Glass Fibre High Strength Concrete, an Alternate to Conventional Concrete

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***Abstract*— Glass fibre is the waste product of the Glass Fibre Cloth manufacturing industry. It is generally considered to be an inert solid waste. Conventional Concrete is a costly composite and does not solve waste problem from the society on the other hand it's structures' face conventional problems like low strength, high permeability. Whereas Glass fibre High Strength Concrete uses waste product of Glass Fibre Cloth Industry and Coal Power Plants which are respectively Glass Fibre and Fly Ash. The Glass fibre being a waste product of Glass Fibre Cloth manufacturing industry, is a cost effective solution as it does not increases cost over the conventional concrete. The effect of glass-fibres when added to the concrete, is increased strength, has been observed worldwide. This experimental investigation compares the fly ash based PPC Glass fibre concrete to the Ordinary Portland Cement Glass fibre concrete, and the former is found to be give higher strength. It has been observed that the workability of concrete reduces by increasing the percentage of glass fibres added. However, observations have been made that this problem can be solved by using fly ash based cement. The results showed that, the long term compressive strength of OPC based GFRC marginally improved but PPC based GFRC showed significant increase of 19% in strength compared to the ordinary concrete.**

The experimental investigation is based on M-30 mix design, as the case of reference, as most of the structural concrete elements are made with concrete having compressive strength 20 MPA to 35 MPA. The study also includes observation from the studies held worldwide and presents the conclusion to a great extent about the usage of glass fibre in High Strength Concrete. Glass Fibre Reinforced High Strength Concrete (GFRHSC), can have revolutionizing effects on India's infrastructure problems along with removing wastes like Fly Ash and Glass Fibre waste, as it gives significantly higher strength and that too comparatively earlier

***Keywords*— Glass fibre Fly Ash Based Concrete, High Strength, Cost Effective**

I. INTRODUCTION

Infrastructure development is impossible without concrete, especially in temperate countries like India. Concrete is used in roads, bridges and buildings.

Concrete can be modified to perform in a more ductile form by the addition of randomly distributed discrete fibres in the concrete matrix and this effect was studied by Mohammadi et al., in 2008. In Fibre Reinforced Concrete (FRC), fibres can be effective in arresting cracks at both macro and micro levels. Many of the current applications of fibre reinforced concrete involve the use of fibres ranging around 1%. Hence an attempt has been made to study the durability performance of Glass Fibres (GF).

Glass fibres are the waste product from Glass Fibre Cloth, manufacturing industries, which supplies this cloth for insulation of electrical equipments to industries like Bharat Heavy Electrical Limited (BHEL). The glass fibres are derived from compositions containing silica. They exhibit useful bulk properties such as hardness, transparency, resistance to chemical attack, stability, and inertness, as well as desirable fibre properties such as strength, flexibility, and stiffness. When these glass fibres are added to fly ash based PPC, it becomes Glass Fibre Reinforced High Strength Concrete (GFRHSC).

Fly-ash based PPC is a special blended cement, produced by inter-grinding higher strength Ordinary Portland Cement clinker with high quality processed flyash .This unique, value-added product has hydraulic binding properties not found in ordinary cements. It is available in specially designed 50-kg bags.

Fly-ash based PPC is made by intergrinding high strength clinker with specially processed fly ash. This imparts a greater degree of glass fibre fineness to Fly-ash based PPC cement, improved workability properties while mixing, and makes concrete more corrosion resistant and impermeable. These features makes GFRHSC for better long-term strength and improved corrosion resistance and therefore, greater life for your constructions. Fly-ash based PPC is also an eco-friendly cement, as fly ash is the waste from the coal based power plants, which if not consumed in bulk(as in fly ash based cement), can have serious implications on the environment.

Fly-ash based GFRC has ingredients which react with calcium hydroxide to form CSH gel, to provide additional strength, which actually makes the concrete grow in strength over the years. It also produces less heat of hydration and offers greater resistance to the attack of aggressive waters than normal Portland cement.

Fly Ash based GFRHSC easily replaces OPC based GFRC and provides additional advantages for practically all types of construction applications - commercial, residential, bungalows, complexes, foundation, columns, beams, slabs and other RCC jobs. It is especially recommended for mass concreting work, and where soil conditions and the prevailing environment take heavy toll of constructions made with ordinary cements.

The Glass fiber has Ultimate Strength of 3000N/mm^2, stiffness of about 50N/mm^2 and Elastic Modulus of 70-80 GPA and low creep at room temperature. It has been successfully tested that 5% glass fiber of cement sand mortar suitable for premix applications and does not result in balling.

Physical Properties will depend on the type and percentage of Fiber and the ultimate strength would be about 1200N/mm^2.

II. LITERATURE REVIEW

1. R.Gowri investigated the effect of glass wool fibres on mechanical properties of concrete and observed that higher percentages of Glass wool fibers greater than one percentage affect the workability of concrete, and may require the use of super plasticizers (workability agents) to maintain the workability and also came to the conclusion that the failure pattern of the specimens, that the formation of cracks is more in the case of concrete without fibres than the glass wool fibre reinforced concrete.
2. K. Chandramouli et,al studied Chloride Penetration Resistance Studies on Concretes Modified with Alkali Resistant Glass Fibers and tested the samples under rapid chloride permeability test hence came to the conclusion that glass fibres improves that durability performance appreciably compared with that of plain concrete.
3. Dr.H.Sudarsana Rao, et. al. in their paper on residual compressive strength of fly ash based glass fibre reinforced high performance concrete subjected to acid attack found that The loss of compressive strength is 22.5% for fly ash based GFRHPC mixes after 90 days immersion in H2SO4acid while similar exposure resulted in a loss of 38.8% for reference M20 concrete. And also confirmed that Fly ash based GFRHPC mixes resisted acid attack in a better way as compared to conventional M20 concrete at all ages of exposure to HCl, Mg SO4and H2SO4.
4. Falah M Wegian,et.al. in their paper Influence of Fly Ash on Behaviour of Fibres Reinforced concrete structures, found that steel fibres do not significantly improve the compressive strength of concrete although it is very effective in resisting flexural tensile stress.
5. Niragi Dave, in "experimental evaluation of low calcium fly ash based geopolymer concrete" found that Geopolymer concrete based on fly ash cannot be considered as complete replacement of cement, but it can minimize the complete dependency on cement.
6. Properties of Fly Ash Based Coconut Fiber Composite, paper by Saravana Raja MohanCompressive concluded that strength of concrete was reduced by 8.5 and 25.31% for the replacement of cement with five percentages of fly ash mixed concrete. Addition of coconut fibers did not have significant effect on the compressive strength of fly ash concrete.
7. M.V. Krishna Rao,et.at. in "Effect of size and shape of specimen on compressive strength of glass fiber reinforced concrete (gfrc)" investigated that the compressive strength based on 150mm cubes is slightly more than 100mm cubes. However, to conclude if 150mm is the optimum, tests on larger cubes like 200mm are to be performed.
8. In the investigation by Liaqat A. Qureshi, et.al under the aegis of An Investigation On Strength Properties Of Glass Fiber Reinforced Concrete, it was observed that the compressive strength of the GFRC shows maximum increment at 1.5%.

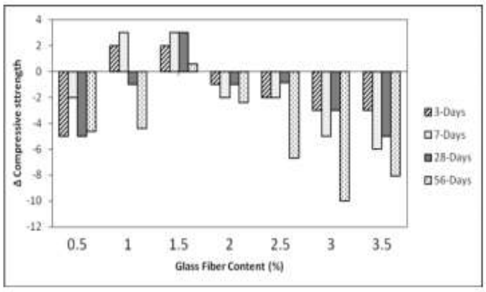


Figure 4. Increase/decrease in cube compressive Strength with glass fibre content

III. MATERIAL AND METHODS

Experimental program has been planned to consider the durability aspect by studying the "Fly ash based GFRHSC of M30 Mix Design". The details of various materials used in this investigation are given in the following sections.

Cement :
Ordinary Portland cement of 43 grade of J.K. Lakshmi Cement Ltd. brand conforming to IS: 12269 standards was used in this investigation. The specific gravity of the cement was 3.10. The initial and final setting times were found as 50 minutes and 365 minutes respectively

Fine Aggregate:
Locally Available fine aggregates were used.
The specific gravity of the sand is found to be 2.67.

Coarse-Aggregate:
Locally Available fine aggregates were used. And a reasonably good grading has been adopted,

60% of the aggregate passing through 20mm I.S.sieve and retained on 10.00 mm I.S.sieve and 40% of the aggregate passing through 10.00 mm I.S.sieve and retained on 4.75 mm I.S.sieve was used in the production of

GFRHSC and its control cubes of M30 mix design and OPC based GFRC cubes of M30 Mix Design. In the production of M20 grade concrete, 20mm maximum size coarse aggregate has been used. The specific gravity of coarse aggregate is 2.75.

Water:

Potable fresh water available from Acquaguard was used for mixing and curing of both GFRHSC mixes and M20 grade concrete.

Super Plasticizer:

To improve the workability of the GFRHPC mixes, a high range water-reducing agent Sika Plastiment 100 has been used in the present work.

Fly ash Based Cement:

ACC Fly-ash based PPC available in 50kg bag.

Glass fibre :

Glass fibre obtained from Glass Fibre Textiles,Govindpura, Bhopal under the trade name Cem-FIl anti crackHD (High Dispersion) glass fibres, was used in the present work. The glass fibre is of 16mm length and 14 micron diameter(average values). The details are presented in Table A

Table A

S.No	Property	Value
1	Filament Diameter	14 Micron
2	Filament per stand	100
3	Length	30-40mm
4	Ultimate Elongation%	2.4
5	Specific Gravity	2.68

A. Casting of Test Specimens

The required quantities of materials are weighed and place over the plat form. Initially the cement and fine aggregate are mixed together in the dry state until they are thoroughly blended. Then the coarse aggregate, glass fibres are added to dry mix of cement and fine aggregate and they are mixed thoroughly until the coarse aggregate and fibres uniformly distributed throughout the batch. Super plasticizer (Sika Plastiment 100) is mixed in water and added to uniformly distributed mass until plastic concrete of uniform colour is achieved. This plastic concrete is placed in the cube. After this the filled moulds are placed over the vibrator for compaction. Later these moulds are kept for 24 hours or 5 days, as required. After 24 hours the specimens are demoulded and cured for 28 days. After 28 days the specimens are taken out form the curing pond and kept under shade for surface dry. Then the cube specimens are tested in compression testing machine of capacity 200 Tonnes. The failure load is noted for each cube specimen and compressive strength is determined.

Fig.1
Fly Ash Based GFRHSC

B. Mix Design

Concrete Mix ratio : of M-30
Water Cement Ratio:
0.45 for fly ash Cement based GFRHSC
0.47 for OPC based GFRC

- ***Glass Fiber Percentage by weight of Cement-***

  1.5% for fly ash Cement based GFRHSC
  1.5% for OPC based GFRC
- ***The respective control mix had 0% glass fiber***
- ***In order to improve the workability the super plasticizer are added in accordance with the in-situ test requirement.***
- ***1% by weight of cement for fly ash Cement based GFRHSC and 1.5% by weight of cement for OPC based GFRC.***
- ***The ratio of the coarse aggregates to the fine aggregates is 60:40***
- ***It was observed that the strength increases if the cubes are demoulded after 5 days.***

C. Mix Design Calculations

According to M-30 Mix Designs as per IS-10262-2009

TABLE II

Mix Calculations	
Volume of Concrete in m^3	1.00
Volume of Cement in m^3	0.12
(Mass of Cement) / (Sp. Gravity of Cement)x1000	
Volume of Water in m^3	0.160
(Mass of Water) / (Sp. Gravity of Water)x1000	
Volume of Admixture @ 0.5% in m^3	0.00160
(Mass of Admixture)/(Sp. Gravity of Admixture)x1000	
Volume of All in Aggregate in m^3	0.718
Sr. no. 1 – (Sr. no. 2+3+4)	
Volume of Coarse Aggregate in m^3	0.445
Sr. no. 5 x 0.62	
Volume of Fine Aggregate in m^3	0.273
Sr. no. 5 x 0.38	
Mix Proportions for One Cum of Concrete (SSD Condition)	
Mass of Cement in kg/m^3	**380**
Mass of Water in kg/m^3	**160**
Mass of Fine Aggregate in kg/m^3	**711**
Mass of Coarse Aggregate in kg/m^3	**1283**
Mass of 20 mm in kg/m^3	**924**
Mass of 10 mm in kg/m^3	**359**
Mass of Admixture in kg/m^3	**1.90**
Water Cement Ratio	**.46 average**

D. Experimental Program

To study the size and shape effect of test specimens on the compressive strength of GFRC a detailed experimental program has been proposed. Table-1 shows the details of the specimens casted to study the same. The details of the companion plain concrete specimens are also given in Table III.

A total of 18 cubes were casted to test the various properties of concrete.

The cubes which contained fiber were demoulded after period of five days and the total of 6 cubes contained fiber; three of them were fly ash based and three were OPC based of Grade 43.

Now, fly ash based cubes and OPC based cubes regarded as control cubes and did not contain fiber, were demoulded the next day which were three in number each.

Three cubes of R.C.C. were also casted which were demoulded after five days.

TABLE III

Experimental Program	Total No.	Demoulded After	Values
The Total Number Of Cubes	18		
Cement Concrete M30; Water Cement Ratio .42	3	1 Day	687
Cement (Fly Ash Based) Concrete M30 proportion Water Cement Ratio .42	3	1 Day	713
Cement Concrete M30; Water Cement Ratio .42	3	5Days	755
Cement (Fly Ash Based) Concrete M30 proportion Water Cement Ratio .42	3	5 Days	780
OPC GFRC; Water Cement Ratio .45	3	5Days	795
PPC GFRC (GFRHSC)	3	5 Days	883

Fig. 2 Casted Cubes

Fig. 3 Compressive Strength Testing of GFRHSC Cube

E. Results and Discussion

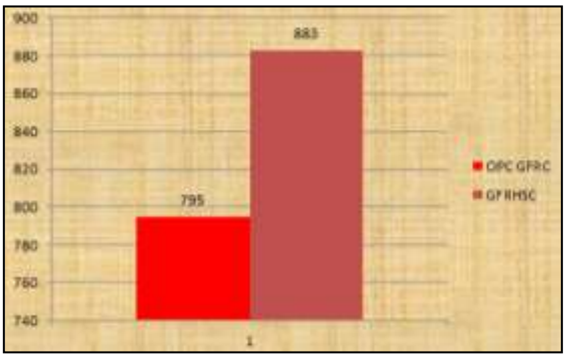
TABLE IV

Sr No	CUBE SYMBOLE	CUBE NUMBER	COMPRESSIVE TEST VALUE(in KN) (RATE OF LOADING 5.2KN/S) (28 Days Strength)	AVERAGE VALUES (in KN)
1	(T) CEMENT CONTROL	T1	724	
	5 Day Demoulding	T2	628	680.67
		T3	690	
2	(CG) CEMENT CONCRETE (GFRC)	1	708	
	5 Day Demoulding	2	748	709.33
		3	672	
3	(FC2) FLY ASH CONTROL	F-5-1	757	
	5 Day Demoulding	F-5-2	642	713.33
		F-5-3	742	
4	(FC3)FLY ASH CONTROL	F-1-1	620	
	1 Day Demoulding	F-1-2	691	687
		F-1-3	750	
5	(FG)FLY ASH FIBER(GFRC)	11	840	
	5 days Demoulding	12	894	883
		13	915	

On the basis of the above observation the graphs are plotted.

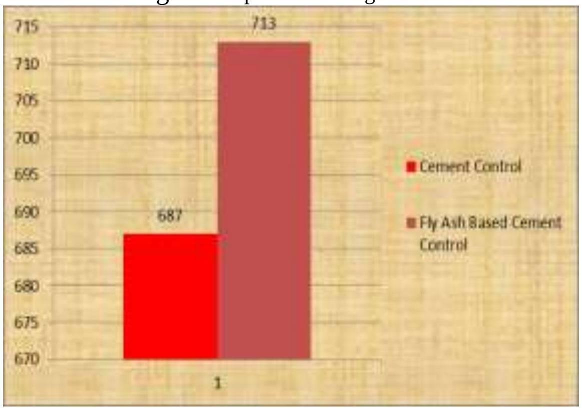
Figure 2, compares the graph of compressive strength of OPC Based Glass fibre reinforced concrete and Fly ash Based Glass fibre High Strength Concrete. The strength of GFRHSC was found to increase by 11% in comparison to OPC based GFRC.

Fig. 3 Compressive Strength



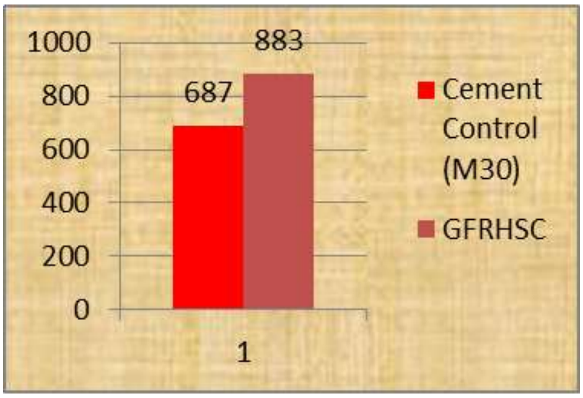
Then on the basis of same Table III, in can be observed that the strength of Fly Ash based Cement Control was higher by 3.6% than the strength of OPC based cement control concrete cubes (Fig. 4). Hence Fly ash was chosen as our base for making high strength concrete.

Fig. 4 Compressive Strength



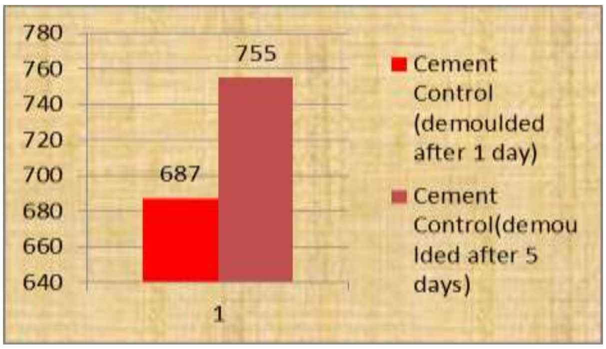
Now, on the basis of Table III, it was also observed that the compressive strength of PPC Based GFRC was higher than that attained in OPC control by 28.5 %.

Fig. 5 Compressive Strength



Increment can be observed in the strength in five days demoulding over one day demoulding. This increment can is shown in the figure 6: there is 10 % increase in compressive strength of concrete cubes, when demoulding is after 5 days, rest all conditions remained the same. This increment as per reviewed literatures can be attributed to heat of hydration which increases the rate of strength gain by the cubes when they remain non-demoulded.

Fig. 6 Compressive Strength



F. Cost Analysis

The cost of the various materials used in the GFRHSC is the same as that of conventional RCC in which super-plasticizers are added for workability. The only addition in GFRHSC is addition of Glass fibre and Fly Ash Based Cement. The cost of Fly Ash based PPC does not have any difference from the cost of conventional Portland Cement.

Glass fibre used in this research being the waste product of the Glass Fibre textile industry has been obtained free of cost and their exclusive cost cannot be determined at this point of time, till its mass production is started.

TABLE V

MATERIAL	OPC BASED GFRC	GFRHSC	RCC
50 KG BAG OF CEMENT	SAME	SAME	SAME
SAND	SAME	SAME	SAME
AGGREGATE	SAME	SAME	SAME
WATER	SAME	SAME	SAME
ADDMIXTURE	SAME	SAME	SAME
FIBRE	FREE OF COST	FREE OF COST	N/A
THE ABOVE COST MENTIONED IS IN INDIAN NATIONAL RUPEE			

IV. CONCLUSIONS

1. It has been observed that the workability of concrete decreases with the addition of Glass Fibers. But this difficulty can be overcome by using fly ash based cement and super-plasticizers.
2. Fly ash based GFRHSC gives significantly more strength (about 28%) than conventional concrete when 1.5% glass fibre is added to it and this percentage is optimum.
3. When delayed demoulding is done, the strength increases in comparison to the conventional demoulding done after one day. The reason to this effect can be possibly attributed to heat of hydration which increases the rate of strength gain by the cubes when they remain non-demoulded.
4. GFRHSC is an economic replacement of RCC, as Glass fibre and fly ash being the waste products of Glass fibre Cloth Industry and Coal Industries respectively.
5. Glass fibre High Strength Concrete can have revolutionizing effect on the infrastructure development of the countries like India, as there is abundant waste of Glass fibre and fly ash is available.
6. GFRHSC successfully addresses pollution from Coal based power plants and glass fibre cloth industry.
7. A monolithic material resulting in a better compressive strength in comparison with conventional RCC along with economy is achieved.

V. ACKNOWLEDGMENT

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