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Experimental Evaluation of Glass Fibre reinforced Geopolymer Concrete (GFGPC)

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Abstract— This paper present the effects of glass fibre on strength and durability properties of Geopolymer concrete. Strength properties were studied through compressive, flexural and split tensile strength tests. Durability properties were explored through the results of water absorption and sorpitivity tests. Locally available fly ash from the industries was used. Sodium silicate and sodium hydroxide were used as alkali activators and its ratio is kept as 2.7. Alkali solution to fly ash ratio as 0.35 and glass fibres was added with the variation of 0.005% to 0.035% by volume of concrete. The strength parameters of Glass Fibre Geopolymer Concrete (GFGPC) were made compared with the control Geopolymer Concrete (GPC). Glass fibres, In spite of being tensile nature, the Glass Fibre Geopolymer Concrete (GFGPC) has increased its compression, flexural and split tensile strength of about 10.5%, 57% and 39% respectively. It was observed that the maximum strength values were attained at the inclusion of 0.025% of glass fibres and further adding by 0.005% there is decrease in strength of about 3.4%, 3.2% and 0.6% as compared to 0.025% inclusion.

Keywords— Fly ash, Alkali activators, Geopolymer concrete, Glass Fibres, Sorpitivity.

I. INTRODUCTION

With the rapid growth of infrastructure there is a greater demand for the construction material. Concrete is the most common material under these circumstances which includes Portland cement, fine aggregate and coarse aggregate. Ordinary Portland cement (OPC) is used as the chief binder for the production of concrete. Hence the cement production is directly proportional to the growth of infrastructure and by the process it leaves a greater impact on environment. It is reported that the worldwide cement industry contributes around 1.65 billion tons of the greenhouse gas emissions annually [1-3]. It is also observed that approximately a ton of carbon dioxide is released for producing one ton of cement which is a serious factor and need to be considered in environmental point of view [4-6]. About 5-8% of all globally human-generated atmospheric CO_2 comes from the cement industry [7]. Among the greenhouse gases, CO_2 contributes about 65% of global warming [8]. Even though the exercise of Portland cement is still inevitable until the predictable future, many experiments are being made in order to lessen the use of Portland cement in concrete. On the other hand, a huge volume of fly ash is generated around the world which is not effectively used, and a larger part of it is being used for filling the earth which majorly affects aquifers and surface bodies of fresh water [17]. Therefore there is a clear need for an alternative to OPC which resulted for the introduction of new material called Fly ash based Geopolymer concrete which provides excellent engineering properties, is reported to be a sustainable alternative construction material [9].

Davidovits[13] proposed that an alkaline liquid can be used to make act in response with the silicon (Si) and the aluminium (Al) in a source material of geological origin such as fly ash and rice husk ash which can be used for the production of binders. Because of the chemical reaction that takes place in this case is a polymerization process, he suggested the term "Geopolymer" to characterize these binders [10-12]. The Geopolymer concrete has high early strength, low shrinkage, freeze-thaw resistance, sulphate-resistance and corrosion resistance properties [14]. These binder material do not results any alkali-aggregate reaction even though it is characterized with high alkali content [15]. Moreover this binder is a low CO_2 cementious material which is environment friendly.

The concept that fibre inclusion as reinforcement is not a new discovery. In early 1960s, there were experiments by made use of glass, steel and synthetic fibres such as polypropylene fibres were made used in concrete, and research into new fibre reinforced concretes continues till today. Due to inclusion of glass fibres to concrete it was noted that there is considerable increase in the split tensile strength of concrete. This inclusion also serves to develop the post-peak tension-softening performance of brittle materials under tensile loading conditions [16]. Past studies indicated that there were several researchers who have investigated the effect of inclusion of fibres in concrete. The present work is the experimental studies on the properties of glass fibre reinforced Geopolymer Concrete. Both strength and durability studies have been conducted to evaluate the performance of Geopolymer concrete with Glass fibres.

II. EXPERIMENTAL PROGRAM

The experimental program involves various process of mix proportioning, mixing, casting, curing and testing of specimens which are elaborated in the following sections.

2.1 Materials used:

Class F fly ash with low calcium content from Rayalaseema Thermal Power Plant, Kadapa, India, having fineness of 290 m^2/kg confirming to the requirements as per IS 3812-2003 code is used. Locally available river sand and crushed quartzite stone aggregate of size 20mm and 10mm nominal size having specific gravities of 2.91 and 2.58 respectively both being confirming to IS 383-2016 were used. Fine aggregate is classified under zone-II

A 12M combination of sodium silicate and sodium hydroxide in the ratio of 2.7 was used as alkali activator. Sodium hydroxide in the form of flakes of laboratory grade with 99% purity is used. Industrial grade sodium silicate with 34.8% of SiO_2 by mass, 16.5% of NaO_2 and water as 48.6% were used.

As per IS: 456-2000 recommendations, the water to be used for such a mix and curing works should be free from any type of deleterious materials. So, in this regard the potable water is used in all operations demanding control over the quality of water. The physical properties of Glass fibres used are presented in Table.1

TABLE I
PHYSICAL PROPERTIES OF GLASS FIBRES USED

Physical properties	**Value as given by the manufacturer**
Specific Gravity	2.68
Elastic Modulus(GPa)	72
Tensile Strength(MPa)	1700
Length(mm)	12

2.2 Mix Design of geopolymer concrete:

In the design of geopolymer concrete (GPC mix), coarse and fine aggregates together were taken as 77% of entire mix which was recommended by previous successful researchers. This value is approximately similar to that used in ordinary Portland cement concrete in which it will be in the range of about 75 to 80 percent of the entire mix. The individual quantities of aggregates were obtained by the wet density of geopolymer concrete. From the past stories it is clear that the density on average of fly ash based geopolymer concrete is similar to that of OPC concrete that has 2400kg/m^3. Knowing the value of concrete density, the combined mass of alkaline liquid and fly ash can be found out. By assuming the ratios of alkaline liquid to fly ash as 0.35, individual masses of alkaline liquid and fly ash were arrived. The individual mass of sodium hydroxide and sodium silicate solutions can be obtained by their assumed ratio (i.e., 2.7). The quantities of ingredients as obtained from mix proportioning are presented in Table.2

TABLE II
QUANTITY OF INGREDIENTS OBTAINED BY MIX DESIGN

Type	**Fly ash kg/m^3**	**NaOH kg/m^3**	**Na_2SiO_3 kg/m^3**	**Fine aggregate kg/m^3**	**Coarse aggregate kg/m^3**	**Total Water kg/m^3**	**Glass fibres gm/m^3**
GPC	365	34.53	93.22	641.51	1290.74	90	0
$GFGPC_{0.005\%}$	365	34.53	93.22	641.51	1290.74	90	134
$GFGPC_{0.015\%}$	365	34.53	93.22	641.51	1290.74	90	402
$GFGPC_{0.025\%}$	365	34.53	93.22	641.51	1290.74	90	670
$GFGPC_{0.035\%}$	365	34.53	93.22	641.51	1290.74	90	938

III. TESTS:

A. *Workability test:*

Workability tests were conducted using slump moulds as it is the quick and easy method to measure the workability of concrete mixes and the test was done in accordance with recommendations of IS 1199-1959

B. *Curing:*

Demoulding of the specimens were done after 48 hours instead of 24 hours since they were not ready to demould at that stage of time. All the specimens were left at the room temperature in ambient curing till the date of testing.

C. *Compression strength test:*

The test was performed as per IS 516-1959. Cubes of size 150mm were prepared and tested after being cured in water for 28days. For specimens with uneven surfaces capping was done.

D. *Flexural strength test:*

For the flexure strength, the specimen of size 100 x 100 x 500 mm after being cured for 28 days are used and the test is conducted as per the recommendations of IS 516-1959.

E. *Split tensile strength test:*

Cylinders of size 150mm x 300mm were prepared and tested for each mix in accordance with the recommendations of IS 5816-1999. The test was done by applying the compression line load along the opposite directions of the cylinder placed with its axis horizontal.

F. *Water absorption test:*

Cubes of size 150mm were tested at 28th day after being oven dried at 105^{o}C for 24 hours. Table.6 represents the water absorption capacity of the specimen after being immersed in water for 30 minutes and 24 hours. This test helps us to determine the porosity or permeability of the specimen.

G. *Sorpitivity test:*

Sorpitivity represents the characteristic of the concrete to absorb water by capillary suction. Cubes of size 150mm were tested at 28th day by sealing all sides with the help of grease and wax. The test is performed in accordance to ASTM-1585.

IV. RESULTS & DISCUSSION:

The variation of compressive strength (7 & 28 days) with the percentage of glass fibres is presented in Fig1. It can be observed that with the increase in glass fibre content, both 7 & 28 days compressive strength increased up to 0.025% and then it started decreasing. The maximum increase in compressive strength is 10.5%. This increase is mainly due to filling up of internal pores by the glass fibres densifying the transition zone.

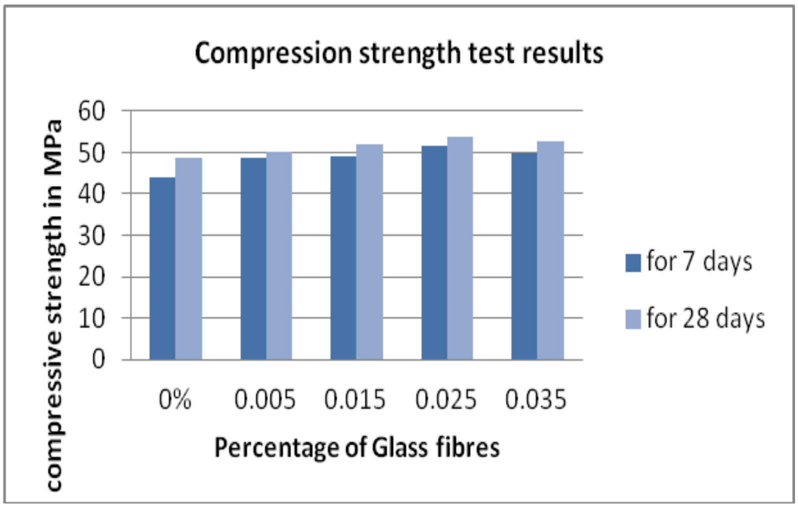

Fig1. Variation of compressive strength with Glass fibre percentage

The variation of 7 & 28 day flexural strength of Glass fibre reinforced Geopolymer concrete with fibre content is depicted in Fig2. It can be observed that the flexural strength increased considerably with increase of glass fibre upto 0.025% and then decreased. The maximum increase in 28 day flexural strength is 57% at 0.025% of glass fibres.

Similar trend is observed for split tensile strength (see Fig3). The maximum split tensile strength is achieved at a percentage of 0.025. The maximum increase in split tensile strength is about 39.3%.

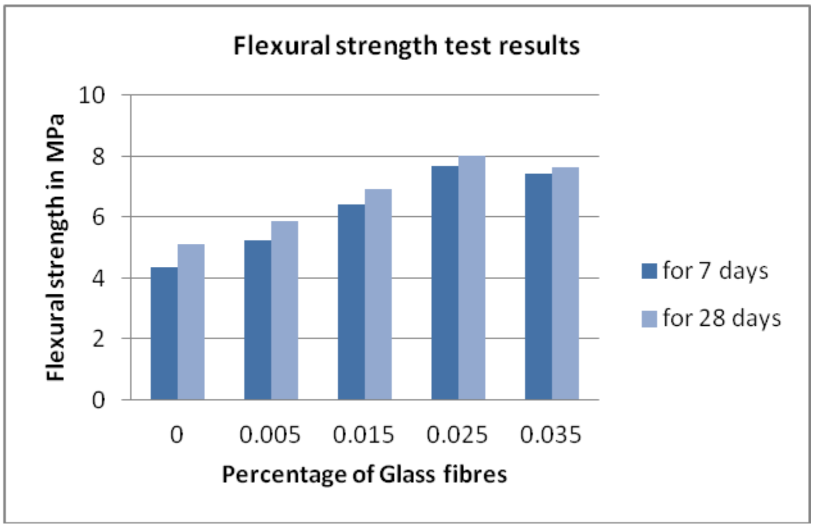

Fig2. Variation of flexural strength with Glass fibre percentage

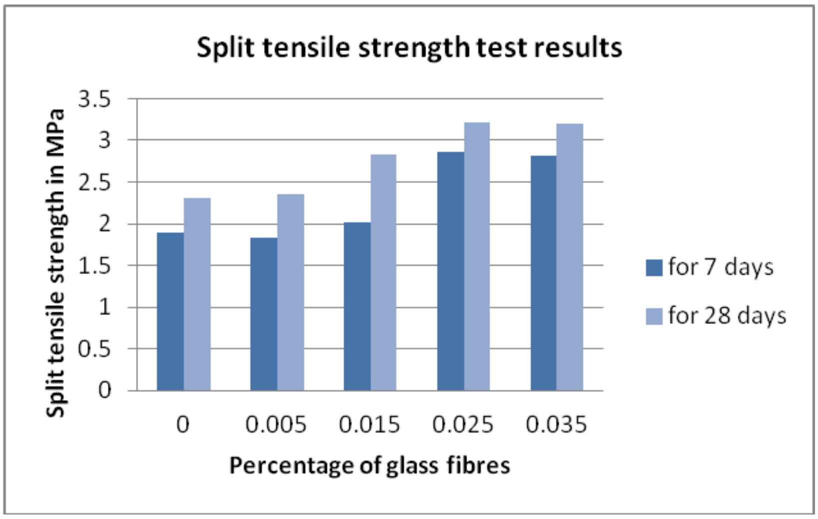

Fig3. Variation of split tensile strength with Glass fibre percentage

To assess the durability the durability of Glass fibre reinforced Geopolymer concrete, water absorption and sorpitivity have been measured. The results of water absorption test (see Fig4) indicate that the percentage of water absorption decreased with increase of Glass fibres up to 0.025%. This clearly indicates the densification of matrix with Glass fibres. As expected the percentage water absorption at 30 minutes is considerably less compared to that at 24 hours for all mixes. Sorpitivity results also indicates the same behaviour (see Fig.5). Thus it can be calculated that addition of Glass fibres up to 0.025% contributes both for strength and durability.

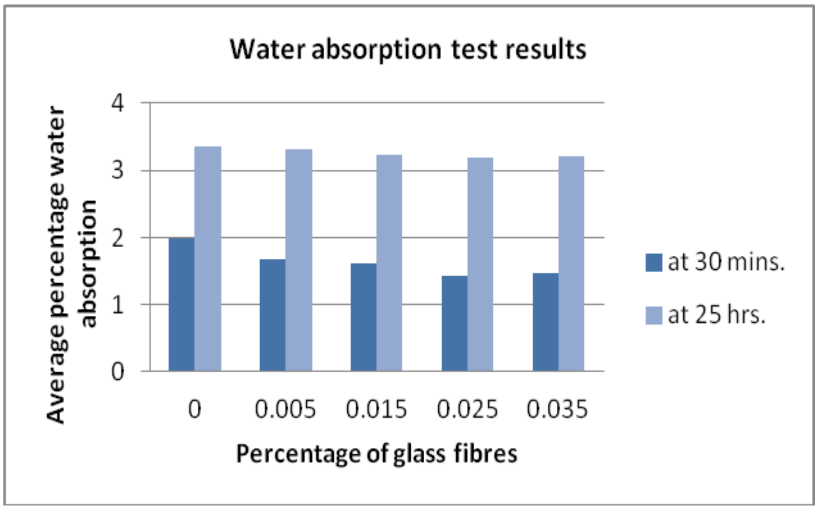

Fig4. Variation of water absorption capacity of concrete specimens with Glass fibre percentage

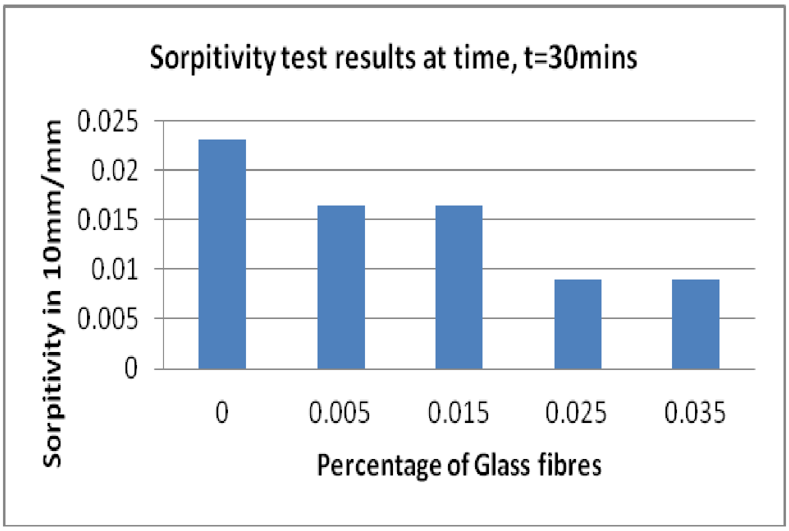

Fig5. Variation of sorpitivity character of concrete with Glass fibre percentage

V. CONCLUSIONS

The following conclusions are drawn based on the experimental work conducted in this investigation:

1. Glass Fibre reinforced geopolymer concrete can completely eliminate the use of conventional cement in concrete, thus making it a sustainable concrete.
2. Inclusion of glass fibres by 0.025% by volume helps in considerable increase in flexural and split tensile strengths.
3. Within short period, low calcium fly ash based Geopolymer concrete has developed good compressive strength and is suitable for structural applications.
4. Inclusion of glass fibres in Geopolymer concrete results in considerable increase in flexural and tensile strength.
5. Addition of 0.025% volume fraction of glass fibre gives maximum increase in compressive, flexural and tensile strengths by 10.5%, 57%, and 39.3% respectively when compared to Geopolymer concrete without glass fibres.
6. From this study it is recommended that 0.025% of glass fibres may be used in Geopolymer concrete for optimum results.

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