concrete with fiber.

3. Experimental Results

All category samples are tested & analyzed for properties of Fresh concrete i.e. Slump, Compaction Factor & Density. These samples are also tested for properties of Hardened concrete i.e. Compressive Strength, Split tensile strength, Flexural Strength.

3.1 Fresh Concrete

The result of Slump Cone Test, Compaction Test, And Density of GPC & fiber reinforced GPC is shown in Table 2 and Fig. 1, Fig. 2, Fig. 3.

Table 2 Properties of Fresh Geopolymer Concrete

Mix ID	Slump Value (mm)	Compaction Factor	Density of concrete (kg/m^3)
GPC 0% fiber	65	0.920	2472.69
GPC1 1.5% fiber of12mm	26	0.880	2532.34
GPC2 1.5% fiber of 20mm	27.6	0.864	2558.03
GPC3 0.75% fiber of 12mm + 0.75% fiber of 20mm	26.8	0.900	2524.44

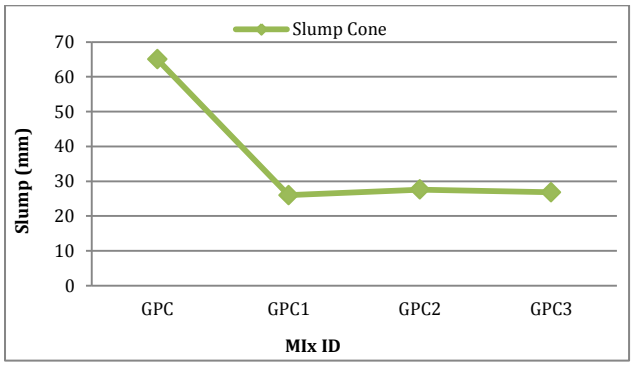

Fig.1 Slump Cone Test

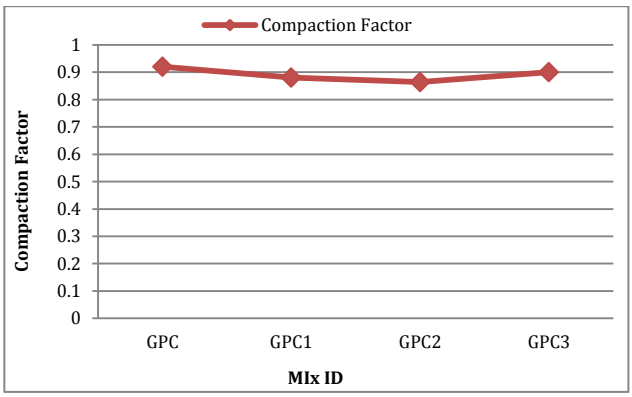

Fig.2 Compaction Factor Test

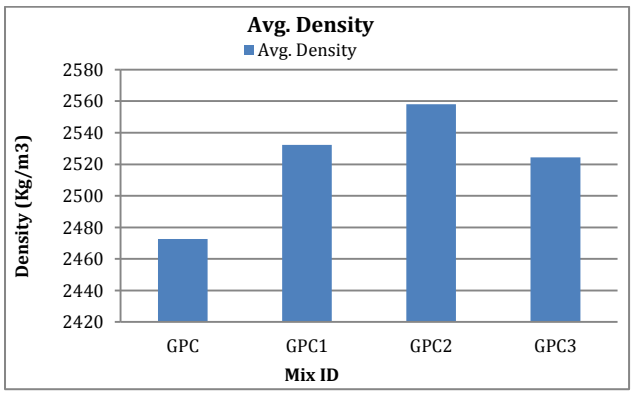

Fig.3 Density of Concrete

4. Result and discussion

4.1 Compressive strength

The result of compressive strength is shown in Table 3 and Fig. 4

Table 3 Compressive Strength of Geopolymer Concrete

Mix ID	Avg. Comp. 'P' load in KN	Avg. Comp. strength in Mpa	% increase in strength
GPC	807.37	35.88	-
GPC1	859.896	38.21	6.097%
GPC2	882.135	39.206	8.483%
GPC3	871.2	38.72	7.335%

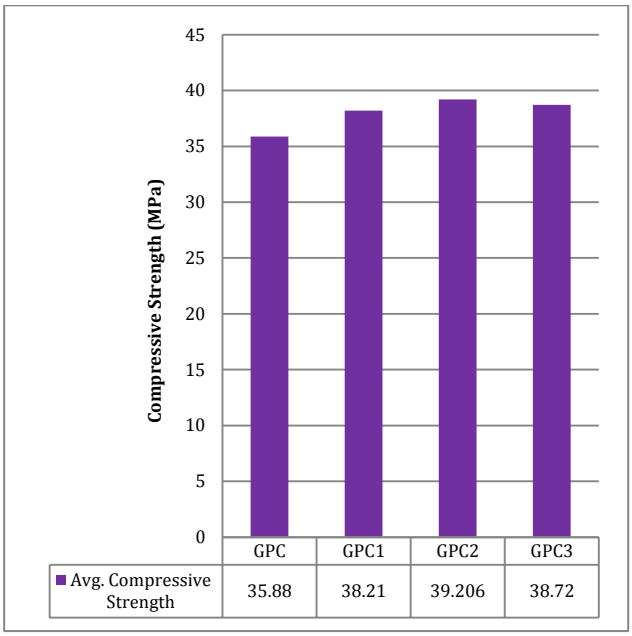

Fig.4 Compressive Strength

4.2 Split up Tensile Strength

The result of Split Tensile Strength is shown in Table 4 and Fig. 4

Table 4 Split Tensile Strength of Geopolymer Concrete

Mix ID	Avg. Load 'P' in KN	Avg. Split Tensile strength in Mpa	% increase in strength
GPC	257.997	3.65	-
GPC1	277.087	3.92	6.887%
GPC2	294.72	4.16	12.259%
GPC3	286.277	4.05	9.876%

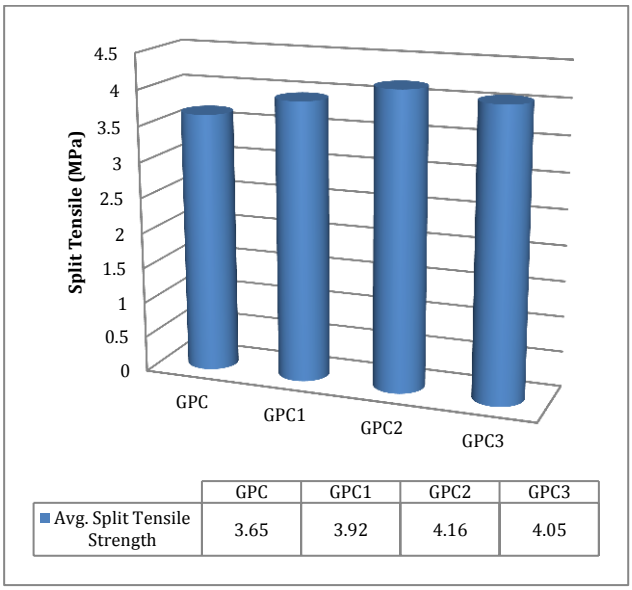

Fig.5 Split Tensile Strength

4.3 Flexural Strength

The result of Flexural Strength is shown in Table 5 and Fig. 6

Table 5 Flexural Strength of Geopolymer Concrete

Mix ID	Avg. load 'P' in KN	Avg. Flexural strength in Mpa	% increase in strength
GPC	24.49	10.28	-
GPC1	27.74	11.65	11.76%
GPC2	30.30	12.73	19.25%
GPC3	28.81	12.10	15.04%

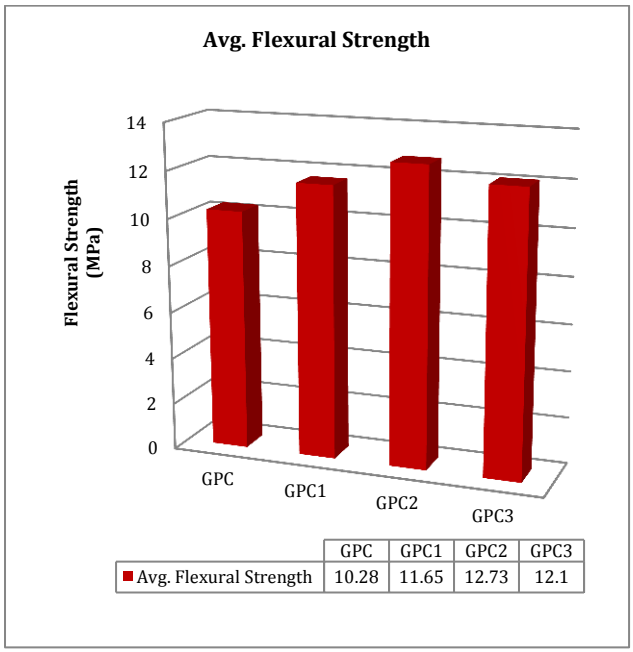

Fig.6 Flexural Strength

Conclusion

The following conclusions could be drawn from the present investigation.

1. Geopolymer concrete is an excellent alternative to Portland cement concrete.
2. Density of Geopolymer concrete is similar to that of ordinary Portland cement concrete.
3. Low calcium fly ash based Geopolymer concrete has excellent compressive strength within short period (3 days) & suitable for structural applications. Inclusion of polypropylene fibers in Geopolymer concrete shows considerable increase in compressive, Split tensile & flexural strength of GPC with respect to GPC without fibers.
4. Compressive strength, Split Tensile Strength & Flexural strength of polypropylene fiber reinforced geopolymer concrete increases with respect to increase in percentage volume fraction of polypropylene fibers from 1.5% of 12mm, 1.5% of 20mm & 1.5% hybrid Polypropylene fiber (0.75% of 12mm + 0.75% of 20mm).
5. Addition of 1.5% volume fraction of polypropylene fibers of 20mm shows maximum increase in Compressive strength, Split tensile Strength & Flexural strength by 8.483%, 12.259% & 19.250% respectively with respect to GPC mix without fibers.

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