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Properties of Hybrid Fibre Reinforced Geopolymer Concrete under Ambient Curing

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Abstract: ***The manufacture of Portland cement releases carbondioxide.The environmental problems caused by cement production can be reduced by finding a substitute conventional concrete material.An environmental friendly concrete is developed by replacing cement by flyash and GGBS and there by forming geopolymer concrete. Evolution of geopolymer concrete cured at ambient temperature broadens its suitability and applicability to concrete based structures. Different molarities of sodium hydroxide solution i.e. 8M, 10M and 12M are taken to prepare different mixes and the compressive strength is calculated for each of the mix.From that optimum molarity was obtained and which is used for further studies. The steel fibres are added in this mix at varying percentages of 0, 0.25, 0.5, 0.75 and 1.After getting the optimum percentage of steel fibres, the polypropylene fibre are varied at 0, 10, 20, 30 and 40 percentages of steel fibre with optimum steel fibre remains constant. For curing, temperature was fixed at room temperature for 24 hours. The specimens are tested after the ages of 28 and 56 days. The test were conducted for cement, chemical admixture, and coarse aggregate & fine aggregate. The concrete specimens were tested for mechanical properties of concrete namely, cube compressive strength, splitting tensile strength, and flexural strength.***

Keywords: Polypropylene Fibre, Geopolymer, Flyash, GGBS

1. Introduction

The applications of concrete in the area of infrastructure, habitation, and transportation have greatly prompted the development of civilization, economic progress, and stability and of the quality of life. However, due to raw materials, some inherent disadvantages of Portland cement are still difficult to overcome. There are two major drawbacks with respect to sustainability. About 1.5 tonnes of raw materials is needed in the production of every tonne of Portland cement, at the same time about one tonne of carbon dioxide (CO2) is released into the environment during the production. Another effort to make environmental friendly concrete is the development of inorganic alumina-silicate polymer, called Geopolymer, synthesized from materials of geological origin or by-product materials such as fly ash, that are rich in silicon and aluminium. It was found that heat-cured low-calcium fly ash-based geopolymer concrete possesses high compressive strength, undergoes very little drying shrinkage and moderately low creep

Geopolymer*:*- It is an inorganic alumina-silicate polymer is synthesized from predominantly silicon and aluminium material of geological origin or by-product materials such as fly ash, ground granulated blast slag (GGBS). Ground Granulated Blast Slag was replaced in different proportions to fly ash to enhance various properties of concrete Geopolymer concrete do not require any water for matrix bonding, instead the alkaline solution react with Silicon and Aluminium present in the fly ash Geopolymer is synthesized by mixing aluminosilicate-reactive material with strong alkali solutions, such as sodium hydroxide (NaOH) or potassium hydroxide (KOH), sodium silicate or potassium silicate. The mixture can be cured at room temperature or temperature cured. The GPC was found to have a highdegree of durability when it had inorganic binder based on alumina and silica containingmaterials like fly ash and GGBS. But, as in conventional reinforced concretes, the GPC alsoneeds to be reinforced with steel bars for its large scale utility in civil engineering structuralapplications. Hence, the investigations on behaviour of Reinforced GPC (RGPC) were undertaken.

The objectives of the work can be summarized as
- To obtain the optimum molarity.
- To develop the proper mix proportion for geopolymer concrete
- To obtain the optimum of steel fibre reinforced geopolymer concrete.
- To obtain the optimum hybrid fibre content in GPC
- Comparison of results of geopolymer concrete specimens with hybrid geopolymer concrete specimens.

2. Experimental Investigation

The main objective of the study is to investigate the impact of steel fibres and hybrid polypropylene-steel fibres on the mechanical properties and ultimate strength of geopolymer concrete under ambient curing condition. The experimental programme consisting of casting and testing of steel fibre reinforced geopolymer concrete specimen and hybrid fibre reinforced geopolymer concrete specimen, to study their mechanical properties.

2.1 Test On Constituent Materials

Flyash:-Low-calcium, Class F, obtained from the silos of Mettur Thermal Power Plant in Tamil Nadu. It is refractory and alkaline in nature, having fineness 2.98 and specific gravity 2.36

Ground Granulated Blast Furnace Slag:-Different laboratory tests were conducted on GGBS to determine Fineness, Specific Gravity. The specific gravity is 3.21 and fineness 2.78.The results conforms to the IS recommendations.

Fine Aggregate:- M sand is to be used as fine aggregate. It is to be used at the Saturated and Surface Dried (SSD) condition. M sand passing through 4.75mm IS sieve conforming to grading zone II of IS 383:1970 was used. Its specific gravity is 2.456.

Coarse aggregate:-Coarse aggregate of maximum size 20 mm from local source was used. The specific gravity is 2.82 and fineness modulus 6.7

Crimped steel Fibres:- Crimped steel Fibres from lathe industry was used.The long fibres were cut to approximately 30mm length,0.5mm dia and aspect ratio 60were used for the study. before using in the mix.Fig shows the steel fibres used for the study

Polypropylene fibres:-Fibres of Virgin Polypropylene Homo-Polymer of length 12mm was used for the study.

Alkaline liquid:-A combination of sodium hydroxide and sodium silicate solutions was used as the alkaline liquid to activate fly ash. A sodium hydroxide solution was prepared by dissolving sodium hydroxide pellets in water. The degree of purity of the pellets was 97% and was taken into account to modify the quantities. Distilled water was used to dissolve the pellets to avoid affecting the solution by tap water contaminations.Adding soluble silica has been shown to have positive effects on the properties and strength of geopolymers. It is also believed that using sodium silicate along with sodium hydroxide, enhances the formation of geopolymers.

Figure 1: Sodium Hydroxide flakes, Sodium silicate solution

Superplasticiser:-In order to achieve the desired workability, a naphthalene based superplasticizer was used as the water reducer. In this project Conplast SP-430 was used as superplasticizer. The dosage of super plasticizer used was 2% of fly ash. It is brown in colour

Figure 2: Conplast

Reinforcement:- High Yield Strength Deformed Steel bars of 6 mm and 8 mm diameter were used for the study. 8 mm bars were used as longitudinal reinforcement and 6 mm bars were used for lateral ties. The pitch of the stirrups was 125 mm.

Water:-Potable water is generally considered as being acceptable. Hence water available in the college water supply system was used for casting.

3. Preliminary Experimental Investigation

3.1 Mix Design

So far no standard mix design approaches are available for GPCs, since they are a new class of construction materials. So trial and error method is adopted. To arrive the mix proportion for the present study, the optimum values of different parameters were adopted from previous literature. The previous results shows that the compressive strength of fly ash-based geopolymer concrete increases with the increases in curing temperature in the range of 60^{o}C to 90^{o}C.But in the present study inorder to keep ambient curing condition, since it is most economical, an optimum replacement of 50% GGBS in flyash was adopted which give better result.

Earlier studies discovered that specimens cured under ambient conditions exhibited significant 28thday compressive strength. From the previous literatures the optimum values taken as, alkaline liquid to fly ash ratio is 0.7 and fine aggregate to total aggregate ratio was 0.3. In the design of geopolymer concrete mix, coarse and fine aggregates together were taken as 77% of entire mixture by mass. From the past literatures it is clear that the average density of fly ash-based geopolymerconcrete is similar to that of OPC concrete (2400 kg/m^3). Knowing the density of concrete, the combined mass of alkaline liquid and fly ash can be arrived at. By assuming the ratios of alkaline liquid tofly ash as 0.35, mass of fly ash and mass of alkaline liquid was found out.

To obtain mass of sodium hydroxide and sodium silicate solutions, the ratio of sodium silicate solution to sodium hydroxide solution was fixed as 2.5. From the test conducted on trial mixes, the mix with 12M of NaOH solution is taken as optimum. The dosage of super plasticizer was 2% fly ash. Extra water (other than the water used for the preparation of alkaline solutions) added to the mix according to the workability desired

Table 1: Trial mixes with different molarity

Parameters	Optimum Value
Curing temperature	Room temperature
Molarity of NaOH	10,12,14
Alkaline liquid to Flyash Ratio	0.7
Na2Sio3 to NaOH	2.5
Fine aggregate to Total aggregate ratio	0.3
Water geopolymer Solid ratio	0.17

Table 2: Compressive Strength of mixes with varying molarity

Molarity	Compressive strength (N/mm^2)
10M	27.55
12M	28.17
14M	26.86

Table 3: Mix Designation

Designation	Fly ash (%)	GGBS (%)	Steel Fibre (%)
GPC	50	50	0
SFRGPC1	50	50	0.1
SFRGPC2	50	50	0.25
SFRGPC3	50	50	0.50
SFRGPC4	50	50	0.75

Table 4: Quantities Of Ingredients Used For Mix Proportions

Particulars	**Quantity (kg/m^3)**
Flyash	550
GGBS	200
Fine aggregate	550
Coarse aggregate	1250
NaOH	16
Na_2SiO_3	95
Water	50

3.2 Specimen Details

Cubes of size 150mm x150mm x 150mm for compressive strength test, cylinders of 150mm diameter and 300 mm and height for splitting tensile strength and beams of size 500mmx100mmx100mm

Table 5: Specimen Details

Mix Designation	Cube	Cylinder	Beam
GPC	6	3	3
SFRGPC1	6	3	3
FRGPC2	6	3	3
SFRGPC3	6	3	3
SFRGPC4	6	3	3
TOTAL	**30**	**18**	**18**

3.3Fresh Properties of concrete

3.3.1Compacting Factor Test

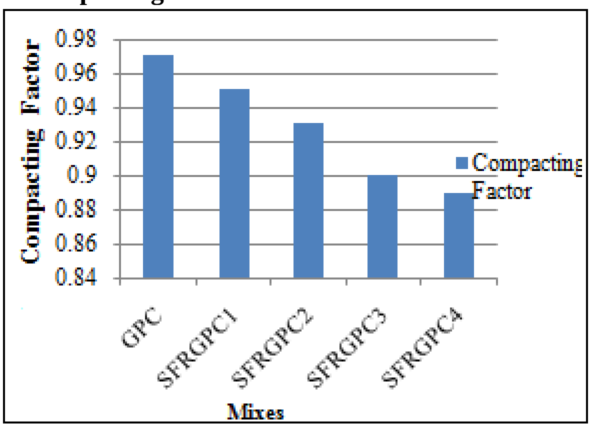

Figure 3: Compactig Factor

3.4 Hardened Properties Of Concrete

3.4.1 Cube compressive strength

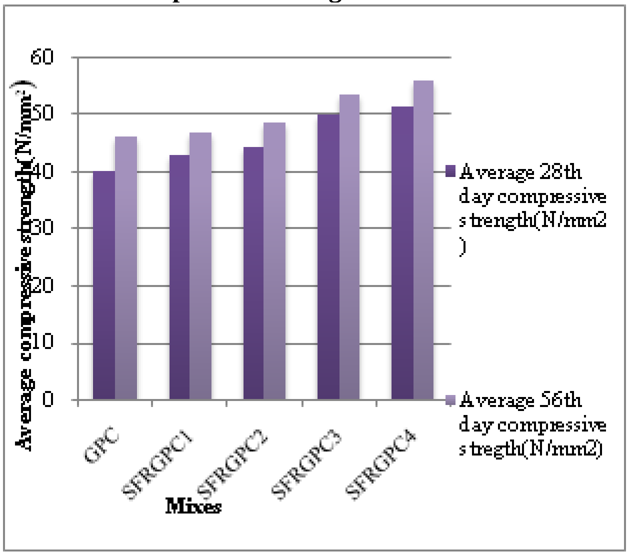

Fig 4 Cube compressive strength

3.4.2 Splitting tensile strength

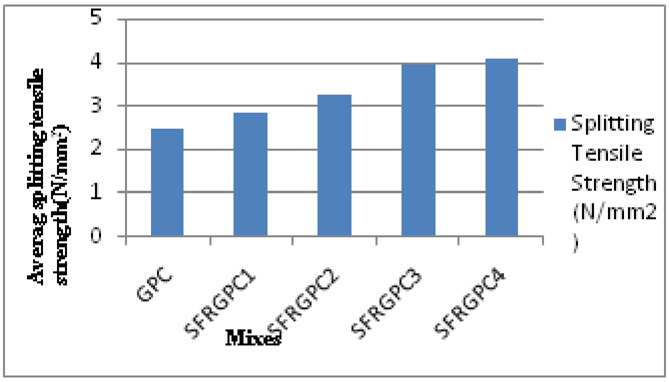

Figure 5: Splitting tensile strength

3.4.3 Flexural strength

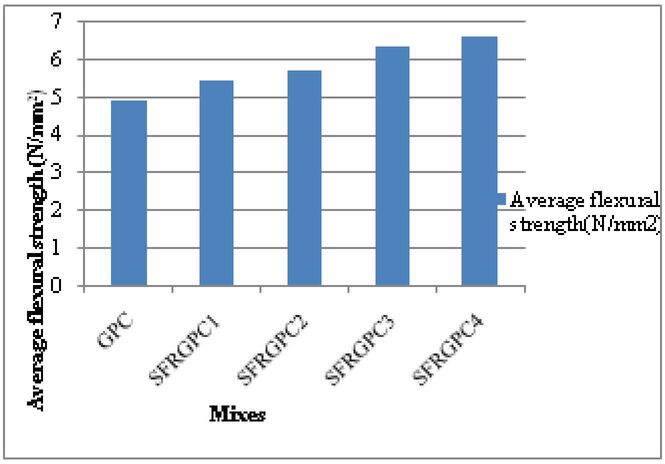

Figure 6: Flexural strength

From this the optimum is choosen as SFRGPC3 ie, Optimum fibres taken as 0.5% as further increase resulted in poor workability. In this optimum mix polypropylene fibre is added at varying percentages of steel fibre from 10 to 40 with the optimum steel fibre kept constant.

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4. Mix Design for Hybrid Fibre Reinforced Geopolymer Concrete (HFRGPC)

Hybrid fibre reinforced geopolymer concrete (HFRGPC) was obtained by adding optimum steel polypropylene fibre in different proportions of steel fibre as 10 to 40%, on to GPC. Crimped steel fibres having diameter 0.50 mm and length 25 mm (aspect ratio 50) and polypropylene fibres of 12 mm length were used.

4.1 Specimen Details

From each mix, 30 cubes of size 150 mm x150 mm x150 mm to determine the compressive strength, 18 cylinders of size 150mm diameter and 300mm height to determine splitting tensile strength and 12 beams of size 500mmx100mmx100mm to determine the flexural strength were also cast in addition to columns.

Table 6: Mix Designations For Different Mixes

Sl. No.	Mix Designation	Mix Details
1	GPC	Control Mix1
2	SFRGPC3	Control Mix2
3	HFRGPC1	0.5% steel fibre and polypropylene fibre in 10% of steel fibre
4	HFRGPC2	0.5% steel fibre and polypropylene fibre in 20% of steel fibre
5	HFRGPC3	0.5% steel fibre and polypropylene fibre in 30% of steel fibre
6	HFRGPC4	0.5% steel fibre and polypropylene fibre in 40% of steel fibre

Table 7: Specimen Details

Mix Designation	Cube	Cylinder	Beam
GPC	6	3	3
SFRGPC3	6	3	3
HFRGPC1	6	6	3
HFRGPC2	6	3	3
HFRGPC3	6	3	3
HFRGPC4	6	3	3
Total	**30**	**18**	**18**

4.2 Tests on specimens

Testing of concrete specimens plays an important role in controlling and confirming the quality of concrete. All the specimens cast were subjected to testing in order to study the effect of replacement of cement with constant amount of flyash and GGBS in the geopolymer concrete at ambient temperature on workability, strength

1. Study on workability
- Compacting factor test

2. Study on strength
- Compressive strength test
- Splitting tensile strength test
- Flexural strength test

5. Results and Discussions

The study on fresh properties of concrete, mechanical properties of concrete are discussed in this chapter.

5.1 Test On Fresh Properties Of Concrete

The values obtained are shown in fig 7. It was found that the value of fresh properties goes on changing with the addition of fibres. As the percentage of polypropylene increases, the fresh properties go on decreasing.

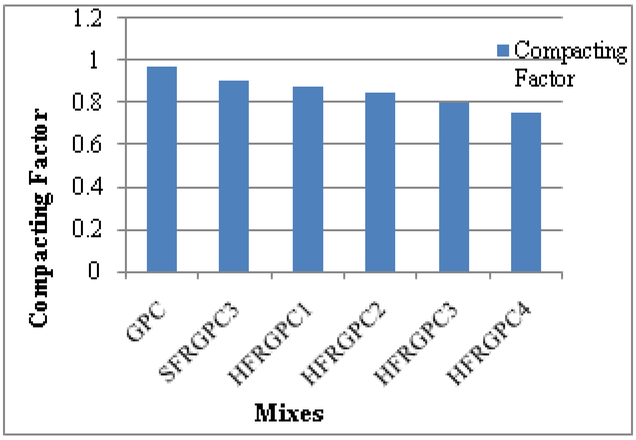

Figure 7: Compacting Factor

5.2 Cube Compressive Strength

Compressive strength of all concrete mixes was determined at 28 and 56 days of curing. Comparing to GPC, HFRGPC2 has showed an increase in strength of 40% at 28 days and 37% at 56 days. Comparing to SFRGPC3, HFRGPC3 has showed an increase in strength of 20% at 28 daysand 24% at 56 days. From the compressive strength test, HFRGPC3 was obtained as the optimum percentage

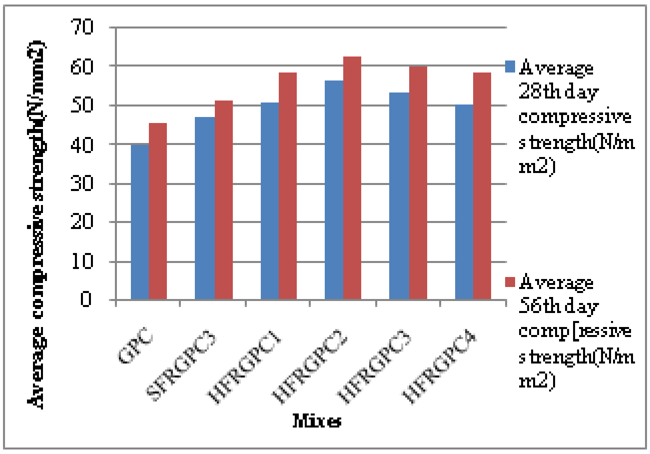

Figure 8: Compressive Strength Of Concrete

5.3 Splitting Tensile Strength

The test results are given in Table 5.3.. Percentage increase in strength of HFRGPC3 was 70% when compared to GPand 7% compared to SFRGPC3

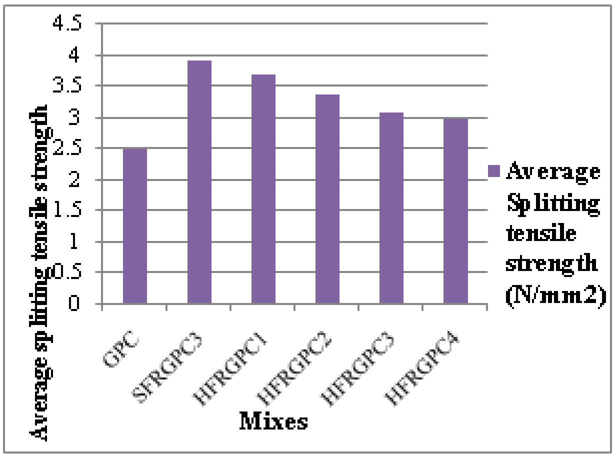

Figure 9: Splitting Tensile Strength

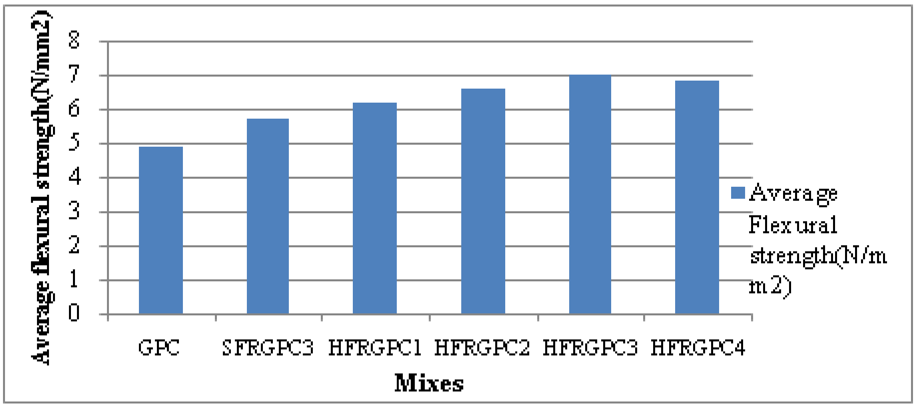

Figure 10: Flexural Strength

5.3 Flexural Strength

Percentage increase in strength of HFRGPC3 was 42% when compared to GPC and23 % compared to SFRGPC

6. Conclusions and Scope

6.1 Conclusions

An experimental investigation was carried out to study the effect of steel fibres and polypropylene fibres on the compressive strength, splitting tensile strength and flexural strength are discussed here.

- When fibre is added to concrete, the mix becomes stiff. So the workability is decreased with addition of fibre. The workability can be improved by adding super plasticizer to some extent.
- In the case of SFRGPC mixes, the mix obtained by the addition of steel fibre in 0.5% of total volume was taken as the optimum mix
- Geopolymer technology encourages recycling of waste & finally it will be an important step towards sustainable concrete technology.
- Geopolymer technology not only contribute to the reduction of greenhouse gas emissions but also reduces disposal costs of industrial waste.
- There is an increase in early age compressive strength due to the addition of fibre in concrete. Comparing to GPC, HFRGPC3 has showed an increase in strength of 40% at 28 days and 37% at 56 days. Comparing to SFRGPC3, HFRGPC3 has showed an increase in strength of 20% at 28 days and 24% at 56 days.
- Percentage increase in splitting tensile strength of HFRGPC3 was 70% when compared to GPC and 7% compared to SFRGPC3.
- Percentage increase in flexural strength of HFRGPC3 was 49 % when compared to GPC and 23% compared to SFRGPC3

6.2 Scope

- The work can be extended by varying different parameters like aspect ratio of fibres ,different combination of fibre.
- This study can be extended to find the crack patterns of beam column joint and durability properties of geopolymer concrete

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