Impact Factor (SJIF): 4.542
International Journal of Advance Research in Engineering, Science & Technology
e-ISSN: 2393-9877, p-ISSN: 2394-2444

Volume 4, Issue 6, June-2017

"AN EXPERIMENTAL STUDY ON MECHANICAL AND DURABILITY PROPERTIES OF STEEL FIBRE REINFORCED GEOPOLYMER CONCRETE"

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ABSTRACT: This paper presents the relative results of an experimental investigation on the mechanical properties of Geopolymer concrete (GPC), Geopolymer Concrete Composites (GPCC) containing 30% Fly ash (FA), 70% Ground Granulated Blast Furnace Slag (GGBS). Sodium based alkaline liquid is used as an activator. The study also analyses the impact of steel fibers mechanical properties of GPCC. Steel fibers were added to the mix in the volume fractions of 0.5%, 1% & 1.5% volume of the concrete. From the results it is observed that as the age of concrete increases the mechanical properties of GPCC are found to be improving significantly. Inclusion of steel fibers resulted in improved compressive and flexural strengths at the early ages. However tensile strength is found to be improved significantly at later stages. The durability tests are conducted on the GPC mix which gives maximum strength on percentage addition of steel fibres.

Keywords- *durability*, geopolymer, compressive strength, flexural strength, steel fibres.

I. Introduction

Concrete is a composite material which is composed of cement, coarse aggregates, fine aggregates and water. Most of the concrete used are portland cement concrete or concrete made with the hydraulic cements.

Portland cement is the most common type of cement generally used. Demand for cement as a construction material is increasing day by day. Cements are large, complex and inherently dusty industrial material and emissions must be controlled. Manufacture of cement causes environmental impacts in all the stages of life. About 1.5 tonnes of raw materials are used to produce 1 tonne of cement and 1.5 tonne of CO_2 is liberated during production of 1 tonne of cement. Producing green cement are been researched by manufacturing processes in order to reduce or eliminate release of damaging pollutants and green house gases mainly CO_2 to the atmosphere. The use of recycled materials and some admixtures into concrete has been a new research in order to reduce CO_2 emissions to the atmosphere. Fly ash is one such material which is replaced by significant amount of cement in the concrete.

Fly ash is a byproduct from burning pulverized coal in electric generation power plants. Fly ash is a substance containing aluminous and siliceous material which forms cement in presence of water.

Concrete made with the fly ash is more stronger and durable when compared to concrete made with the cement. Concrete with full replacement of fly ash is named as a Geopolymer concrete.

1.1 Durability of Geo-polymer concrete

Generally durability refers to the lifespan of untroubled performance. The capability of concrete to resist weathering action, chemical attack and abrasion in order to maintain several engineering properties is known as "Durability". Since different concrete requires different degree of durability depending on its use, it is not always an limited property. The service life and durability of the structure mainly depends on the material properties such as permeability, Sorptivity and water absorption. Durability of concrete is an important aspect in the performance of structures when exposed to aggressive environments. In order to conclude the durability of fly ash based geopolymer concrete its necessary to study its resistance to chemical and acid attack, resistance against freezing and thawing and resistance to various temperature.

1.2 Properties of Geopolymer concrete

- Higher compressive and flexural strength
- Higher durability
- Impermeable
- Elastic modulus
- Higher resistance to acid attack
- Higher resistance to chemical attack
- Resistance to heat
- Bleeding free

II. Methodology

2.1 Objectives of this project

- To study the effect of alkaline to fly ash ratio.
- To study the effect of varying molarity of NaOH.
- To study the effect of addition of steel fibres to Geopolymer concrete.
- To study the durability characterstics of Geopolymer concrete by conducting various test.

2.2Materials used:

2.2.1Fly ash:

Fly ash is a byproduct of pulverized coal. Low calcium fly ash has been used to manufacture of Geo-polymer concrete which is rich in aluminium and silicon oxides. In this project, fly ash is collected from raichur thermal power plant. The physical and chemical properties of fly ash is determined as per IS:3812 table 2:

Fly ash

Physical properties of Fly ash

SL.NO	Description	Values	Requirement as per IS:3812-2003
1	Specific gravity	2.15	2.8
2	Fineness	2	3.2

2.2.2 GGBS:

Ground granulated blast furnace(GGBS) was used as source material for geopolymer production.GGBFS which is a by-product of iron manufacturing as a replacement of ordinary Portland cement for the production of concrete. By studying the several reviews of the use GGBFS in concrete we got to know that it improving workability, durability and the long term strength in concrete. Since slag is a by-product, use of these has environmental advantages, such as low energy, use of secondary raw material and low pollutant gas emission.

GGBS

The physical and chemical properties of GGBS is listed as per IS:383-1970 below:

Physical properties of GGBS

Sl. No	Description	Values
1	Specific gravity	2.62
2	Fineness	2.1

2.2.3 Coarse aggregates:

Coarse aggregates used are crushed type of angular shape. The size of coarse aggregates is 12mm down size. The specific gravity of coarse aggregates is 2.65.

Coarse aggragates

2.2.4 Fine aggregates:

Manufactured sand is crushed fine aggregate produced from a source material. It is collected from RMC plant Yalahanka, Bangalore. The physical properties of M sand is shown below as per respective code reference.

Physical properties of M sand:

SL NO	Description	Value
1	Specific gravity (As per IS 2386-1963) Part 3	2.6
2	Fineness modulus (as per IS:383-1970)	2.7
3	Bulking of sand (As per IS:2386-1963) Part 3	8%

M sand

2.2.5 Alkaline liquids:

Soduim hydroxide:

Soduim hydroxide solids are available in the form of pellets which is used in the preparation of alkaline acti

vator.

Soduim silicate:

Soduim silicate is available in the form of solution supplied by manufacturer. The chemical composition of soduim silicate is 14.7% of Na2O, 29.4% of SiO2 and 55.9% of water by mass.

Soduim hydroxide flakes

2.2.6 Steel Fibres:

Steel fibres will reduce steel reinforcement requirements, improve ductility, structural strength, reduce crack widths and control the crack widths tightly thus improve durability, improve impact and abrasion resistance The fibre composite pronounced post cracking ductility which is unheard of in ordinary concrete.

Steel fibres

2.3 Mix design of concrete:

Mix design of Geo-polymer concrete

Geopolymer concrete mix design for M40 was done as per guidelines given by paper B.V.Rangan.

Mix proportion of Geo-polymer concrete with different molarity

Mix	Fly ash Kg/m³ (30%)	GGBS Kg/m³ (70%)	Sand Kg/m³	Coarse aggregate Kg/m³	NaOH Kg/m³		Soduim silicate Kg/m³	Alkaline to fly ash	Water to GPS
					mass	molarity			
1	121	285	554	1294	49	8	97	0.35	0.2

2	121	285	554	1294	49	12	97	0.35	0.18
3	121	285	554	1294	49	16	97	0.35	0.162
4	118	276	554	1294	53	8	105	0.4	0.215
5	118	276	554	1294	53	12	105	0.4	0.198
6	118	276	554	1294	53	16	105	0.4	0.195
7	114	266	554	1294	57	8	115	0.45	0.237
8	114	266	554	1294	57	12	115	0.45	0.22
9	114	266	554	1294	57	16	115	0.45	0.202

2.4 Tests performed on geopolymer concrete:

2.4.1 Compressive strength of geopolymer concrete

The test for compressive strength of geopolymer concrete is carried out as per IS 516-1959. The standard size of cubes used for the testing is 150×150×150mm. The cubes were tested under universal testing machine (UTM). The maximum load applied on the specimens were noted. The strength is obtained by dividing total load on the specimens to the actual area of spcimen.

$$fck = \frac{P}{A}$$

Where,

P = maximum load on the specimen

A = area of the specimen(mm^2)

The cubes was tested for 3 days, 7 days & 28 days of curing at room temperature.

2.4.2 Split tensile strength of Geopolymer concrete

The split tensile test is the indirect test which is used to determine the tensile strength of the concrete. in this test the cylinders of size 30cm height and 15cm diameter are casted and tested by applynig compressive line load along the opposite generators of concrete cylinders placed horizontaly with its axis. Due to this compressive loading the tensile stresses are formed on the surface of the cylinders. The test results are given by the equation

$$fsp=\frac{2P}{\Pi DL}$$

where,

P=load on the specimen

D=diameter of specimen (mm)

L=length of specimen (mm)

2.4.3 Intrusion of steel fibres on compressive strength of GPC mix:

From the above study, the GPC mix of alkaline to fly ash ratio 0.35 and 16M soduim hydroxide gives higher compressive sterngth for which effect of steel fibres is studied. The % addition of steel fibres to the mix were 0.5%,1% & 1.5%. The compressive strength of GPC mix was studied for different % of steel fibres.

The mix proportion of GPC for 0.5%,1% & 1.5% steel fibres are shown in the table below:

Mix	Fly ash	GGBS	Coarse aggragates	Fine aggregates	Soduim hydroxide (16M)	Soduim nitrate solution	Steel fibres	AL/FL
1	121	285	1294	554	49	97	0.5%	0.35
2	121	285	1294	554	49	97	1%	0.35
3	121	285	1294	554	49	97	1.5%	0.35

III. Results and discussions

3.1 Test results of conventional concrete:

Test results of conventional concrete

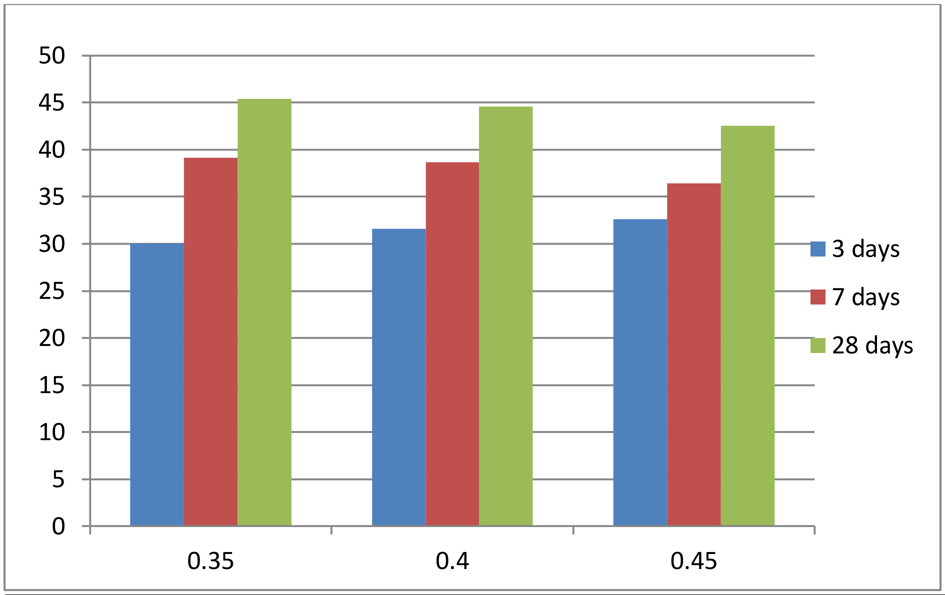
Mix	Average compressive strength N/mm²			Average split tensile strength N/mm²		
	3 days	7 days	28 days	3 days	7 days	28 days
1	17.25	28.2	42.3	1.43	2.15	3.24

3.2 Compressive strength of geopolymer concrete

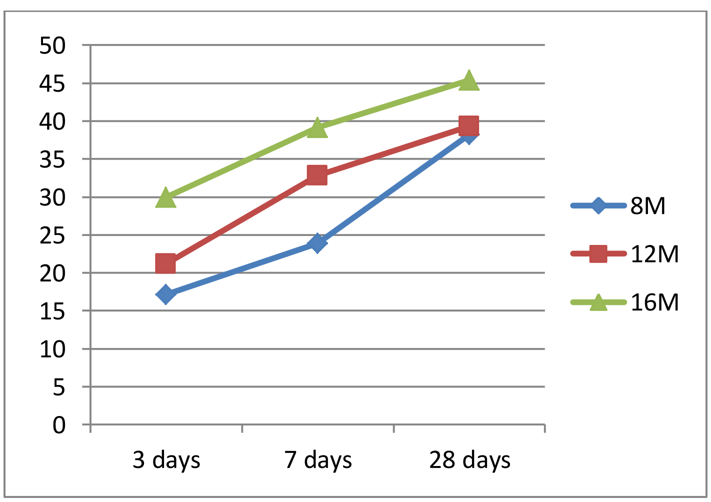
Test results

Mix	Compressive strength N/mm²			Special features	
	3 days	7 days	28 days	Molarity of NaOH	AL/FA
1	17.11	23.86	38.23	8	0.35
2	21.21	32.84	39.3	12	0.35

3	30	39.15	45.4	16	0.35
4	18.22	21.73	37.5	8	0.4
5	27.3	31.24	36.8	12	0.4
6	31.6	38.65	44.61	16	0.4
7	15.95	20.10	37.32	8	0.45
8	26.31	30.54	36.31	12	0.45
9	32.63	36.41	42.53	16	0.45



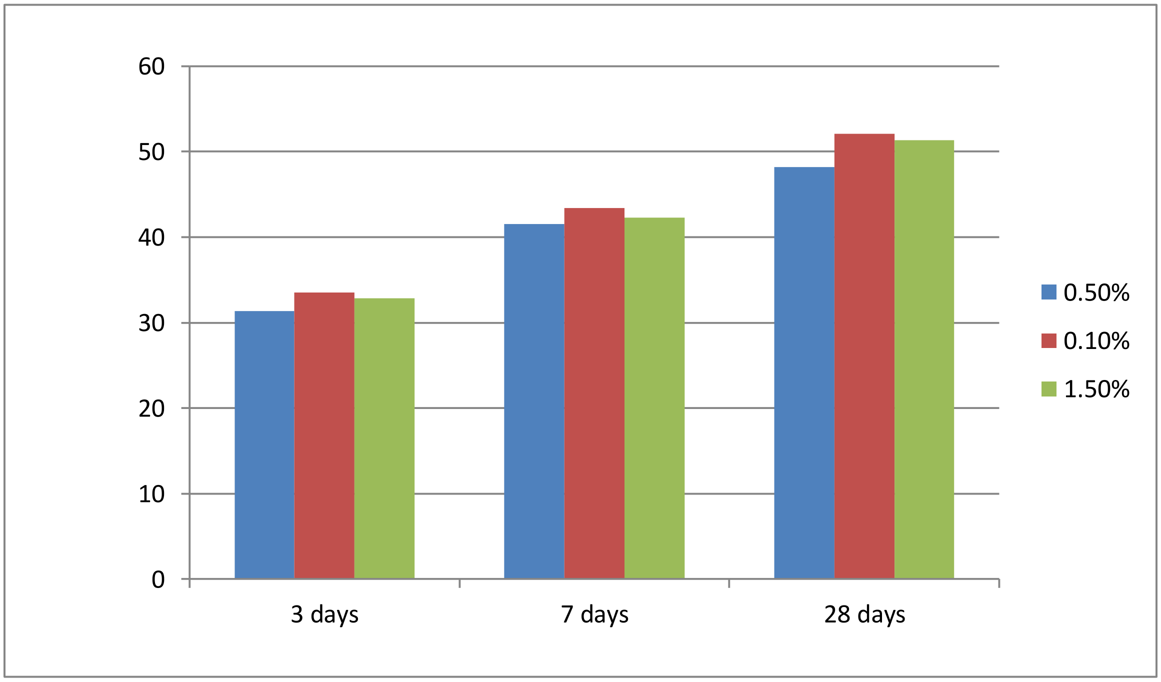
Compressive strength versus AL/FA ratio



Compressive strength v/s Molarity

3.3 Effect of steel fibres on geopolymer concrete

Mix	Average Compressive strength N/mm²			Average Split tensile strength N/mm²		
	3 days	7 days	28 days	3 days	7 days	28 days
SFRGPC (0.5%)	31.37	41.5	48.23	1.50	2.32	2.65
SFRGPC (1%)	33.45	43.4	52.12	1.76	2.57	2.86
SFRGPC (1.5%)	32.86	42.3	51.34	1.68	2.48	2.73



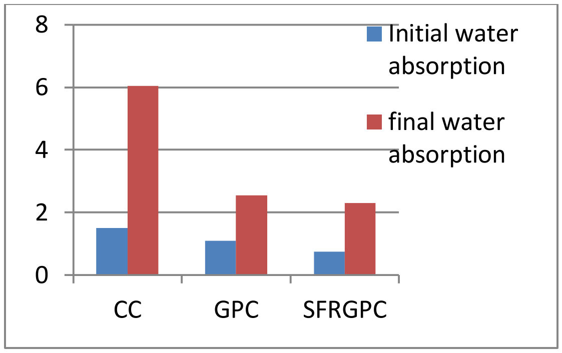
Compressive strength v/s age of concrete

3.4 Durability Tests:

Durability test is performed for the GPC mix which gives higher strength. The durability study is done for the GPC mix of AL/FA 0.35 and 16M soduim hydroxide with intrusion of 1% steel fibres. These test results were compared with the conventional concrete & normal geo-polymer concrete.

3.4.1 Water Absorption and Permeable Voids:

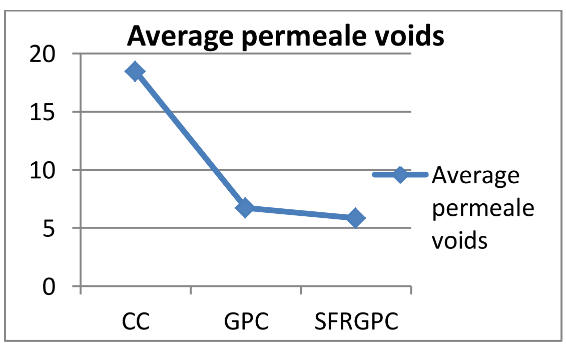
Mix	Initial water absorption (W2-W1)/W1×100	Final water absorption (W3-W1)/W1×100
CC	1.83	8.10
GPC	1.23	2.91
SFRGPC	0.78	2.40



From the above graph it can be seen that the initial and final water absorption of geopolymer concrete is lower when compared to conventional concrete. This is due to presence of fly ash and GGBS in the mortar. Since fly ash is the filler material, it fills all the pores thereby reduction in the water absorption. It can also be seen that with addition of 1% steel fibres, the water absorption can be further reduced.

3.4.2 Permeable voids:

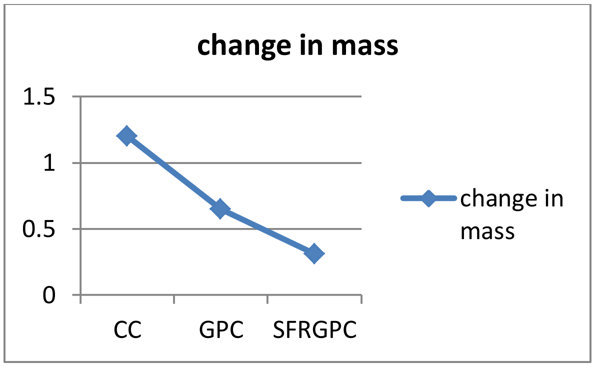
Mix	Average permeable voids (%)
CC	18.45
GPC	6.74
SFRGPC	5.87

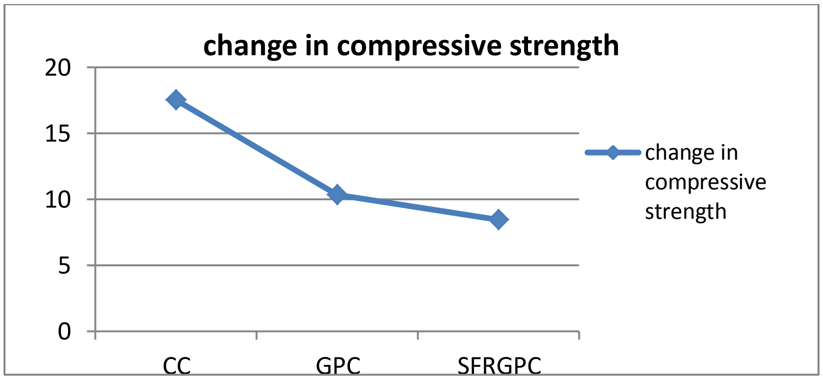


3.4.3 Sulphate Attack Tests:

There is no change in the visual appearance of specimens when exposed to soduim sulphate solution for 28 days. There is no any crack, surface erosion and spalling on the surface of specimens even after 28 days of exposure to sulphate solution.

Mix	Change in mass (%)	Change in compressive strength in (%)
CC	1.20	29.34
GPC	0.298	10.35
SFRGPC	0.312	8.43





IV. Conclusion

- Increase in alkaline to fly ash ratio decreases the compressive strength of geopolymer concrete. Hence alkaline to fly ash ratio of GPC mic choosen was 0.35.
- The GPC mix of 16M gives higher strength when compared to 8M and 12M. Hence increase in the molarity of soduim hydroxide increases the strength characterstics of geopolymer concrete.
- The intrusion of steel fibres increases the strength parameter of GPC mix with 1% dosage. Further there is decrease in the strength of GPC mix with 1.5% dosage.
- The water absorption for 1% SFRGPC is found to be lower than the plain geopolymer concrete and conventional concrete.
- The change in the mass of the SFRGPC is lower than geopolymer concrete and conventional concrete when exposed to sulphate solution for 28 days.
- There is increase in compressive strength of SFRGPC with reference to normal GPC and CC when exposed to soduim sulphate solution for 28 days.

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