EXPERIMENTAL STUDY OF GEOPOLYMER CONCRETE BY USING GLASS FIBERS

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ABSTRACT: ***This paper presents the progress of the research on making Geopolymer concrete using the Thermal Power Plant fly ash. The project aims at making and studying the different properties of Geopolymer concrete using this fly ash and the other ingredients locally available materials. Potassium Hydroxide and sodium Hydroxide solution were used as alkali activators. The actual compressive strength of the concrete depends on various parameters such as the ratio of the activator solution to fly ash, morality of the alkaline solution, ratio of the activator chemicals, curing temperature etc. In recent years, Concrete usage around the world is second only to water. Ordinary Portland cement (OPC) is conventionally used as the primary binder to produce concrete. The amount of the carbon dioxide released during the manufacture of OPC due to the calcinations of limestone and combustion of fossil fuel is in the order of one ton for every ton of OPC produced. In addition, the extent of energy required to produce OPC is only next to steel and aluminum. Attempts to reduce the use of Portland cement in concrete are receiving much attention due to environment-related. Fly ash-based Geopolymer 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. Geopolymer 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 fiber reinforced Geopolymer Concrete which contains fly ash, alkaline liquids, fine and coarse aggregates and glass fibers. The effects of inclusion of glass fibers on density, compressive strength and flexural strength of hardened geopolymer 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 fibers were added to the mix in 0.01%, 0.02%, and 0.03% by volume of concrete.

I INTRDUCTION

Geopolymer concrete is an innovative and eco-friendly construction material and an alternative to Portland cement concrete. Use of geopolymer reduces the demand of Portland cement which is responsible for high CO_2 emission.

Geopolymer was the name given by Daidovits in 1978 to materials which are characterized by chains or networks or inorganic molecules. Geopolymer cement concrete is made from utilization of waste materials such as fly ash and ground granulated blast furnace slag (GGBS). Fly ash is the waste product generated from thermal power plant and ground granulate blast furnace slag is generated as waste material in steel plant.

Both fly ash and GGBS are processed by appropriate technology and used for concrete works in the form of geopolymer concrete. The use of this concrete helps to reduce the stock of wastes and also reduces carbon emission by reducing Portland cement demand.

Geopolymer concrete:

The production of one ton of cement emits approximately one ton of carbon dioxide to the atmosphere which leads to global warming conditions. A need of present status is, should we build additional cement manufacturing plants or find alternative binder systems to make concrete? On the other scenario huge quantity of fly ash are generated around the globe from thermal power plants and generally used as a filler material in low level areas. Alternative binder system with fly ash to produce concrete eliminating cement is called "Geopolymer Concrete".

Geopolymer concrete building

Recently world's first building Structural Building, The University of Queensland's Global Change Institute (GCI) has been constructed with the use of geopolymer concrete. It is a four storey high building for public use.

Composition of Geopolymer Cement Concrete Mixes:

Following materials are generally used to produce GPCCs:

Fly ash, GGBS, Fine aggregates and coarse aggregates Catalytic liquid system (CLS): It is an alkaline activator solution (AAS) for GPCC. It is a combination of solutions of alkali silicates and hydroxides, besides distilled water. The role of AAS is to activate the geopolymeric source materials (containing Si and Al) such as fly ash and GGBS.

II LITERATURE RIVIEW

Yasir Sofi and Iftekar Gull states that the properties of fly ash based Geopolymer concrete. M20 grade GPC can be formed by adopting nominal mix of 1:1.5:3 (fly ash: fine aggregates: coarse aggregates) by varying alkaline liquid to fly ash ratio from 0.3 to 0.45. The compressive strength, tensile strength and flexural strength tests were conducted on geopolymer concrete and parameters that affect it are analyzed and proved experimentally. The durability properties like permeability and acid attack are also studied. From the test results, it was concluded that geopolymer concrete possesses good compressive strength and offers good durability characteristics. With the increase of alkaline liquid to fly ash ratio strength decreases and alkaline liquid to fly ash ratio less than 0.3 is very stiff.

P. K. Jamdade and U. R. Kawade states that the strength of Geopolymer concrete by using oven curing .In this study Geopolymer concrete is prepared by mixing sodium silicate and sodium hydroxide with processed fly ash. The concrete is cured at different condition and different temperatures i.e; 600C, 900C and 1200C so as to increase the strength of concrete.

It was observed that higher curing temperature resulted in larger compressive strength of Geopolymer concrete, even though an increase in the curing temperature beyond 600C did not increase the compressive strength substantially. Also longer curing time improved the polymerization process resulting in higher compressive strength of Geopolymer concrete.

Aminul Islam Laskar and Rajan Bhattacharjee states that the variation of workability of fly ash based Geopolymer concrete with the variation of lignin based plasticizer and poly-carboxylic ether based super plasticizer. It has been observed that there exists a critical value of molar strength of sodium hydroxide beyond which super plasticizer and plasticizer have adverse effect on workability of fly ash based geopolymer concrete.

III MATERIALS USED

The geopolymer concrete used in the project is a mixture of fly ash, cement, fine aggregates, coarse aggregates, glass fiber, sodium hydroxide, sodium silicate, super plasticizer, water.

Fly ash:

Quantity and fineness of fly ash plays an important role in the activation process of geopolymer. It was already pointed out that the strength of geopolymer concrete increases with increase in quantity and fineness of fly ash.

Fly ash

Cement:

Cement is a binder, a substance used in construction that sets and hardens and can bind other materials together. The cement of OPC 43 grade is used in the research.

Aggregates:

Aggregates are inert mineral material used as filler in concrete which occupies 70–85 % volume. So, in the preparation of geopolymer concrete, fine and coarse aggregates are mixed in such a way that it gives least voids in the concrete mass.

Coarse aggregates:

Generally, the size of coarse aggregate ranges from 5 to 150mm for normal concrete used for structural members such as beams and columns, the maximum size of coarse aggregate is about 25 mm for mass concrete used for dams or deep foundations.

Fine aggregates:

Locally available river sand having a bulk density of 1693 kg/m3, fineness modulus of 2.75, specific gravity of 2.81 and conforming to grading zone-III

Sodium Silicate:

Sodium silicate is the common name for compounds with the formula $(Na_2SiO_2)_nO$. A well-known member of this series is sodium Metasilicate, Na_2SiO_3. Also known as water glass or liquid glass, these materials are available in aqueous solution and in solid form.

Sodium silicate solution

$$Na_2CO_3 + SiO_2 \rightarrow Na_2SiO_3 + CO_2$$

Sodium Hydroxide:

Sodium hydroxide (NaOH), also known as lye and caustic soda is an inorganic compound. It is a white solid and highly caustic metallic base and alkali of sodium which is available in pellets, flakes, granules, and as prepared solutions at different concentrations. Sodium hydroxide forms an approximately 50% (by mass) saturated solution with water.

NaOH solution

Super plasticizer:

To achieve workability of fresh Geopolymer Concrete, Sulphonated naphthalene polymer based super plasticizer Complast SP430 in the form of a brown liquid instantly dispersible in water, Use of super plasticizer permits the reduction of water to the extent up to 30 percent without reducing the workability, in contrast to the possible reduction up to 15 percent in case of plasticizers.

Complast SP430

Glass fiber:

Glass fiber (or glass fiber) is a material consisting of numerous extremely fine fibers of glass.

Glassmakers throughout history have experimented with glass fibers, but mass manufacture of glass fiber was only made possible with the invention of finer machine tooling. In 1893, Edward Drummond Libby exhibited a dress at the World's Columbian Exposition incorporating glass fibers with the diameter and texture of silk fibers.

Glass Fiber in Strand Form Glass Fiber in Mat Form

EXPERIMENTAL PROGRAM AND MIX DESIGN

The number of specimens required for this research was shown in the below table for this research it requires 48 cube specimens, 24 cylinder specimens, 24 prism specimens.

S.no	% fiber	Compressive strength				Split tensile strength		Flexural strength	
		1day	3days	7days	28days	7days	28days	7days	28days
1	0.00%	3nos	3nos	3nos	3nos	3nos	3nos	3nos	3nos
2	0.01%	3nos	3nos	3nos	3nos	3nos	3nos	3nos	3nos
3	0.02%	3nos	3nos	3nos	3nos	3nos	3nos	3nos	3nos
4	0.03%	3nos	3nos	3nos	3nos	3nos	3nos	3nos	3nos
Total		48 cubes				24 cylinders		24 prisms	

Mix design for M30 grade geopolymer concrete is **1:1.82:3.37.**

TESTS TO BE CONDUCTED ON SPECIMEN

Water absorption:

The water absorption test has been carried out to know the percentage of water absorbed by the specimens, to study the relative porosity or permeability characteristics of geopolymer concrete at 28 days. The specimens used for this test were cubes of size 150 mm x 150 mm.

SORPTIVITY:

Oven dried cube specimens of 150 mm size 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.

Sorptivity test

IMPACT RESISTANCE:

The impact resistance of the specimens was determined to check the failure strength and cracking strength the test specimen consists of concrete discs of 150 mm diameter and 64 mm thick.

Moulds used for casting specimens for impact test

4.2.4. DENSITY:

Density was calculated by measuring the weight of cube specimens before subjecting them to compression test.

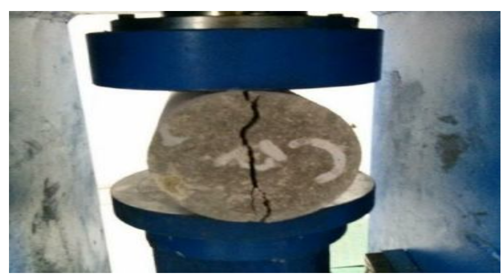
COMPRESSIVE STRENGTH:

Totally 48 cubes of size 150 mm x 150 mm x 150 mm were cast to study the compressive strength of geopolymer concrete.

Compressive strength of geopolymer concrete equipment

4.2.6. SPLIT TENSILE STRENGTH

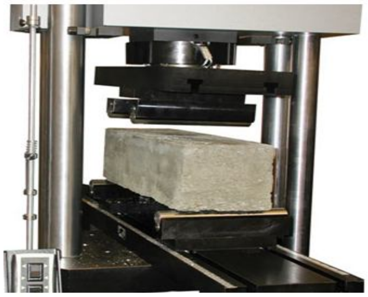
Totally 24 cylinders having a diameter of 150 mm and 300 mm length were cast to evaluate the split tensile strength of geopolymer concrete



Split tensile strength of geopolymer concrete equipment

4.2.7. FLEXURAL STRENGTH:

Totally eighteen prisms of size 700mmx150mm x150 mm were cast to study the flexural strength of geopolymer concrete.



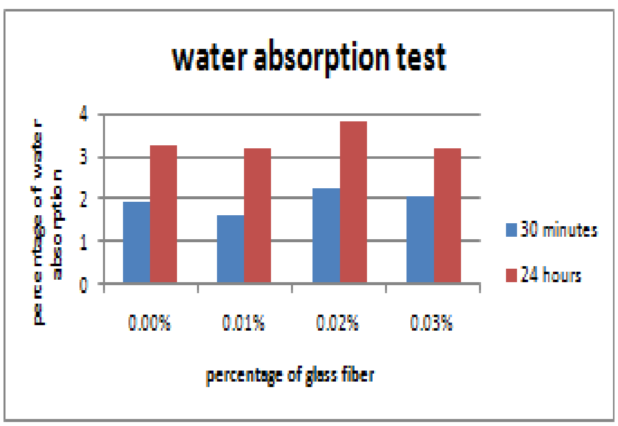
Flexural strength of geopolymer concrete equipment

RESULTS AND ANALYSIS

5.1. Water absorption:

S.no	% Glass	Initial weight in grams	Weight in grams		Water absorption		Average water absorption in %	
			At 30 mins	At 24 hours	30 mins	24 hours	30 mins	24 hours
1	0.00%	2291	2331	2362	1.75	3.10	1.96	3.24
		2320	2363	2389	1.85	2.97		
		2251	2302	2333	2.27	3.64		
2	0.01%	2334	2369	2403	1.50	2.96	1.62	3.20
		2291	2330	2364	1.70	3.19		
		2285	2323	2364	1.66	3.46		
3	0.02%	2274	2324	2358	2.20	3.69	2.23	3.79
		2352	2402	2440	2.13	3.74		
		2296	2350	2386	2.35	3.92		
4	0.03%	2300	2348	2374	2.09	3.22	2.08	3.17
		2296	2339	2364	1.87	2.96		
		2333	2333	2411	2.27	3.34		

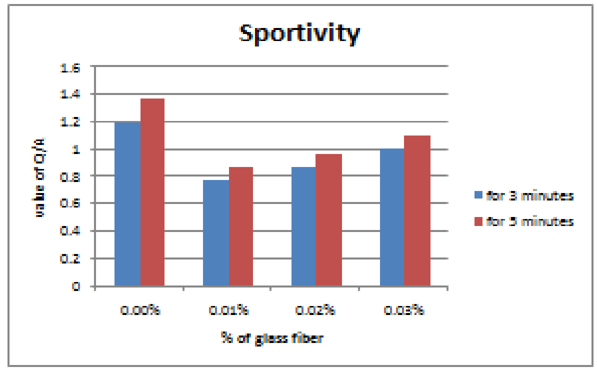
Graph:



5.2. Sorptivity:

$\frac{wt}{a}\sqrt{t}$ minutes	Q/A in mm			
	0.00%	0.01%	0.02%	0.03%
2	0.8000	0.5000	0.5000	0.5667
3	0.9667	0.6333	0.7000	0.8000
4	1.2000	0.7667	0.8667	1.000
5	1.3667	0.8667	0.9667	1.1000
6	1.5333	0.9667	1.1000	1.2667
7	1.7667	1.0667	1.2000	1.4000
8	1.9333	1.2000	1.3333	1.5333
9	2.1333	1.3000	1.4667	1.7000
10	2.2667	1.4000	1.5667	1.8000
11	2.4667	1.4333	1.6333	1.9000

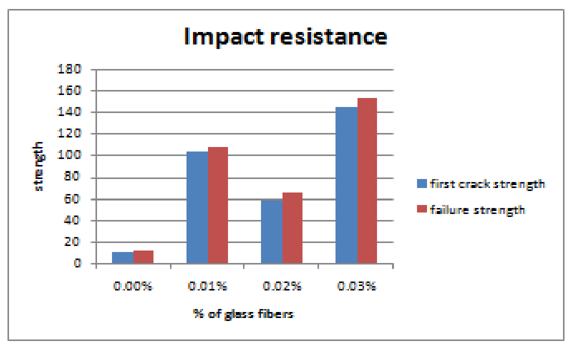
Graph:



5.3. Impact resistance:

% of glass fiber	First crack strength(blows)			average	Failure strength (blow)			average
	Specimen 1	Specimen2	Specimen3		Specimen1	Specimen2	Specimen3	
0.00%	10	12	9	10	11	13	11	12
0.001%	99	109	104	104	112	103	110	108
0.002%	54	64	58	59	60	71	63	65
0.003%	152	144	145	147	154	155	151	153

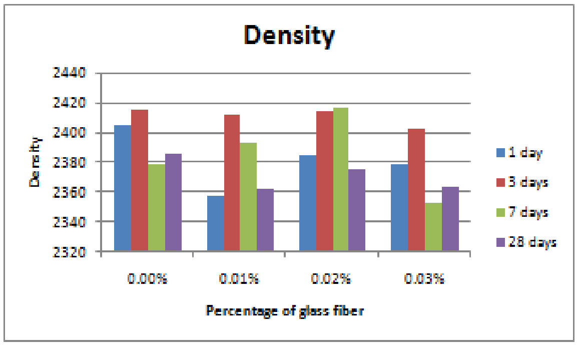
Graph:



5.4. Density:

s.no	%glass fiber	Avg weight in kg				Avg density in kg/m^3			
		1day	3days	7days	28days	1day	3days	7days	28days
1	0.00%	8.177	8.152	8.028	8.052	2404.94	2415.31	2378.77	2385.88
2	0.01%	7.958	8.142	8.076	7.972	2358.02	2412.35	2392.79	2361.98
3	0.02%	8.047	8.149	8.157	8.017	2384.20	2414.42	2416.79	2375.31
4	0.03%	8.027	8.108	7.942	7.978	2378.27	2402.47	2353.09	2363.95

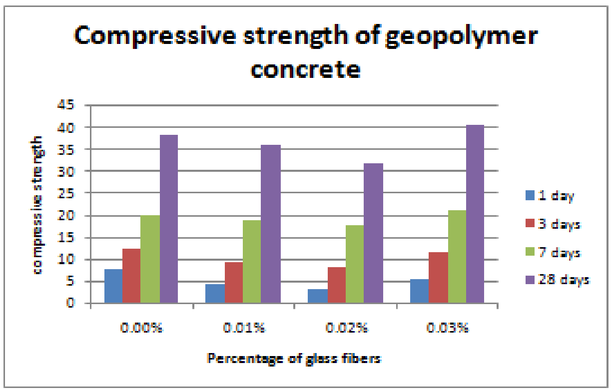
Graph:



5.5. Compressive strength of geopolymer concrete:

S.no	% of glass fiber	Compressive strength of geopolymer concrete			
		1 day	3 days	7 days	28 days
1	0.00%	7.79	12.43	19.83	38.28
2	0.01%	4.22	9.07	18.9	35.97
3	0.02%	3.17	8.22	17.76	32.08
4	0.03%	5.36	11.51	21.19	40.73

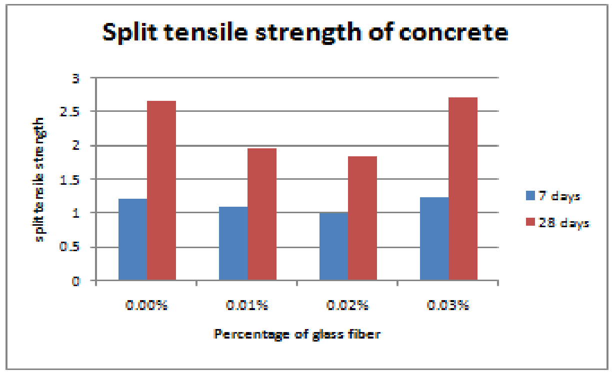
Graph:



5.6. Split tensile strength of geopolymer concrete:

S.no	% of glass fiber	Split tensile strength	
		7 days	28 days
1	0.00%	1.22	2.67
2	0.01%	1.09	1.96
3	0.02%	1.00	1.86
4	0.03%	1.24	2.71

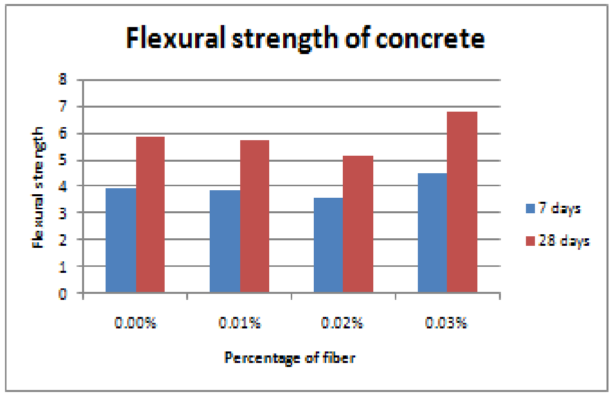
Graph:



5.7. Flexural strength of concrete:

S.no	% of glass fiber	Flexural strength of concrete	
		7 days	28 days
1	0.00%	3.93	5.87
2	0.01%	3.87	5.73
3	0.02%	3.60	5.13
4	0.03%	4.47	6.80

Graph:



VI CONCLUSIONS

Based on the experimental study the following conclusions are made on geopolymer concrete

1. Density of geopolymer concrete ranges from 2335 kg/m3 to 2422 kg/m3, 2356 kg/m3 to 2438 kg/m3 and 2321 kg/m3 to 2421kg/m3 for 0.01%, 0.02% and 0.03% of glass fibers respectively. It was noticed from the test results that except at the age of 7 days,

for all other ages, inclusion of glass fibers in concrete resulted in decrease in unit weight.

2. The addition of 0.01% and 0.02% of glass fibers to concrete does not seems to increase the compressive strength while the compressive strength of geopolymer specimens with 0.03% of glass fibers increases with respect to that of the control mix. The decrease in 28 days compressive strength was found to be 6% and 16% for 0.01% and 0.02% of glass fibers respectively and the increase in compressive strength was about 6% for addition of 0.03% of glass fibers with reference to control mix.

3. The average split tensile strengths of geopolymer concrete with 0.01% and 0.02% volume fraction of glass fibers decreases while the tensile strength of geopolymer concrete with 0.03% volume fraction of glass fibers increases with respect to that of the geopolymer mix without fibers. The decrease in tensile strength was about 27% and 30% for addition of 0.01% and 0.02% volume fraction of glass fibers respectively with reference to geopolymer mix and increase in tensile strength was about 1% for addition of 0.03% volume fraction of glass fibers with reference to geopolymer mix.

4. A similar trend was noticed for flexural strength as well. The flexural strengths of geopolymer with 0.01% and 0.02% volume fraction of glass fibers decreases while the flexural strength of geopolymer with 0.03% volume fraction of glass fibers increases with respect to that of the control geopolymer concrete mix. The decrease in flexural strength was about 1% and 12% for addition of 0.01% and 0.02% of glass fibers whereas an increase in flexural strength of about 16% was observed for 0.03% of glass fibers with reference to geopolymer concrete mix.

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