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Properties of Glass Fibre Reinforced Geopolymer Concrete

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ABSTRACT: *This paper presents results of an experimental program to determine mechanical properties of Glass fibre reinforced Geopolymer Concrete which contains fly ash, alkaline liquids, fine & course aggregates & glass fibres. The effects of inclusion of glass fibers on density, compressive strength & flexural strength of hardened geopolymer concrete composite (GPCC) was studied. Alkaline liquids to fly ash ratio were fixed as 0.35 with 100% replacement of ordinary Portland cement by fly ash. For alkaline liquid combination ratio of Sodium hydroxide solution to Sodium silicate solution was fixed as 1.00. Glass fibers were added to the mix in 0.01%, 0.02%, 0.03% & 0.04% by volume of concrete. Based on the test results it was observed that the glass fibers reinforced geopolymer concrete have relatively higher strength in short curing time (3 days) than geopolymer concrete & Ordinary Portland cement concrete.*

Keywords*: alkaline liquids, compressive strength, density, flexural strength, fly ash, glass fibers.*

I. INTRODUCTION

With infrastructure development growing, demand for concrete as construction material is on increase worldwide, 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. & about 1.0 ton of carbon dioxide (Co_2) is liberated during production of one ton of Portland cement [4 -11]. The environmental effects associated with production of Portland cement, created an urgent need to develop alternative binder to make concrete. The development of fly ash based geopolymer concrete is in response for the need of greener concrete. The abundant availability of fly ash worldwide create an opportunity to utilize this byproduct of burnt coal as substitute for Portland cement to manufacture concrete.[5]

Davidovits (1988) proposed that an alkaline liquids could be used to react with the Silicon (Si) & Aluminium (Al) in source material of geological origin or in byproduct material such as Fly ash, Metacolin, Ground granulated blast furnace slag (GGBS) Rice husk ash (RHA) etc. to produce binders. [2]

Geopolymer concrete does not utilize any Portland cement in it, however the binder is produced by the reaction of an alkaline liquids with a source material which is rich in Silica & Alumina.[3]. The geopolymer paste binds the loose course & fine aggregates & other un reacted materials together to form geopolymer concrete.The manufacture of geopolymer concrete is carried out using the usual concrete technology methods [1].

High early strength, low shrinkage, freeze thaw resistance, sulphate resistance, & corrosion resistance are the properties of geopolymer concrete.[3] Geopolymer concrete composites are good candidate material of construction from strength & durability considerations. Also bond strength of Geopolymer concrete with rebars is higher than cement concrete.[5]

The water absorption of fly ash geopolymer is less than 5% which is low & Apparent Volume of Permeable Voids is less than 12% (which is classified as good). [10] Water to geopolymer solid ratio is the most influential parameter to increase strength, & to decrease the water absorption / Apparent Volume of Permeable Voids & water permeability.[10]

Fibre reinforced concrete is relatively new composite material in which fibres are introduced in matrics as micro reinforcement so as to improve the tensile cracking & other properties of concrete.[7] Some type of fibres produce greater impact abrasion & shatter resistance in concrete .Addition of glass & polypropylene fibres to concrete increase the splitting tensile strength & compressive strength of concrete by approximately 20-50% [6]. The compressive, split tensile, flexural & bond strength of geopolymer concrete with 100% replacement of cement by fly ash have increase as the fibre content increased. The maximum value of all these strengths obtained at 0.03% of fibre content.

II. EXPERIMENTAL INVESTIGATIONS

2.1 Materials

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

Fly ash

Fly ash is a residue from the combustion of pulverized coal collected by mechanical or electrostatic separators from the flue gases of thermal power plants. The spherical form of fly ash particles improves the flow ability & reduces the water demand. In this experimental work low calcium dry fly ash (Pozzocrete-83) procured from Dirk India limited Nashik obtained from Ekalahare (Nashik) thermal power station was used as source material Fineness of fly ash particles in terms of Specific surface was 430 m^2/Kg .

Alkaline liquids

A combination of Sodium hydroxide solution & Sodium silicate solution was used as alkaline activators for geopolymerization. Sodium hydroxide is available commercially in falkes & pellets form. For this experimental program Sodium hydroxide flakes with 98% purity were dissolved in distilled water to make NaOH solution.

Sodium silicate is available commercially in solution form which was used as such. The chemical composition of Sodium silicate is Na_2O=16.37%, SiO_2=34.35% (total solids=50.72%.), water=49.28%

Aggregates

Course aggregates comprising of max size 20mm having fineness modulus of 6.60, bulk density of 1603 Kg/m^3 , & specific gravity of 2.603 were used.

Fine aggregates (sand) is clean dry river sand was sieved through 4.75mm sieve to remove pebbles, confirming to grading zone I as per IS 383-1970 having specific gravity 2.576, bulk density of 1793 kg/m3, & fineness modulus of 3.35 was used. Both aggregates were in saturated surface dry condition.

Glass Fibres

Glass fibres are made of silicon oxide with addition of small amount of other oxides Glass fibres are characteristic for their high strength, good temperature resistance, corrosion resistance & available at low price. In this investigation alkali resistance glass fibres of 12mm length & 14 microns nominal diameter having density of 2680Kg/m^3 were used.

2.2 Mix design for Glass fibre reinforced Geopolymer concrete

The basic mixtures proportions used for the trial mixtures was based upon previous research on geopolymer mixture proportions [9,12]. In this investigation mix design procedure developed by Shri S. V. Patankar [8] for their PhD thesis work was adopted. Alkaline liquids to fly ash ratio by mass was fixed as 0.35. For alkaline liquid combination ratio of Sodium hydroxide solution to Sodium silicate solution was fixed as 1.00 . Mix proportions for characteristic strength of 30Mpa are described in table 1

Table1: Mix proportions for geopolymer concrete with & without glass fibres

Mix ID	Fly Ash in Kg/m^3	Fine aggregates in Kg/m^3	Course aggregates in Kg/m^3	NaOH Solution inKg/m^3	Na2SiO3 Solution in Kg/m^3	Extra water in Kg/m^3	Glass fibers in gm/m^3
GPC 0.00% fibres	360.00	692.53	1287.78	63.00	63.00	73.68	0.00
GPCC1 0.01% fibres	360.00	692.53	1287.78	63.00	63.00	73.68	268.00
GPCC2 0.02% fibres	360.00	692.53	1287.78	63.00	63.00	73.68	536.00
GPCC3 0.03% fibres	360.00	692.53	1287.78	63.00	63.00	73.68	804.00
GPCC4 0.04% fibres	360.00	692.53	1287.78	63.00	63.00	73.68	1072.00

2.3 Preparation of Geopolymer concrete composites

To prepare 13 molarity concentration of Sodium hydroxide solution 520gm of Sodium hydroxide flakes was dissolved in distilled water & make up to one liter . The mass of NaOH solids was measured as 38.5%. 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 $70^0$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 aggragates, were dry mixed in drum mixer for about three minutes. The extra water was added to alkaline solution prior to mixing of concrete. Then alkaline solution along with extra water added to dry mix thoroughly for four minutes to get homogeneous mix. For glass fibres reinforced geopolymer concrete mixes, fibres were added to dry mix in four different proportions such as 0.01%.0.02%, 0.03%, & 0.04%by volume of concrete. In this experimental work, 100 X 100 X 100mm size cubes, & 100 X 100 X 500mm size prisms were cast for testing of compressive & flexural strength. After 24 hours of casting all specimens were demoulded & then placed in an oven for thermal curing (heating) at specified temperature of 90^0C for eight hours duration. Then specimens were removed from oven & kept at room temperature. After 3 days, weight of specimens was taken to determine density & tests for compressive strength & Flexural strength were conducted

III. RESULTS & DISCUSSIONS

3.1 Density

Average density values of geopolymer concrete with & without glass fibers was 2650 kg/m^3 which is nearly equal to that of conventional concrete.

3.2 Compressive strength test

The average compressive strength of geopolymer concrete with & without glass fibres at the age of 3 days & 28 days with heat curing of eight hours at 90^0C are described in Table 2 & figure 1

Table 2: Compressive strength of Geopolymer concrete

Mix ID	Age of concrete	Av. Comp load in KN	Av. Comp strength in Mpa	% increase in strength
GPC	3 days	336.67	33.67	-
GPCC- 1	3 days	363.33	36.33	7.9 %
GPCC- 2	3 days	390.00	39.00	15.83 %
GPCC- 3	3 days	423.33	42.33	25.72 %
GPCC- 4	3 days	360.00	36.00	6.98 %
GPC	28 days	363.33	36.33	-
GPCC- 1	28 days	383.33	38.33	5.5 %
GPCC- 2	28 days	400.00	40.00	10.10 %
GPCC- 3	28 days	436.67	43.67	20.20 %
GPCC- 4	28 days	403.33	40.33	11.01 %

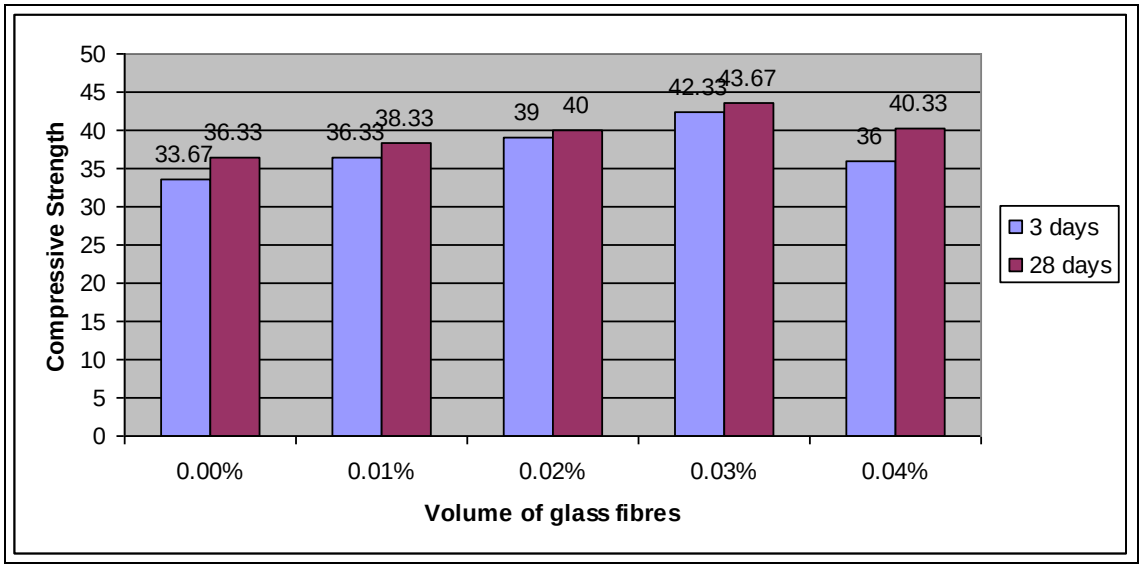

Figure 1: Compressive strength of GPCC

Compressive strength of GPCC was increased with respect to increase in percentage volume fraction of glass fibres Addition of 0.03% volume fraction of glass fibres shows maximum increase in compressive strength i.e. 20.2%with respect to GPC mix without fibres

3.3 Flexural strength

The flexural strength of Geopolymer concrete with & without glass fibres at 3 days & 28 days for heat curing of eight hours are represented in Table 4 & figure 2

Table: 4 Flexural Strength for geopolymer concrete with & without glass fibres.

Mix ID	Age of concrete	Av. Flexural load in kgf	Av. Flexural strength in Mpa	% increase in Flexural strength
GPC	3 days	970	3.81	0.0 %
GPCC- 1	3 days	1320	5.17	35.69 %
GPCC- 2	3 days	1480	5.81	52.49 %
GPCC- 3	3 days	1520	5.96	56.43 %
GPCC- 4	3 days	1300	5.10	33.85 %
GPC	28 days	1020	4.00	0.00%
GPCC- 1	28 days	1380	5.41	35.25%
GPCC- 2	28 days	1520	5.96	49.00%
GPCC- 3	28 days	1600	6.28	57.00%
GPCC- 4	28 days	1400	5.49	37.25%

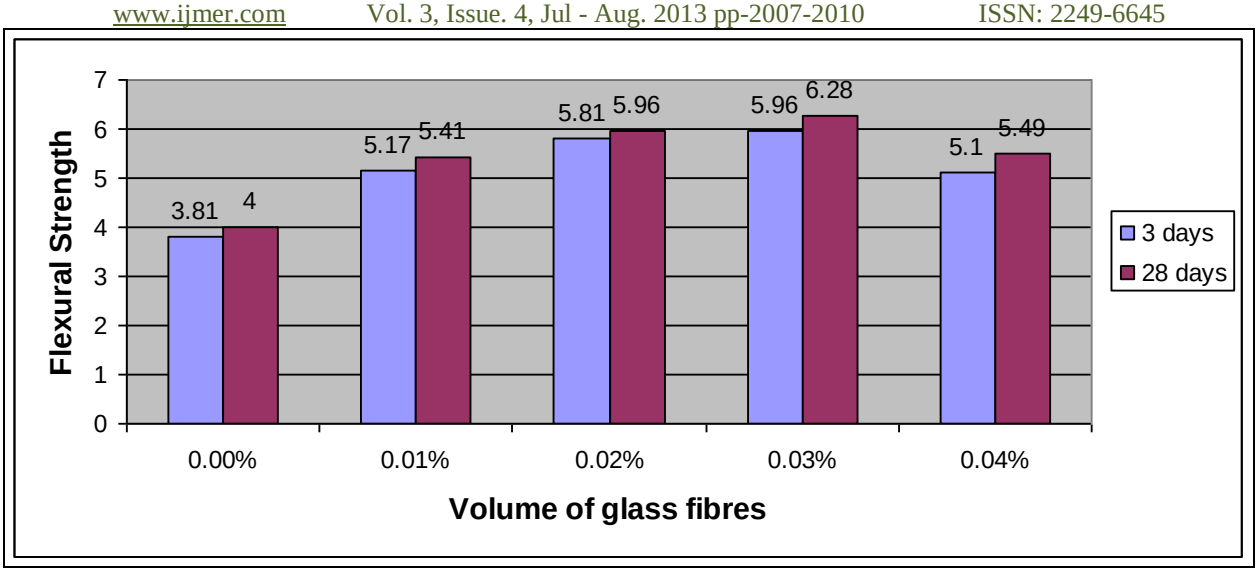

Figure 2 : Flexural strength of GPCC

From test results it can be observed that flexural strength of geopolymer concrete was increased as the volume fraction of glass fibre is increased. Addition of glass fibres increased flexural strength by 57 % with respect to GPC mix without fibre. Flexural strength was highest at 0.03% of glass fibres.

IV. Conclusions

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 glass fibres in Geopolymer concrete shows considerable increase in compressive, & flexural strength of GPCC with respect to GPC without fibres.
4) Compressive strength & Flexural strength of glass fibre reinforced geopolymer concrete increases with respect to increase in percentage volume fraction of glass fibres from 0.01%,0.02%,0.03% &0.04%.
5) Addition of 0.03% volume fraction of glass fibres shows maximum increase in Compressive strength & Flexural strength by 20.2%, & 57% respectively with respect to GPC mix without fibres.

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