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Glass Fiber geopolymer concrete

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Abstract—**Concrete is the most durable, versatile & reliable construction material in the construction industry. Concrete is used more than any other manmade material in the world. Second most consumable material after water in the world is concrete. Portland cement production is the second carbon di oxide generator industry after the automobile industries which cause pollution to atmosphere. Producing one tons of cement releases 0.87 tons of CO2. The global release of CO2 from all sources is estimated at 23 billion tons a year and the Portland cement production accounts for about 7% of total CO2 emissions. So finding any other alternative for cement was needed to reduce pollution done during production of cement. Innovative construction materials which produce by chemical action of inorganic molecules can replace cement in concrete known as Geopolymer concrete. The study shows results of experimental program on mechanical properties such as compressive strength, flexural strength, and split tensile strength of Geopolymer concrete in two composite 90% fly ash, 10% cement and 10% lime with varying percentage of glass fiber. The effect of addition of glass fibers on the different mechanical properties of geopolymer concrete by replacing 10% fly ash by cement & lime was studied. Based on test result it was observed that glass fiber geopolymer concrete have relative higher strength than plain geopolymer concrete & it neglect the limitation of heat curing due to replacing lime & cement in concrete mix.**

Keyword: - Geopolymer concrete, Fly ash, Strength, Glass fiber, Lime, Ambient curing etc.

I.INTRODUCTION

The development of science and technology is continues process for improvement of infrastructure all over the world. As infrastructure development with technology there is growing demand for concrete as construction material worldwide, this ultimately increases the demand for cement. Ordinary Portland cement is the most commonly use building material which is basic material of concrete, mortar & grouts. From last few years cement production in India increases from 207 million metric tons in 2010 to 407 million metric tons in 2017. That statistics makes India second largest cement producer in world. Production of Ordinary Portland Cement is highly energy intensive consume significant amount of non-renewable natural resources & release large amount of Co_2 in atmosphere. To producing 1 tons of cement required 2 tons of raw materials (shale & limestone) & release 0.87 tons of Co_2. The global release of CO2 from all sources is estimated at 23 billion tons a year and the Portland cement production accounts for about 7% of total CO2 emissions. Due to production of Portland cement it is estimated that by the year if 2020, the CO_2emission rise by about 50% from the current level. Therefore to preserve the global environment from the impact of cement production, it is now believed that necessary to replace Portland cement. In this regard the geopolymer concrete is one revolutionary research related to construction material, resulting in low-cost and environmental friendly material as an alternative to the Portland cement. Geopolymerconcrete 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 CO_2than the Portland cement. Therefore the use of geopolymer concrete not only significantly reduces the CO_2 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 fibers as reinforced in concrete is not new for enhance the strength of concrete. From the

1960's steel, glass and synthetic fiber were used in concrete and research into new fiber reinforced concrete continues today. Concerning with structural applications fiber 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.

II.LITERATURE REVIEW

Mazaheripour H, Ghanbarpour S. the study shows the influence of polypropylene fibers on the performance of light weight self-compacting concrete onits wet condition as well as mechanical properties of the hardened concrete. Author conclude that applying 0.3% volume fractions of polypropylene fiber to the light weight self-compacting concrete resulted in 40% reduction in the slump flow from 720 mm to 430 mm.On compressive strength and elastic modulus of light weight self-compacting concrete the polypropylene fibers did not impact. However applying these fibers at their maximum percentage volume determined through this study, the results shows that it increases the tensile strength by 14.4% in the splitting tensile strength test, and 10.7% in the flexural strength in flexural test.[7]

K. Vijaia, R. Kumuthaa and B.G.Vishnuramb, author examined the different properties of hardened concrete such as density, compressive strength, split tensile strength and flexural strength of Geopolymer Concrete Composites (GPCC) containing 90% Fly ash (FA), 10% Ordinary Portland Cement (OPC), alkaline liquids and glass fibers. Glass fibers were added to the concrete in volume fractions of 0.01%, 0.02% and 0.03% by volume of concrete. The study represent replacement of 10% of fly ash by OPC in GPC mix eliminates the two limitations of Geopolymer Concrete (GPC mix) such as delay in setting time and necessity of heat curing to gain strength which results in Geopolymer Concrete Composite (GPCC mix). Used the test result of 7 and 28 days of compression, flexure and split tensile strength by ambient and heat curing to conclude that as glass fiber percentage increases strength increases.[1]

Mr.R.Balamuruganet.al,in this paper to increase the strength of concrete quality wise author adds glass fiber in concrete and replaces conventional concrete with geopolymer concrete. To determine the mechanical properties of glass fibregeopolymer concrete (GGPC), which contains fly ash, alkaline liquid and glass fibres. Alkaline liquid to fly ash ratio was fixed as 0.35% by volume of cement and add the glass fibres in the ratio of 1%,2%,and 3% by volume of concrete. From experimental research, results and comparison author stated that glass fibers shown good results. Compressive strength, flexural strength and split tensile strength for these glass fibers are more as compared to Conventional concrete. It can also be concluded that Flexural strength and split tensile strength shows almost 40 to 50% increase in strength as compared to 0% glass fibers. It also concluded that Compression strength shows almost 20 to 30% increase in strength as compared to 0% glass fibers. Geopolymer concrete possessed the ability to enhanced mechanical properties than conventional concrete of the same grade. The compressive strength is found to be much more for normal concrete with the addition of glass fibers as compared to the geopolymer concrete with the addition of glass fibers. [2]

III.METHODOLOGY

A. Materials

The material used for making glass fiber reinforced geopolymer concrete are low calcium dry fly ash as source material, alkaline liquid, coarse aggregate, fine aggregate, cement, lime, glass fiber and water.

Fly ash

Fly ash is a residue of combustion of pulverized coal collected by mechanical or electrostatic separators from the chimney gasses of thermal power plants. The spherical form of fly ash particles improves the flow ability & reduces the water demand. In this experimental work low calcium dry fly ash (Pozzocrete-83) produced from Dirk India limited, Nashik obtained from Ekalahare(Nashik) thermal power station. The fineness of fly ash particle of specific surface was 368 m^2/kg.

Alkaline liquid

A combination of sodium hydroxide and sodium silicate solution was used as alkaline activators for geopolymerization. Sodium hydroxide is available in market in pallet and flakes form. In this experimental study sodium hydroxide flakes with 97% purity of 13 molarity dissolved in distilled water to prepare NaOH solution. Sodium silicate generally available in white viscous solution form uses along with sodium hydroxide. The chemical composition of sodium silicate is Na_2O=14.53%, SiO_2=23.72% (Total Solids = 38.25%), Water = 61.75%.

Aggregate

Course aggregate of size up to 20mm having fineness modulus 6.66, bulk density of 1630 kg/m^3 and specific gravity of 2.603 were used.Fine aggregate is cleaned dry river sand having specific gravity 2.576 and fineness modulus 3.35 was used.

Cement

Cement used in concrete to replacement of fly ash by 10% to avoid the heat curing limitation in geopolymer concrete. The most common type of cement used is Ordinary Portland cement of 53 grades.

Lime

The locally available hydrated lime which generally used as construction material was used for early setting at room temperature. Lime was added in 10% as replacement of fly ash. The lime is a solid composite material having specific gravity 2.7 and bulk density 1425 kg/m3. It comes in solid lump form when convert it to powder form has average particle size of 25micron.

Glass fiber

Glass fibres are made of silicon oxide with addition of small amount of other oxides Glass fibres are characteristic for their high strength, good temperature resistance, corrosion resistance & available at low price. In this study alkali resistance glass fibre of length 12mm &nominal diameter 14 microns with density of 2680Kg/m3 going to use used the above data provided by supplier.

B. Mix Design of Geopolymer Concrete

To prepare mix design of M30 grade of geopolymer concrete following initial information

1. Characteristic compressive strength (Fck) = 30 Mpa
2. Type of curing = Ambient Curing (adding 10 % OPC)
3. Workability = 25 to 50 % Medium.
4. Fineness of Fly Ash = 367 m^2/Kg
5. Alkaline activator
    a) Molarity of NaOH = 13
    b) Concentration of Na_2SiO_3 = 38.25%
6. Solution to Fly Ash ratio = 0.35
7. Sodium silicate to sodium hydroxide ratio by mass = 2

Table 1 Mix Proportion of M30 grade Geopolymer Concrete.

Ingredients of geopolymer concrete	**Fly ash**	**Lime/ Cement**	**NaOH**	**Na_2SiO_3**	**Sand**	**Course Aggregate**	**Total Water**	**Extra water**
Quantity (kg/m3)	432	48	56	112	641.2	1190.8	93.57	--
Proportion	1		0.45		1.34	2.50	0.196	

Table 2 Mix Proportion of M30 grade Geopolymer Concrete with Quantity

Mix ID		**% of Glass Fiber**	**Fly ash Kg/m^3**	**Lime/ Cement Kg/m^3**	**NaOH Kg/m^3**	**Na_2SiO_3 Kg/m^3**	**Sand Kg/m^3**	**Course Aggregate Kg/m^3**	**Total Water L /m^3**	**Glass fibers Kg/m^3**
Adding cement	**Adding lime**									
G1	**S1**	0 %	432	48	56	112	641.2	1190.8	93.57	--
G2	**S2**	0.1%	432	48	56	112	641.2	1190.8	93.57	2.48
G3	**S3**	0.2%	432	48	56	112	641.2	1190.8	93.57	4.96
G4	**S4**	0.3%	432	48	56	112	641.2	1190.8	93.57	7.44
G5	**S5**	0.4%	432	48	56	112	641.2	1190.8	93.57	9.92

IV. RESULT& DISCUSSION

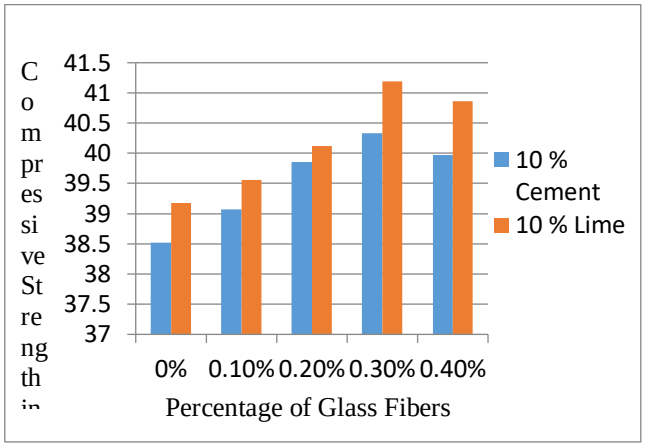
A. Compressive Strength

The test was performed on the concrete cube of standard size 150x150x150 mm the average compressive strength geopolymer concrete with glass fiber at the age of 7 days, 14 days and 28 days for both by adding lime and cement. Due to replacing 10% fly ash by lime and cement curing given is ambient curing.

Table 3 Compressive strength result of Glass fiber Geopolymer concrete with partial replacement of lime

Sr No	Sample	% of Glass fiber	Compressive Strength in N/mm2		
			3 days	7 days	28 days
1	S1	0%	13.15	22.28	39.18
2	S2	0.1%	13.28	24.10	39.56
3	S3	0.2%	13.72	25.26	40.12
4	S4	0.3%	14.08	26.42	41.19
5	S5	0.4%	13.39	26.12	40.86

Table 4 Compressive strength result of Glass fiber Geopolymer concrete with partial replacement of Cement



Graph 1 Glass fiber Geopolymer concrete compressive strength after 28 days with cement and lime

B. Flexural Strength

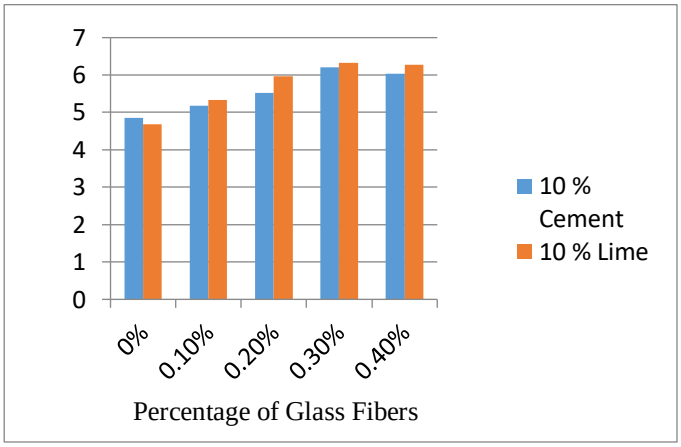
The flexural test on glass fiber geopolymer concrete is taken on the standard beam specimen of size 100x100x500 mm were supported symmetrically over a span of 400 mm. The average flexural strength of Glass fiber Geopolymer concrete at age 28 days with adding lime and cement is given in table no. 5 & 6.

Sr No	Sample	% of Glass fiber	Flexural Strength after 28 days in N/mm2
1	S1	0%	4.69
2	S2	0.1%	5.33
3	S3	0.2%	5.96
4	S4	0.3%	6.32
5	S5	0.4%	6.28

Table 5 Flexural strength result of Glass fiber Geopolymer concrete with partial replacement of lime

Table 6 Flexural strength result of Glass fiber Geopolymer concrete with partial replacement of Cement

Sr No	Sample	% of Glass fiber	Compressive Strength in N/mm2		
			3 days	7 days	28 days
1	G1	0%	13.05	22.28	38.52
2	G2	0.1%	13.17	23.10	39.07
3	G3	0.2%	13.26	24.50	39.85
4	G4	0.3%	13.52	25.71	40.33
5	G5	0.4%	13.64	25.28	39.97



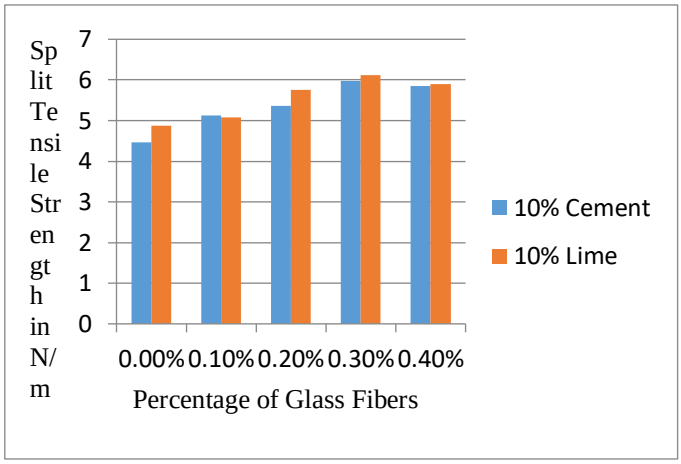
Graph 2 Glass fiber Geopolymer concrete flexural strength after 28 days with cement and lime

C. 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 result of Glass fiber Geopolymer concrete with partial replacement of lime

Table 8 Split Tensile strength result of Glass fiber Geopolymer concrete with partial replacement of Cement



Graph 3 Glass fiber Geopolymer concrete split tensile strength after 28 days with cement and lime

D. Rebound Hammer Test

Rebound hammer test is used to be finding the compressive strength of concrete members. It consists of spring controls hammer that slides on a plunger within a tubular housing.

Sr No	Sample	% of Glass fiber	Compressive Strength after 28 days in N/mm2
1	S1	0%	39.16
2	S2	0.1%	39.56
3	S3	0.2%	40.11
4	S4	0.3%	40.75
5	S5	0.4%	40.16

Sr No	Sample	% of Glass fiber	Flexural Strength after 28 days in N/mm2
1	G1	0%	4.86
2	G2	0.1%	5.18
3	G3	0.2%	5.52
4	G4	0.3%	6.20
5	G5	0.4%	6.03

Sr No	Sample	% of Glass fiber	Compressive Strength after 28 days in N/mm2
1	G1	0%	39.05
2	G2	0.1%	39.20
3	G3	0.2%	39.47
4	G4	0.3%	40.12
5	G5	0.4%	40.07

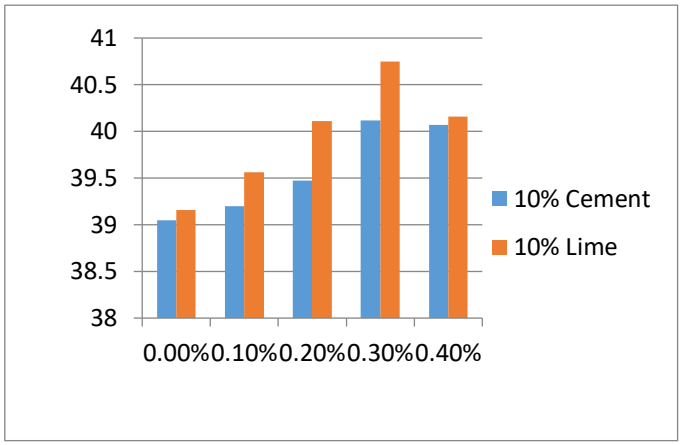
After impact the hammer rebounds. The distance traveled by mass, is called as rebound number.

Table 9 Rebound hammer compressive strength of Glass Fiber Geopolymer Concrete after 28days with partial replacement of lime

Sr No	Sample	% of Glass fiber	Split Tensile Strength after 28 days in N/mm2
1	S1	0%	4.87
2	S2	0.1%	5.08
3	S3	0.2%	5.76
4	S4	0.3%	6.12
5	S5	0.4%	5.90

Sr No	Sample	% of Glass fiber	Split Tensile Strength after 28 days in N/mm2
1	G1	0%	4.46
2	G2	0.1%	5.12
3	G3	0.2%	5.36
4	G4	0.3%	5.97
5	G5	0.4%	5.85

Table 9 Rebound hammer compressive strength of Glass Fiber Geopolymer Concrete after 28days with partial replacement of cement



Graph 4 Rebound Hammer Compressive strength of Glass fiber Geopolymer Concrete after 28 days
With cement and lime.

V. CONCLUSION

- The workability of glass fiber geopolymer concrete is medium in range there is no effect of glass fiber on workability of concrete.
- It is found that by partially replacing lime & cement to fly ash in geopolymer concrete eliminate two limitation of geopolymer concrete such as delay in setting time and necessity of heat curing to gain strength.
- On basis of results it is concluded that 0.3% of glass fiber in mix shows optimum results in compression, flexural and split tensile.
- It is observed that adding glass fibersup to 0.3% possible to mix in concrete but in further condition it is difficult to mix glass fibers in homogenously in concrete.
- Compressive, flexural and tensile strength of glass fiber geopolymer concrete is more by replacing lime for ambient curing as compared to replacement to cement
- Glass fiber in geopolymer concrete improve structural strength reduce crack width and control width tightly, thus improved flexural strength and durability of geopolymer concrete.

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