Evaluation of Water Absorption and Sorptivity Properties of Fly Ash, GGBS, M-Sand Based Glass Fiber Reinforced Geopolymer Concrete

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Abstract – *Concrete is a major construction material using worldwide and the concrete industry is the largest user of natural resources in the world. This use of concrete is driving the massive global production of cement. The manufacturing of cement emits enormous amounts carbon dioxide in to atmosphere. The emission of carbon dioxide in the production of cement is due to clinker production, combustion of fuels in the cement kilns, and the use of energy for grinding raw materials and clinker. The worldwide concern on carbon dioxide emissions has prompted the research into the replacement of cement with supplementary cementitious materials such as fly ash and slag. Geopolymer concrete is the concrete which does not utilize any portland cement in its production rather, the binder is an alkali activated alumino-silicate. Geopolymer is a specialized material resulting from the reaction of a source material that is rich in silica and alumina with alkaline solution. It is essentially portland cement free concrete. This material is being studied extensively as a ecofriendly alternative to normal portland cement concrete. This research paper deals with the study of Water absorption and sorptivity properties of Glass fiber reinforced Geopolymer concrete prepared by using Fly ash, GGBS, M-Sand and Coarse aggregates. Volume fraction of glass fibers : 0% , 0.01% , 0.02% and 0.03%. NaOH and* Na_2SiO_3 *solutions used as alkaline liquid and 16M Concentration of NaOH was maintained. The specimens cured at* 90^oc *in dry air oven for 24 hours then all the specimens were left at room temperature in ambient curing till the date of testing. Addition of glass fibers to GPCC results in decrease in sorptivity coefficient and absorption rates because of denser structure due to lesser number of interconnected pores as compared to control GPCC specimens.*

***Key Words*:** Ecofriendly, Glass fiber, Molarity, Sorptivity, Volume fraction…

1.Introduction

Concrete is a major building material which is widely usig in the construction of infrastructures. One of the ingredients usually used as a binder in the manufacture of concrete is the Ordinary Portland Cement (OPC). The increasing worldwide production of OPC to meet infrastructure developments indicates that, the concrete will continue to be a opt material of construction in the future. However, it is well known that the production of OPC not only consumes significant amount of natural resources and energy but also releases huge quantities of carbon dioxide (CO_2) to the atmosphere. Environmental pollution is the major concern at present. To solve this issue it is essential to find an alternative binding material. Geopolymer concrete is one such alternative to OPC. Joseph Davidovits, French materials scientist in 1978 coined the term Geopolymer. Geopolymers are new binder materials manufactured by activating an aluminosilicate source materials such as fly ash, silica fume, blast furnace slag etc, with a highly alkaline solution and moderate thermal curing.

At present the quality of concrete based primarily on strength. It has been suggested that the quality of concrete should be measured not only by strength but also its durability characteristics. The performance of concrete is greatly affected by its exposure to aggressive environments, more precisely its transport properties. The ingress of moisture and the transport properties of these materials have become the underlying source for many engineering problems such as corrosion of reinforcing steel, and damage due to freeze-thaw cycling or wetting and drying cycles. The present investigation aimed to evaluate the Water absorption and Sorptivity properties of Fly ash and GGBS based Glass fiber reinforced geopolymer concrete composites for different fibre volume fractions.

2. Materials

2.1. Fly ash: The fly ash used in the present investigation was from BTPS KPCL, Kudathini, Bellary (Dist.), Karnataka. It is pozzolonic fly ash belonging to ASTM classification "F". The fly ash is collected directly from open dry dumps. The colour of fly ash is light grey, Surface area is 310 m^2/kg and Specific gravity is 2.1.

2.2. GGBS: The GGBS used in the present investigation was from RMC Ready mix (India), Kumbalagod Industrial Area, Bangalore. The white coloured GGBS has specific gravity of 2.8 and Surface area of 450 m^2/kg.

2.3. Fine aggregate - M - sand: The M- Sand used in the Present investigation is from Tavara Mines & Minerals, Jigani Industrial area, Anekal Taluk, Bangalore, Karnataka. It satisfies the requirements of grading "Zone 2" as per IS: 383-1970 (Reaffirmed in 2007).

2.4. Coarse aggregates: The coarse aggregate used in the Present investigation was brought from a local supplier, Magadi road, Bangalore, Karnataka. . For present work Coarse aggregates of size 16mm passing and 12.5mm retained were used.

2.5. Sodium hydroxide and sodium silicate: The alkaline liquid used in the present study was a combination of sodium hydroxide and sodium silicate solutions in a definite proportion. Sodium-based solutions were chosen because they were cheaper than potassium-based solutions. Sodium silicate facilitates faster dissolution of the binder components. Both the alkalis were of commercial grades and procured from local suppliers. Sodium hydroxide pellets were of 99% purity, with Specific Gravity of 2.13. The aqueous solution of sodium silicate with SiO_2 / Na_2O ratio of 2.06 and pH 12 was used.

2.6. Super plasticizer: To achieve workability of fresh geopolymer concrete, Sulphonated naphthalene polymer based super plasticizer Conplast SP430 in the form of a brown liquid instantly dispersible in water, manufactured by Fosroc Chemicals (India) private limited, Bangalore, was used in all the mixtures.

2.7. Water: Distilled water was used for the preparation of sodium hydroxide solution and for extra water added to achieve workability.

2.8. Glass fibers: Alkali resistant glass fibres having a length of 12 mm and a diameter of 0.014 mm were used. As per manufacturers data these fibres have a density of 2680 kg/m3, modulus of elasticity of 72000 MPa and yield strength of 3400 MPa.

3. Preparation Of Alkaline Activator Solution

A combination of Sodium hydroxide solution of 16 molarities and sodium silicate solution was used as alkaline activator solution for geo polymerization. To prepare sodium hydroxide solution of 16 molarity (16 M), 640 g (16 x 40 i.e, molarity x molecular weight) of sodium hydroxide flakes was dissolved in distilled water and makeup to one litre.

4. Mix Proportion of GFRGPCC

In case of GFRGPCC mixes glass fibres were added to the GPCC mix in three volume fractions such as 0.01%, 0.02% and 0.03% by volume of the concrete. The mix proportions are given in Table 1.

Fly Ash kg/m^3	394.3
Fine Aggregate kg/m^3	554
Course Aggregate kg/m^3	1294
NaOH Solution kg/m^3	46.06
Na2SiO3 Solution kg/m^3	112.64
Extra Water kg/m^3	3.943

Table-1: The mix proportions of GPCC and GFRGPCC

The prepared solution of sodium hydroxide of 16 M concentration was mixed with sodium silicate solution one day before mixing the concrete to get the desired alkalinity in the alkaline activator solution. Initially Fine aggregates, fly ash, coarse aggregates and polypropylene fibres were dry mixed for 3 minutes in a horizontal pan mixer. After dry mixing, alkaline activator solution was added to the dry mix and wet mixing was done for 4 minutes. Finally extra water along with super plasticizer was added.

5. Experimental investigation

The main aim of present investigation was to study the water absorption and sorptivity of controlled GPCC specimens without fibers and Glass fiber reinforced geopolymer concrete (GFRGPCC) . It also studies the effect of addition of Glass fibers on the water absorption and sorptivity characteristics of Fly ash , GGBS and M-Sand based geopolymer concrete composites.

6. Water Absorption

Water absorption is the amount of water absorbed by the specimen under specified conditions. Water absorption of concrete plays an important role for the durability. The test was performed to evaluate the water absorption characteristics of geopolymer concrete.

6.1. Specimen casting and Testing procedure

The water absorption test has been carried out according to ASTM C 642-82. To study the water absorption characteristics of GPCC and GFRGPCC at 90 days, the specimens used for this test were cubes of size 100 mm x 100 mm. The specimens cured at 90^{o}c in dry air oven for 24 hours then all the specimens were cured for 90 days at room temperature in ambient curing. The difference between the saturated mass and oven dried mass of the specimens expressed as a fractional percentage of oven dried mass gives the water absorption.

6.2. Results and Discussions

The values of saturated water absorption of theGPCC and GFRGPCC specimens at 90 days were found out for immersion after 30 minutes and after 24 hours and are calculated and presented in Table-2.

Specimens	Avg. initial weight (gms)	Avg. weight (gms)		Avg. water absorption in %	
		30 mins	24 hrs	30 mins	24 hrs
GPCC	2318	2342	2354	1.03	1.55
GFRGPCC (0.01)	2311	2324	2336	0.56	1.08
GFRGPCC (0.02)	2307	2319	2324	0.52	0.73
GFRGPCC (0.03)	2310	2321	2332	0.47	0.95

Table-2: Water absorption test results

The initial absorption values at 30 minutes for all the mixes were compared with recommendations given by Concrete Society (CEB). From the test results, it can be seen that absorption values at 30 minutes for the GFRGPCC specimens for all fiber volume fractions were lower than the limit of 3% specified for good concretes according to BS 1881-Part 5. The water absorption values after 24 hours also indicate that the geopolymer concrete composite specimens reinforced with 0.01%, 0.02% and 0.03% of glass fibres were having lower absorption rate compared to control GPCC specimens as shown in Chart-1.

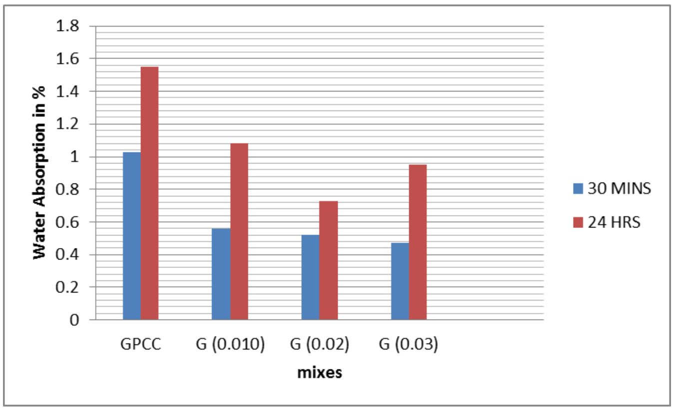

Chart-1: Water absorption at 30 minutes and 24 hrs

7. SORPTIVITY

The sorptivity test is a simple and rapid test to determine the tendency of concrete to absorb water by capillary suction. The test was developed by Hall (1981) and is based on Darcy's law of unsaturated flow. ASTM – 1585 -04 codes were followed to conduct the test. Sorptivity is a uni-directional water absorption front within a specimen. The gain in mass per unit area over the density of water is plotted versus the square root of the elapsed time. The slope of the line of best fit of these points (ignoring the origin) is reported as the sorptivity.

$$i = S\sqrt{t}$$

S= sorptivity in mm, t= elapsed time in mint. I=Δw/Ad Δw= change in weight, A= cross sectional area of the specimen through which water penetrated. d= density of water

Sorptivity can be related to the hydraulic diffusivity of the material. In short, sorptivity is based on the rate of absorption, which is proportional to the cross sectional area exposed to moisture and time.

7.1. Specimen casting and testing procedure

The cube specimens, 150mm x 150mm x150 mm size were casted and cured at 90°c in dry air oven for 24 hours then all the specimens were cured for 90 days at room temperature in ambient curing. Oven dried cube specimens were exposed to the water by placing it in a pan. The water level in the pan was maintained at about 5 mm above the base of the specimens during this experiment.

At regular times, the mass of the specimens was measured using a balance, then the amount of water adsorbed was calculated and normalized with respect to the cross section area of the specimens exposed to the water at various times such as 1, 4, 9, 16, 25, 36, 49, 81, 100, 121, 144 and 169 minutes To determine the sorptivity value, Q/A was plotted against the square root of time t . The sorptivity value was calculated from the slope of the linear relation between Q/A and √t.

7.2. Results and Discussions

The sorptivity test values of GPCC and GFRGPCC specimens are presented in table-3. From the test results, cumulative adsorbed volume after time 't' per unit area of inflow surface is calculated and shown in chart no 2, 3, 4, and 5 for 0%, 0.01%, 0.02%, and 0.03% glass fiber volume fractions respectively.

Specimens	Sorptivity in mm/min$^{0.5}$
GPCC	0.0283
GFRGPCC (0.01%)	0.0228
GFRGPCC (0.02%)	0.0256
GFRGPCC (0.03%)	0.0178

Table -3: Sorptivity test values at 90 days

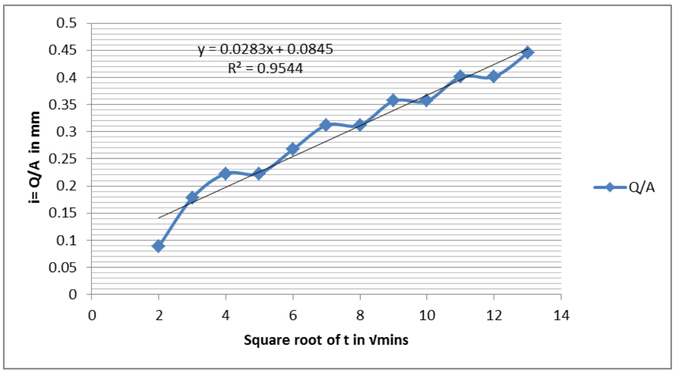

Chart-2: Q/A Vs √t for GPCC Specimens

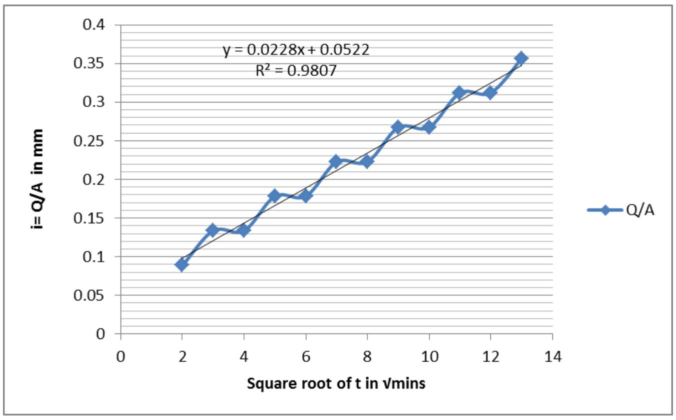

Chart-3: Q/A Vs √t for G (0.01) Specimens

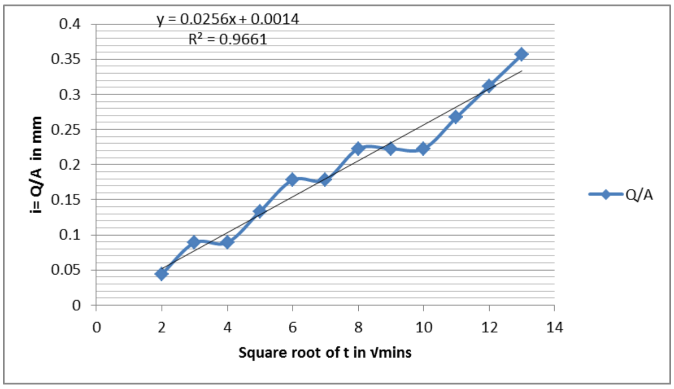

Chart-4: Q/A Vs √t for G (0.02) Specimens

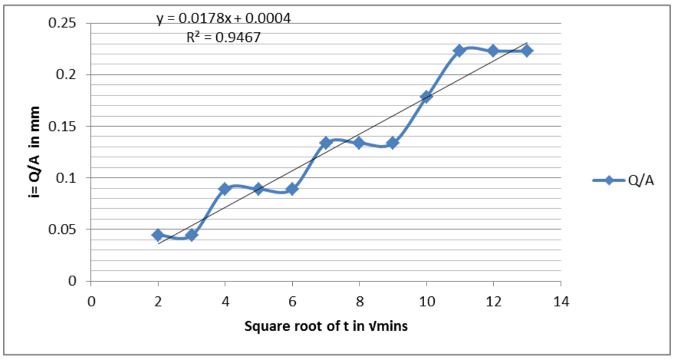

Chart-5: Q/A Vs √t for G (0.03) Specimens

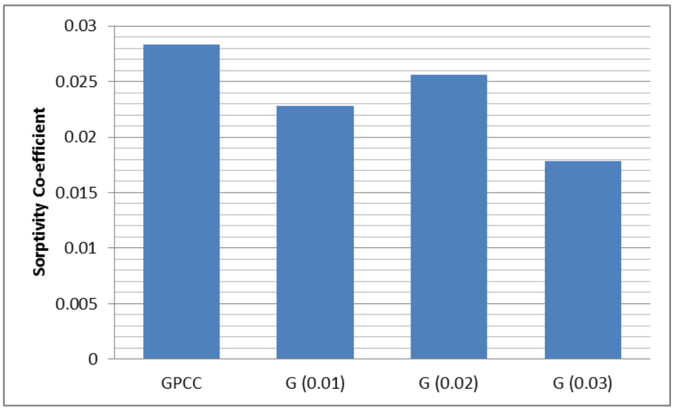

Chart-6: Sorptivity values of GPCC and GFRGPCC Specimens

Due to the addition of glass fibers, the sorptivity coefficient decreases as shown in Chart-6. However the sorptivity values increases as the volume fraction of glass fibers increases. Sorptivity values of specimens containing fibers were too low which indicates that the interfaces are filled properly by the paste and fibers resulting in reduction of pore radius of the concrete. These specimens have a denser structure due to lesser number of interconnected pores as compared to control GPCC specimens.

8. CONCLUSIONS

Based on the results obtained in this investigation, the following conclusions were drawn:

[1] The water absorption values at 30 minutes for the GPCC and GFRGPCC specimens for all fiber volume fractions were lower than the limit of 3% specified for good concretes according to BS 1881-Part 5.

[2] The water absorption values after 24 hours also indicate that the geopolymer concrete composite specimens reinforced with 0.01% 0.02% and 0.03% of glass fibres were having lower absorption rate compared to control GPCC specimens.

[3] As a result of addition of glass fibres, the sorptivity coefficient decreases. However the sorptivity values decreases as the volume fraction of glass fibers increases except for 0.02 % glass fiber volume fraction.

[4] Sorptivity values of specimens containing fibers were too low which indicates that the interfaces are filled properly by the paste and fibers resulting in reduction of pore radius of the concrete. These specimens have a denser structure due to lesser number of interconnected pores as compared to control GPCC specimens.

9. REFERENCES

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