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EXPERIMENTAL STUDY ON GEOPOLYMER CONCRETE BY USING GLASS FIBRES

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ABSTRACT: Global release of CO_2 from all sources is estimated as 23 billion tons per year and the Portland cement production accounts for about 7% of total CO_2 emissions. So finding any other alternative for cement was needed to reduce pollution done during production of cement. So Innovative construction materials which produce by chemical action of inorganic molecules can replace cement in concrete known as Geo polymer concrete. Fly ash-based Geo polymer concrete is a 'new' material that does not need the presence of Portland cement as a binder. The role of Portland cement is replaced by low calcium fly ash. Geo polymer is an inorganic alumino-Hydroxide polymer synthesized from predominantly silicon (Si) and aluminum (Al) materials of geological origin or by product materials such as fly ash. This paper presents results of an experimental program to determine mechanical properties of Glass fibre reinforced Geo polymer Concrete which contains fly ash, alkalin liquids, fine and coarse aggregates and glass fibres. The effects of inclusion of glass fibres on density, compressive strength and flexural strength of hardened geo polymer 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 fibres were added to the mix in 1%, 2%, 3% and 4 % by volume of concrete.

Key Words: Fly ash, Glass fibre, Compressive strength, Split-Tensile strength.

1. INTRODUCTION

1.1 General

Geopolymer concrete is the best innovation which able to replace the use of cement in concrete. Geopolymer is a type of formless alumino-silicate product that shows the ideal properties of rock-forming element i.e. hardness, chemical stability and strength etc. properties of geopolymer includes high early strength, low shrinkage, sulphate resistance etc. Geopolymer concrete is the composite material of fly ash and alkaline liquid like sodium silicate & sodium hydroxide. Fly ash is by product of coal obtained from thermal power plant is plenty available worldwide. Fly ash is rich in silica and alumina reacted with alkaline solution produced aluminosilicate gel that acted as the binding material for the concrete. The curing method for geopolymer concrete is heat curing which help to achieve strength to the concrete. It was observed that geopolymeric cement generates 5-6 times less CO2 than the Portland cement. Therefore the use of geopolymer concrete not only significantly reduces the CO2 emission as compared to cement industries, but also utilizes the industrial wastes or by-products used in composition. The polymerization process happens in the geopolymer concrete caused to gain strength for that providing heat is major issue. Giving oven curing or heat curing is one of the important part of geopolymer concrete that limitation can

neglect by adding lime or cement in partial replacement of fly ash. The heat produced by lime and cement help to gain strength to geopolymer concrete but effect of these material in geopolymer concrete is slightly different in present study both material replaced by fly ash to study the effect of each.

Also the concept of adding fibres as reinforced in concrete is not new for enhance the strength of concrete. From the 1960's steel, glass and synthetic fibre were used in concrete and research into new fibre reinforced concrete continues today. Concerning with structural applications fibre concrete possesses many advantages compared to the traditional structural concrete such as increase in compressive, flexural and spilt tensile strength also durability and other properties positively affect.

Geopolymer is a type of concrete with amorphous, alumino-silicate product that exhibits the ideal properties of rock forming properties i.e. hardness, chemical stability and longevity. The properties of geopolymer concrete include high early strength, low shrinkage, freeze-thaw resistance, sulphate resistance and corrosion resistance. However, geopolymer concrete does not utilize any Portland cement in it and the binder is produced by the reaction of an alkaline liquid with a source of material which is rich in silica and alumina.

Figure 1. Geopolymer building

1.2 properties of glass fibres

Glass fibres are available in continuous or chopped lengths. Glass fibres have large tensile strength and elastic modulus but have brittle stressstrain characteristics and low creep at room temperature. Glass fibres are usually are usually round and straight with diameters from 0.005 mm to 0.015 mm. They can be also bonded together to produce the bundle of glass fibres with diameter up to 1.3 mm.

Figure 2. Glass Fibre in Strand Form

Figure 3. Glass Fibre in Mat Form

1.3 Aim of the Study

The present study deals with the manufacture and the mechanical properties of low-calcium fly ash and glass fibre based Geopolymer concrete (GPC).

The aims of the study were:

1. To understand the manufacturing process of Fly-ash and glass fibre based Geopolymer concrete.
2. To ascertain it's suitability as an alternative to conventional cement concrete.
3. To calculate the compressive and tensile strength of concrete

To produce Eco-friendly concrete with high strength

2. LITERATURE REVIEW

Ammar Motorwala et al reported an important observation that curing under normal sunlight yielded strength of 16 N/mm2. This test was done in the month of February 2012 in Sardar Vallabhbhai National Institute of Technology, Surat (Gujarat) in India where the ambient temperature was around 25^0C, hence, similar test when conducted in hotter months can yield still better results. Thus, making insitu use of fly ash concrete a future possibility.

Chandan Kumar et al have reported their investigations on Flyash based Geopolymer concrete and have ascertained that higher compression strength for the geopolymer mix can be obtained by using (i) Higher molarity of Sodium Hydroxide solution up to 16M (ii) Higher Sodium Silicate to Hydroxide ratio, (iii) Higher temperatures of curing (40^o-100^oC) and (iv) Providing a Rest period (the time taken between casting of specimens and the commencement of curing) of up to 3 days. They have also reported that an addition of super plasticizer up to 2% by weight of Fly ash improved workability with nominal changes in compressive strengths values.

Gourley(2003) in Geopolymers; Opportunities for Environmentally Friendly Construction Materials, has stated that Low-calcium (ASTM Class F) fly ash is preferred as a source material than high calcium (ASTM Class C) fly ash. The presence of calcium in high amount may interfere with the polymerization process and alter the microstructure of Geopolymer concretes so obtained.

Hardijito & Rangan observed that higher concentration of sodium hydroxide (molar) resulted higher compressive strength and higher the ratio of sodium silicate-to-sodium hydroxide liquid ratio by mass, showed higher compressive strength of geopolymer concrete. They also found that the increased in curing temperature in the range of 30^o 90°C increased the compressive strength of geopolymer concrete and longer curing time also increased the compressive strength. They handled the geopolymer concrete up to120 minutes without any sign of setting and without any degradation in the compressive strength, resulted very little drying shrinkage and low creep.

3. METHODOLOGY

3.1 Manufacturing Process of Geopolymer Concrete

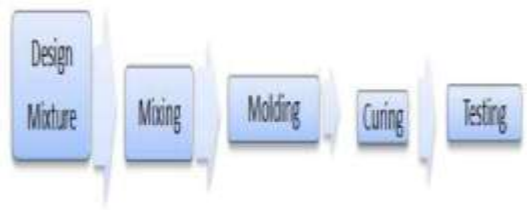
Concrete mixture design process is vast and generally based on performance criteria. The aggregates and the fly ash are mixed dry in a pan mixer for about 4 minutes. At the end of this dry mixing, the activator solution (prepared one day prior to casting), the super plasticiser, and the extra water (if any) are mixed together, and then added to the solid particles and the mixing continued for another 3 to 5 minutes. The fresh concrete is expected to have a stiff consistency and was glossy in appearance. The fresh concrete mixture was then cast in moulds in three layers and vibrated for 10 seconds on a vibrating table.

The previous studies on Geopolymer concrete revealed that geopolymer concrete did not attain any strength at room temperature or by water curing. The Geopolymer concrete will harden at steam curing or hot air curing and the minimum curing period shall be 24 hours. After casting the specimens, they were kept in rest period in room temperature for 2 days. The term 'Rest Period' was coined to indicate the time taken from the completion of casting of test specimen to the start of curing at an elevated temperature. The geopolymer concrete was demoulded and then placed in an autoclave for steam curing for 24 hours at a temperature of 60^o C. The cubes were then allowed to cool in room temperature for 24 hours.

3.2 Preparation of GPCC Specimens with Inclusion of Glass Fibres

The prepared solution of sodium hydroxide of 12M concentration was mixed with sodium silicate solution one day before mixing of concrete to get the desired alkalinity in the alkaline activator solution. Initially coarse aggregate, fine aggregate, cement, fly ash, and GGBS were dry mixed for three minutes in the mixer. Now add the calculated amount of glass fibres into the concrete mixer after separating the fibres into pieces. After dry mixing, alkaline activator solution was added to the dry mix and wet mix was done for 4 minutes. Finally, extra water along with super plasticizer was added. The mixing of total mass was continued until the binding paste covered all the aggregates and mixture become homogeneous and uniform in color. Each specimen was cast in three layers by compacting manually as well as by using vibrating table. Each layer received 25 strokes of compaction by standard compaction rod for concrete, followed by further compaction on the vibrating table. The specimens were removed from the mould immediately after 24 hours since they set in a similar fashion as of conventional concrete. All the specimens were left at room temperature in ambient curing till the date of testing.

FLOW CHART:



4. MATERIALS AND PROPERTIES

Fly Ash: Class F fly ash is used in the study

Table 1: properties of Fly ash

S.NO	PHYSICAL PROPERTIES	TEST RESULTS	Specification As per IS: 3812-1981
1.	Bulk density(Kg/M^3)	1010	1120
2.	Specific gravity	2.22	to 2.42

Fine Aggregates: Fine aggregate used in the experiments was locally available river sand conforming to IS 383- 1970(6). The physical properties of the fine aggregates were tested in accordance with IS 2386(10).

Table 2: Physical properties of Fine Aggregate

S.No.	Property	Test Method	Value
1	Fineness modulus	Sieve analysis (IS 2386-1963 Part 2)	3.13
2	Specific gravity	Pycnometer (IS 2386-1963 Part 3)	2.6
3	Bulk density (kg/m^3)	(IS 2386-1963 Part 3)	1830
4	Water absorption	(IS 2386-1963 Part 3)	1.02%

Coarse Aggregates: The pulverized total was utilized from the nearby quarry. In this examination the total was utilized of 20mm down and tried according to Seems to be: 2386-1963(I, II, III) determination. The properties of coarse total are appeared in Table underneath:

Table 3: properties of coarse aggregate

S.NO	PHYSICAL PROPERTIES	TEST RESULTS
1.	Specific Gravity	2.78
2.	Water absorption	2.22%
3.	Bulk density(g/cc) (loose condition)	1.53 g/cc
4.	Bulk density(g/cc)	1.68 g/cc

	(compacted condition)	
5.	crushing value	13.98%
6.	Impact value	12.71%
7.	Fineness Modulus	7.89

Alkaline activator solution: A combination of Sodium Silicate and 10 Molar Sodium Hydroxide was used in the experimental work. They were mixed together one day prior to the day of casting in the ratio of NaOH: Na_2SiO_3 of 1: 2.5

Super Plasticizer: SP430 in the form of a brown liquid is used

Water: For the purpose of mixing and curing of concrete, portable water conforming to IS 456:2000(4) was used.

The mix proportions are assumed as follows, based on past literature.

5. MIX DESIGN

Table 4. MIX DETAILS FOR M_{30} CONCRETE (1:1.5:3.3)

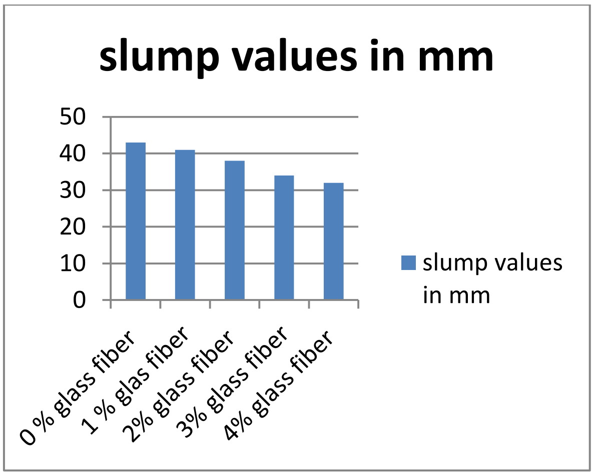
Material	Quantity
Fly Ash	408 kg/m³
Fine aggregate	612.00 kg/m³
Coarse aggregate	1346.4 kg/m³
Sodium Silicate solution	103 kg/m³
Sodium Hydroxide solution (10 molar)	41 kg/m³
Super Plasticizer	4 kg/m³
Additional Water	20 kg/m³

6. RESULT AND DISCUSION

6.1 Workability of concrete for the given specimen

Table 5. workability of the given specimen

S.No	Specimen	Slump values In mm
1	0% Glass fibre	43
2	1% Glass fibre	41
3	2% Glass fibre	38
4	3% Glass fibre	34
5	4% Glass fibre	32



6.2 Test Results of Compressive Strength for M30 Grade Concrete

The casted cubes were tested for their compressive strengths at 7days, 14days, 28days respectively and the results are tabulated as follows. Geopolymer concrete is designated as GPC

Table 6. Compressive strength of Geopolymer concrete

Sr.No	Sample	% of Glass fibre	Compressive Strength in N/mm2		
			3 days	7 days	28 days
1	S1	0	13.14	22.29	39.16
2	S2	1	13.21	24.14	39.55
3	S3	2	13.66	25.28	40.15
4	S4	3	14.02	26.45	41.17
5	S5	4	13.40	26.11	40.83

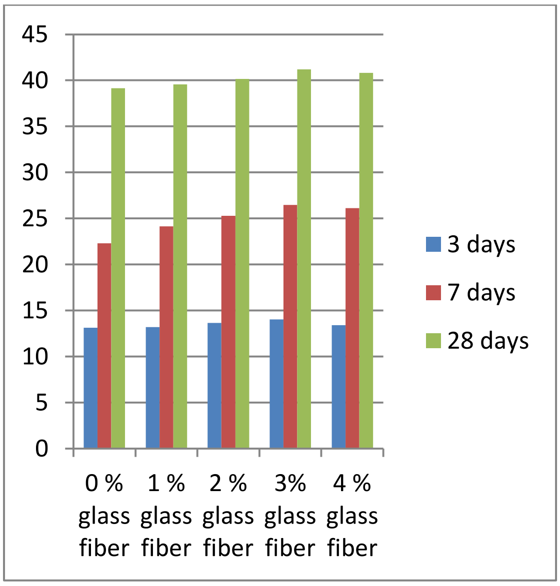


Figure 5: the above figure showing the different percentage of glass fibre compressive strength

Result: It is seen from the Graph that the goepolymer concrete with glass fibre given Maximum strength at 3 % of glass fibre which is 41.17 KN/M^2

6.3 Split tensile strength

The split tensile test used to determine tensile strength of concrete. The split tensile test conducted on cylinders of 150mm dia.x300mm height. Split tensile strength of cylinder specimens is determined by placing between the two plates of Compression Testing Machine.

Table 7: Split tensile strength of Geopolymer concrete

Sr.No	Sample	% of Glass fibre	Compressive Strength in N/mm2	
			7 days	28 days
1	S1	0	3.21	4.87
2	S2	1	3.30	5.08
3	S3	2	3.69	5.76
4	S4	3	3.98	6.12
5	S5	4	3.83	5.90

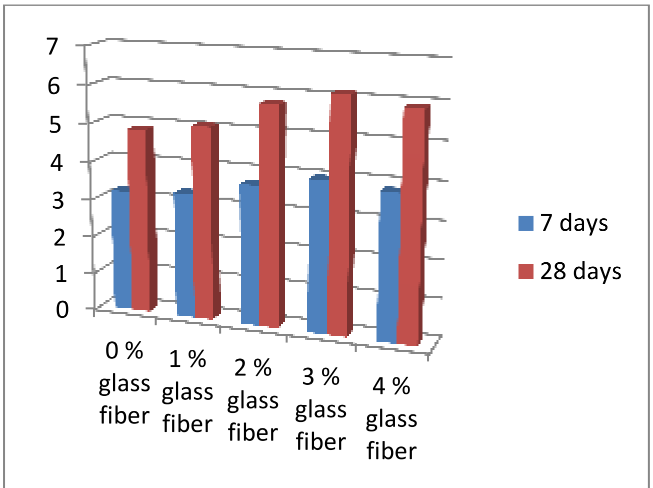


Figure 6: the above figure showing the different percentage of glass fibre tensile strength

Result: It is seen from the Graph that the goepolymer concrete with glass fibre given Maximum tensile strength at 3% of glass fibre which is 6.12 KN/M^2

6.4 Flexural Strength

The flexural test on glass fibre geopolymer concrete is taken on the standard beam specimen of size 100x100x500 mm were supported symmetrically over a span of 400 mm. The average flexural strength of Glass fibre Geopolymer concrete at age 28 days with adding lime and cement is given in table.

Table 8: Flexural Strength Split tensile strength

Sr.No	Sample	% of Glass fibre	Flexural Strength Strength in N/mm2	
			7 days	28 days
1	S1	0	2.98	4.69
2	S2	1	3.36	5.33
3	S3	2	3.87	5.96
4	S4	3	4.11	6.32
5	S5	4	4.05	6.28

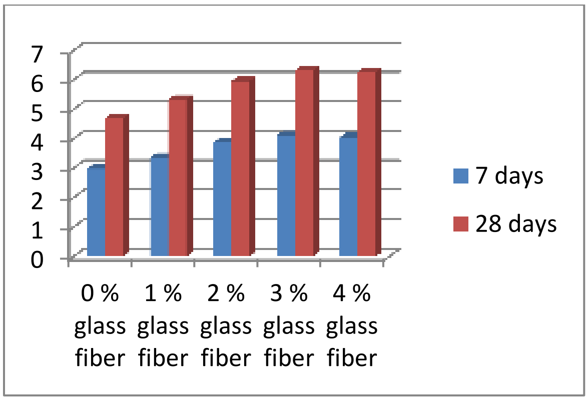


Figure 7: the above figure showing the different percentage of glass fibre flexural strength

Result: It is seen from the Graph that the goepolymer concrete with glass fibre given flexural strength at 3 % of glass fibre which is 6.32 KN/M^2

7. CONCLUSIONS

Fly ash based Geopolymer Concrete had exhibited good compression strength as per the mix desired and is suitable for structural applications.

Resistance to Sulphuric acid attack of Geopolymer concrete was observed to be twice that of conventional cement concrete at all ages of testing.

Similarly, resistance to Sodium Sulphate attack of Geopolymer concrete was observed to be more than twice that of conventional cement concrete at all ages of testing.

It can thus be said that Geopolymer concrete possesses excellent mechanical properties and durability for aggressive environment compared to Convention Cement Concrete.

The cost of chemicals used in geopolymer concrete had made it a bit expensive compared to Portland cement concrete. But taking into consideration, the fact that geopolymer concrete needs no separate water curing and reduced maintenance charges in the long run, Fly ash based Geopolymer concrete can be conveniently employed as a replacement of Cement concrete.

The results from the present experimental work, which dealt with acid and sulphate resistance criteria, place Geopolymer concrete as a promising alternative to conventional cement concrete.

FUTURE SCOPE

Variation in strength of Fly ash based Geopolymer concrete by varying the molarities of the alkaline liquid can be investigated.

- Only sulphuric acid and sodium sulphate resistances have been tested in the present study. Geopolymer concrete can be further studied for its permeability, resistance to chlorides, split tensile strength, flexural strength and other mechanical properties.
- Ground Granulated Blast Furnace slag based Geopolymer concrete can be similarly investigated. Other source materials can include rice husk ash, kaolinite clays etc.
- The effect of curing period on the strength of Geopolymer concrete can be studied.
- The liquid to Fly ash ratio employed in the current investigation is 0.35. Tests can be performed by varying this ratio and comparing its effect on compression strength.
- The ratio of sodium silicate to sodium hydroxide considered in the study was 2.5. Behavior of geopolymer concrete under a different ratio can be investigated.
- Development of high strength Geopolymer concrete manufactured with silicates and hydroxides of potassium can be tested.
- In the present experimental work, only cubes of 15x15x15 cm were tested. Geopolymer concrete can be casted into cylinders and beams to study its compression and flexural strength.
- All the works executed by dry-heat curing can be experimented with steam curing mode.
- Studies can be carried out on the addition of various fibres in Geopolymer concrete and their effect on enhancement of strengths.

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