An Experiential Evaluation of Strength Properties on Concrete with Glass Fibre as a Replacement Material

Gift Pon Lazarus D[1]

[1]*Assistant Professor Department of Civil Engineering,MRIIRS,Faridabad.*

Abstract- **Concrete is the most widely used construction material has several desirable properties like high compressive strength, stiffness and durability under usual environmental factors. Plain concrete possess very low tensile strength, limited ductility and little resistance to cracking .Internal micro cracks are inherently present in concrete and its poor tensile strength is due to propagation of such micro cracks. Fibres when added in certain percentage in the concrete improve the strain properties well as crack resistance, ductility, as flexure strength and toughness. Mainly the studies and research in fiber reinforced concrete has been devoted to steel fibers. In recent times, glass fibres have also become available, which are free from corrosion problem associated with steel fibres. Glass fibre reinforced concrete (GFRC) is a concrete made primarily of hydraulic cements, aggregates and discrete reinforcing glass fibres. GFRC is a relatively new material. This is a composite material consisting of a matrix containing a random distribution or dispersion of small fibres, either natural or artificial, having a high tensile strength. Due to the presence of these uniformly dispersed fibres, the cracking strength of concrete is increased and the fibres acting as crack arresters. The present studies outlines the experimental investigation conducts on the use of glass fibres with structural concrete. The GFRC (Glass fibre reinforced concrete) affects properties like compressive strength, flexure strength, toughness, modulus of elasticity were studied.**

Keywords- **GFRC,** Workability**, Compressive strength, Flexural strength.**

I. Introduction

1. Study of Glass Fibre Reinforced Concrete

Concrete is one of the most widely recognized development material for the most part delivered by utilizing locally accessible ingredients. The development of concrete has brought about the essential need for additives both chemical and mineral to improve the performance of concrete. Hence varieties of admixtures such as fly ash, coconut fibre have been used so far. Hence an attempt has been made in the present investigation to study the behaviour of glass fibre in concrete. The present trend in concrete technology is towards increasing the strength and durability of concrete to meet the demands of the modern construction. The main aim of the study is to study the effect of glass fibre in the concrete. Glass fibre has the high tensile strength and fire resistant properties thus reducing the loss of damage during fire accidents. The addition of these fibres into concrete can dramatically increase the compressive strength, tensile strength and split tensile strength of the concrete. In this study, tests have done for the concrete with glass fibre of 0.5%, 1%, 2% and 3% of cement by adding as an admixture. Glass fibre has used over 30 years in several construction elements, mainly non constructional ones, like façade panels, piping for sanitation, decorative non recoverable form work and other products. Glass fiber concrete (GFC) consists basically of a matrix composed of cement, sand, water, and admixtures, in which short length glass fibers are dispersed. The effect of the fibers in this composite leads to an increase in the tension and impact strength of the material. Glass wool, which is commonly known as "fibreglass" today, however, was invented in 1938 by Russell Games Slayter of Owens-Corning as a material to be used as insulation. It is material made from extremely fine fibers of glass. Fibreglass is a lightweight, extremely strong, and robust material. Although Its bulk strength and weight properties are also very favorable when compared to metals, and it can be easily formed using moulding processes. Glass is the oldest, and most familiar, performance fibre.

2. Properties and applications of GFRCSustainability:

The present of glass fibre in concrete improves various properties like compressive strength, flexural strength, modulus of elasticity, durability, toughness and ease of application. GFRC has various applications in construction field such as building renovation works, water and drainage works, bridges and tunnels lining panels, permanent formwork method of construction, architectural cladding, acoustic barrier and screens.

The use of GFRC mixes has opened up a plethora of new design possibilities for contractors who make concrete countertops, fireplace surrounds, wall panels, furniture, and other decorative elements. Because GFRC is significantly lighter in weight and higher in tensile strength than conventional concrete, countertop slabs can be made without seams and span greater lengths. Concrete countertops are a handcrafted surface popular in kitchens that offer complete customization. With concrete you can have a functional and beautiful countertop in small and large kitchens alike.

Colour:

The ability to create counters in the color, finish, size and shape of your choice is amazing. GFRC can be cast using decorative form liners to create architectural wall panels as thin and light as standard wood paneling while permitting more flexibility in shape, color, and texture.

GFRC fireplace surrounds can span from floor to ceiling without requiring special reinforcement, and hearths and mantles can extend from wall to wall or be cantilevered to appear as if floating on air. GFRC can even be used outdoors to make artificial rock formations, permitting the creation of dramatic rock and waterscapes without the need to haul in heavy boulders.GFRC offers the same decorative versatility as conventional concrete. It can be formed into nearly any shape and stained or integrally colored. Various tints of gray, white, and buff can be achieved by using colored cements or pigments. The surface finish can be lightly textured or polished smooth to expose the aggregate. And GFRC can be seeded with colored decorative glass or stone to create granite-like effects. glass fibre also used in making artificial rocks are a dramatic yet economical way to enhance water features, landscapes, buildings, and more.

Strength:

Using fiber reinforcement yields a higher strength to weight ratio than unreinforced precast concrete. As a result, the product is durable and lighter in weight, which significantly reduces the cost of freight transportation and installation. The fiber-wrapped skin is more resistant to environmental degradation and corrosion under the attack of chemicals. Easily adapts to any shape of the concrete allowing flexibility in design. An environmentally friendly composite made of natural raw materials with low energy consumption. Rock and stone have long been valued as natural, distinctive landscaping elements. But getting the rock exactly where you want it, even if you live in an area where real rock is readily available, is no easy feat. Imagine, for example, the equipment, effort, and expense that would be required to haul large boulders weighing at least a ton each into a backyard and then to stack them around an in-ground pool or pond. That's why more and more landscape and swimming pool designers and contractors are turning to faux rock. Not only can artificial rocks be molded, textured, and colored to exactly replicate the look and feel of real rock formations, they also can be built onsite, eliminating the inconvenience and expense of hauling. They are used in retaining walls and fences, erosion control, animal habitants, gold cources and parks, terraces and pool decks, planter boxes, fish ponds etc.

Properties of GFRC

Strength of GFRC is developed due to high contents of alkali resistant glass fibers and acrylic polymer. Since the cement contents are high, and the ratio of water to cement is low, the GFRC strength under compressive loads is high. These materials also possess great tensile and flexural strength. The fiber orientation determines the effectiveness of fiber resistance to loads. The fiber must be stiff to ensure the provision of required tensile strength. Thus, the performance of these materials is better than the normal concrete. The high fiber content bears the tensile loads, while the concrete is flexible due to the polymers. The physical properties of GFRC are better than the non-reinforced concrete. Steel reinforcement that has been suitably designed considerably increases the strength of products that are cast with normal concrete or GFRC. However, GFRC cannot substitute reinforced concrete if heavy loads are required to be endured. GFRC are best suitable for light loads.

II. LITERATURE REVIEW

Pshtiwan N. Shakor & Prof. S.S.Pimplikar concluded that glass fibres lose a proportion of their pristine strength when placed in a Portland cement environment. AR fibres have a superior performance to other types, and are likely to retain long term tensile strengths of about 1000-1200 N/mm2 at ambient temperatures in a cement environment. This includes not only an assessment of fibre content and matrix strength, but also such details as fibre distribution, orientation, and effectiveness of bonding. Possible manufacturing or materials faults can also be diagnosed. Also it shows that the MOR and LOP in drying condition test have higher result than wet condition around (1- 5) MN/m2 difference. The main difference between dewatered and non-dewatered GRC is the difference in density which has two effects. Firstly although the fibre content by weight is the same, the higher density of the dewatered board gives a higher fibre volume fraction giving higher strengths. Secondly the dewatered board has better compaction and reduced porosity giving better fibre/matrix bond strength. Cement, when reinforced with glass fibre, produces precast elements much thinner— typically 10 mm—than would be possible with traditional steel-reinforced precast concrete, where 30mm or more concrete cover to the steel is essential as protection against corrosion. Thinner sections are also made possible by the low water: cement ratio of the material, the lack of coarse aggregate, and its low permeability. As a result, panels of equal strength and function of precast concrete can be produced with thinner sections and therefore less weight. Special methods have been suggested to reduce the sensitivity to poor and non uniform water curing. The addition of polymer latex has been reported to be effective in eliminating the adverse effects of lack of water curing. It has been suggested that for ARGRC, the addition of 5% polymer solids by volume, without any moist curing, may replace the recommended practice of seven days curing in a composite without the polymer. The tests conducted

on GFRC in laboratory have shown good resistance for fire, since the major use of GFRCs is for architectural building panels. In these buildings, fire resistance becomes an important factor in design. . When cement, mortar or concrete is splashed or otherwise brought into contact with window glass, etching occurs. This is because the alkali in cement attacks some of the silicates that are used in glass manufacture. The stock used in making glass fibres has better alkali resistance than window glass because zirconia is used as one of the constituents. Tests on telecommunication towers by using GRC with carbon fibre and/or stainless steel bars have shown that GRC can be used as structural material, with reduced weight and has good durability properties. According to the results of the tests performed in small specimens the average values of the main material properties are: compression strength: 41 MPa, tension strength: 3.7 MPa; initial Young modulus: 16.5 GPa. The mixes with 1.5% volume of fibres gave optimum composite properties in terms of compressive strength with 25.39% strength improvement. The highest increase in split tensile strength was observed in mixes with 1.5% of volumes of fibres and found to be5.76% higher strength than reference concrete. Similarly, the highest flexural strength was observed in mixes with 1.5% of volume of fibre and found to be 72.5% more than reference concrete.
Kavita Kene, et al conducted experimental study on behavior of steel and glass Fiber Reinforced Concrete Composites. The study conducted on Fiber Reinforced concrete with steel fibers of 0% and 0.5% volume fraction and alkali resistant glass fibers containing 0% and 25% by weight of cement of 12 mm cut length, compared the result.

G. Jyothi Kumari, et al studied behavior of concrete beams reinforced with glass fiber reinforced polymer flats and observed that beams with silica coated Glass fiber reinforced polymer (GFRP) flats shear reinforcement have shown failure at higher loads. Further they observed that GFRP flats as shear reinforcement exhibit fairly good ductility. The strength of the composites, flats or bars depends upon the fiber orientation and fiber to matrix ratio while higher the fiber content higher the higher the tensile strength.

Dr. P. Srinivasa Rao, et al conducted durability studies on glass fiber reinforced concrete. The alkali resistant glass fibers were used to find out workability, resistance of concrete due to acids, sulphate and rapid chloride permeability test of M30, M40 and M50 grade of glass fiber reinforced concrete and ordinary concrete. The durability of concrete was increased by adding alkali resistant glass fibers in the concrete. The experimental study showed that addition of glass fibers in concrete gives a reduction in bleeding. The addition of glass fibers had shown improvement in the resistance of concrete to the attack of acids.

S. H. Alsayed, et al studied the performance of glass fiber reinforced plastic bars as reinforcing material for concrete structures. The study revealed that the flexural capacity of concrete beams reinforced by GFRP bars can be accurately estimated using Review on the Performance of Glass Fiber Reinforced Concrete 283 the ultimate design theory. The study also revealed that as GFRP bars have low modulus of elasticity, deflection criteria may control the design of intermediate and long beams reinforced with FDRP bars.

Yogesh Murthy, et al studied the performance of Glass Fiber Reinforced Concrete. The study revealed that the use of glass fiber in concrete not only improves the properties of concrete and a small cost cutting but also provide easy outlet to dispose the glass as environmental waste from the industry. From the study it could be revealed that the flexural strength of the beam with 1.5% glass fiber shows almost 30% increase in the strength. The reduction in slump observed with the increase in glass fiber content.

III. MATERIALS USED

1. Cement

Pozzolana Portland cement is used in the project work, as it is readily available in the local market. The cement used in the project work has been tested for various preparations as per IS: 4031-1988 and found to be conforming to various specifications of IS: 1489-1991. The specific gravity was 2.6.

2. Fine Aggregates

Locally available river sand conforming to grading zone 2 of IS: 383-1970. Clean and dry river sand available locally will be used. Sand passing through IS 4.75mm sieve will be used for casting all the specimens

3. Coarse Aggregates

Crushed annular granite metal from a local source was used as a coarse aggregate. The specific gravity was 2.7, the coarse aggregate used in the project work of 60% of 20mm aggregate and 40% of 10mm aggregate.

4. Glass Fibre

It is the material made from extremely fine fibres of glass. It is a light weight, extremely strong and robust material. There are distinctive sorts of fibre however in these we have taken E-glass fibre to show better resistance and a very good insulation to electricity.

IV. Mix Design

1. Stipulations for Proportioning of Mix Design

a) Grade designation = M 30
b) Type of cement = OPC 43 grade
c) Maximum nominal size of aggregate = 20 mm
d) Minimum cement content = 320 kg/m^3
e) Maximum water-cement ratio = 0.45
f) Workability = 75 mm
g) Type of aggregate = crushed angular
h) Maximum cement content =450 kg/m^3
i) Aggregate zone = I

2. Target Strength for Mix Proportioning

$$f'_{ck} = f_{ck} + 1.65s$$

Where,

f'_{ck}= target average compressive strength at 28 days,

F_{ck}= characteristic compressive strength at 28 days, and

s = standard deviation

Standard deviation, s =5 N/mm^2

Target mean strength= 30 + 1.65 × 5 =38.25 N/mm^2

3. Selection of Water-Cement Ratio

From Table 5 of IS 456, maximum water-cement ratio = 0.45

Based on experience, adopt water-cement ratio as 0.44

0.44 < 0.4, hence OK

Estimated water content for 75mm slump = 186 + 3/186×100 =191litre

4. Calculation of Cement Content

Water cement ratio=0.44
Cement content = 191/0.44 = 435kg/m3
From Table 5 of IS 456, minimum cement
Content for 'severe' exposure condition = 320 kg/m^3 350 kg/m ^{3}
> 320 kg/m^3, hence, O.K
Volume of coarse aggregate corresponding to 20 mm size aggregate and fine aggregate (Zone I) for water-cement ratio of 0.50 =0.60

In the present case water-cement ratio is 0.44. Therefore volume of coarse aggregate is required to be increased to decrease the fine aggregate content. As the water-cement ratio is lower by 0.06, the proportion of volume of coarse aggregate is increased by 0.012 (at the rate of -/+ 0.01 for every ± 0.05 change in water-cement ratio). Therefore, corrected proportion of volume of coarse aggregate for the water-cement ratio of 0.40 = 0.612

For pump able concrete these values should be reduced by 10 percent.
Therefore, volume of coarse aggregate = 0.612 x 0.9 = 0.55.
Volume of fine aggregate content = 1-0.55 =0.45.

5. Mix Calculation

The mix calculation per unit volume of concrete shall be follows:

Volume of concrete = 1 m^3

Volume of cement $= \frac{435}{3.15 \times 1000} = 0.138$ m^3

Volume of water $= \frac{191}{1 \times 1000} = 0.191$ m^3

Volume of all in aggregate = 1- (0.138+0.191)
= 0.671 m^3

Mass of coarse aggregate = 0.671×0.55×2.74×1000

= 1011.1 kg

Mass of fine aggregate = 0.671×0.45×2.74×1000

= 827.34 kg

The quantities used for preparation of concrete are given below:

Cement : 435kg/m^3

Water : 191kg/m^3

Fine aggregate : 827kg/m^3

Coarse aggregate : 1011kg/m^3

Size of aggregate : 20mm

Slump : 75mm

W/c : 0.44

V. TESTING

5.1. Test on Compressive Stregth

Out of numerous tests conducted to the solid, this is the most extreme essential which gives a thought regarding every one of the attributes of cement. By this single test one can judge that whether Concreting has been done appropriately or not. For solid shape test two sorts of examples either 3D squares of 15 cm X 15 cm X 15 cm or 10cm X 10 cm x 10 cm relying on the measure of total are utilized. For the majority of the works cubical moulds of size 15 cm x 15cm x 15 cm are normally utilized. The glass fibres are included at the rate of 0.5%, 1%, 2% and 3% of cement. This solid is poured in the mould and altered legitimately so as not to have any voids. Following 24 hours these moulds are evacuated and test examples are placed in water for curing. These examples are tried by pressure testing machine following 7 days curing or 28 days curing. The compressive strength after 7 days of curing for 0.5%, 1%, 2% and 3% of glass fibre ratio in concrete is 17.7 N/mm2, 20.76N/mm2, 19.64N/mm2, 18.4N/mm2 respectively and after 28 days of curing it comes out to be 27.06 N/mm2, 28.46 N/mm2, 26.98N/mm2 and 26.10 N/mm2 respectively. As we can see that the compressive strength is very high at 1% having for 7 days is 20.76N/mm2 and for 28 days is 28.46N/mm2.

Table: 1 (Compressive Strength)

S.No	M_{20} + Glass fibre	Compressive strength (N/mm^2)	
		7 Days	28 Days
1	0.50%	17.7	27.06
2	1%	20.76	28.46
3	2%	19.64	26.98
4	3%	18.4	26.108

5.2. Test on Flexural Strength

The test can be performed in accordance with as per BS 1881. A simple plain concrete beam is loaded at one third span points. Typical standard size of example 500 x 100x 100 mm is utilized. Set up the test example by including the glass fibre at the rate of 0.5%, 1%, 2% and 3% by filling the solid into the mould in 3 layers of roughly equivalent thickness. Pack every layer 35 times utilizing the packing bar as determined previously. Packing ought to be circulated consistently over the whole cross segment of the bar mould and all through the profundity of every layer. The example put away in water might be tried instantly on expulsion from water for 7 and 28 days.

Flexural Strength (Mpa) = $pl/bd2$

Where,

P=Failure Load

L=c/c distance=500mm

b=width of the specimen=100mmL

d=Depth of the specimen=100mm

Table: 2 (Flexure Strength)

S.No	M_{20} + Glass fibre	Flexure Strength (N/mm^2)	
		7 Days	28 Days
1	0.50%	1.42	2.25
2	1%	1.47	2.94
3	2%	1.3	2.6
4	3%	1.28	2.45

5.3. Test on Split Tensile Strength

To locate the split elasticity the barrels were placed in the moulds of measurements 300mm length and 150mm diameter across with M_{20} grade concrete. Set up the test example by including the glass fibre at the rate of 0.5%, 1%, 2%, 3% were additionally included. While placing the barrels the compaction is done utilizing the table vibrator. Finally the top layer of the example is completely levelled and very much wrapped up. From time of casting 24 hours the barrels were de-moulded and were kept for curing in curing tank for 28days. After 28days curing is done these examples have been tried in pressure testing machine. The split rigidity is figured as takes after

Split tensile strength (Mpa) = $2p/\pi Dl$

Where,

P=Failure load

D=Diameter of Cylinder

L=Length of cylinder

Table: 3 (Split Tensile Strength)

S.No	M_{20} + Glass fibre	Split Tensile Strength (N/mm^2)	
		7 Days	28 Days
1	0.50%	1.41	3.4
2	1%	2.83	3.92
3	2%	2.62	3.57
4	3%	2.43	3.42

5.4. Effect of Compressive strength on Glass Fiber Concrete:

This figure represents the graph between the Compressive strength Vs % of glass fibre. The glass fibre is added at the rate of 0.5%, 1%, 2%, and 3%. Out of these, the compressive strength is very high at 1% having for 7 days is 20.76N/mm2 and for 28 days is 28.46N/mm^2.

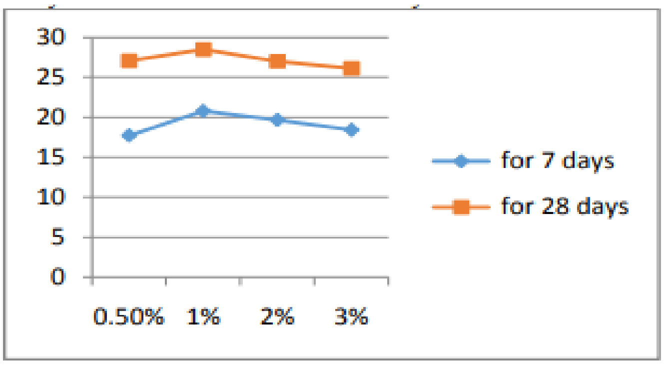

Fig1: Compressive strength vs % of glass fibre

5.5. Effect of Flexural strength on Glass Fiber Concrete:

This figure represents the graph between the Compressive strength Vs % of glass fibre. The glass fibre is added at the rate of 0.5%, 1%, 2%, and 3%. Out of these, the tensile strength is very high at 1% having for 7 days is1.47N /mm2 and for 28 days is 2.94N /mm^2.

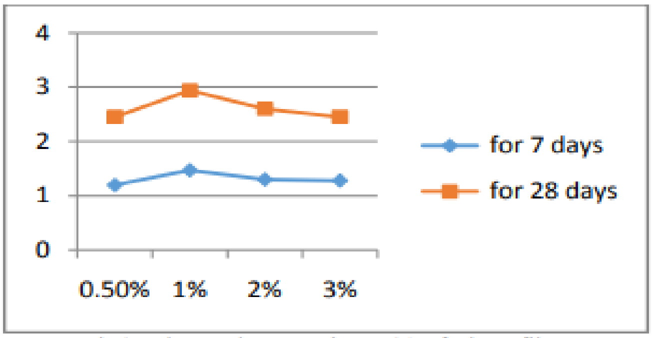

Fig2: Flexural strength vs. % of glass fibre

5.6. Effect of Split Tensile strength on Glass Fiber Concrete:

This figure represents the graph between the Split Tensile strength vs % of glass fibre. The glass fibre is added at the rate of 0.5%, 1%, 2%, and 3%. Out of these, the split tensile strength is very high at 1% having for 7 days is 2.83 N /mm2 and for 28 days is 3.92N /mm^2.

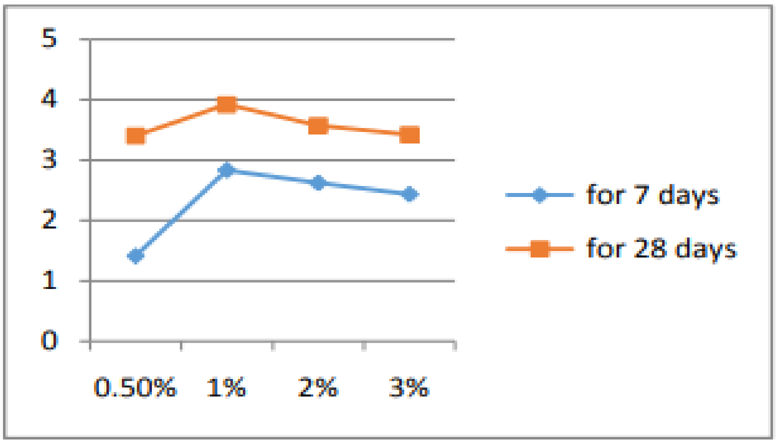

Fig3: Split Tensile strength vs. % of glass fibre

Above graphs shows the various effect of glass fibre on reinforcement concrete. A various attempts are done for finding the properties of glass fibre reinforcement concrete. From the studies we have found that expected outcomes of my report will be the increase in compressive strength, flexural strength and split tensile strength on different glass fibre content. Addition of glass fibre in reinforced concrete increases the toughness as compare with conventional reinforced concrete. The value of toughness also increased when we use glass fibre content in concrete. The modulus of elasticity of glass fibre reinforced concrete also increased as compared with conventional reinforced concrete. The percentage increase of compressive strength of various grades of glass fibre concrete mixes compared with 28 days compressive strength. There is a percentage increase of flexure strength of various grades of glass fibre concrete mixes compared with 28 days compressive strength

VI. CONCLUSION

- The present study concluded that the addition of glass fibres at 0.5%, 0.1%, 2% and 3% of cement reduces the cracks under different loading conditions.
- It has been observed that the workability of concrete increases at 1% with the addition of glass fibre.
- The increase in compressive strength, flexural strength, split tensile strength for M-20 grade of concrete at 7 and 28 days are observed to be more at 1%. We can likewise utilize the waste product of glass as fibre.
- It has been observed that there is a gradual increase in compressive strength compare to the normal concrete. The workability of concrete decreases from 1% due to the addition of fibre.
- The compressive strength is very high at 1% having for 7 days is 20.76N/mm2 and for 28 days is 28.46N/mm^2.
- The tensile strength is very high at 1% having for 7 days is1.47N /mm^2 and for 28 days is 2.94N /mm^2
- The split tensile strength is very high at 1% having for 7 days is 2.83 N/mm^2 and for 28 days is 3.92N /mm^2.
- Consolidation for sprayed GFRC, no vibration is needed. For poured, GFRC, vibration or rollers are easy to use to achieve consolidation.
- Toughness of GFRC doesn't crack easily-it can be cut without chipping.
- Surface finishing because it is sprayed on, the surface has no bug holes or voids.
- Adaptability on sprayed or poured into a mould, GFRC can adapt to nearly any complex shape, from rocks to fine ornamental details.
- GFRC will outlast precast concrete, cast stone, even some natural stone." Durability has been increased through the use of low alkaline cements and pozzolans.
- Sustainability because it uses less cement than equivalent concrete and also often uses significant quantities of recycled materials (as a pozzolan), GFRC qualifies as sustainable.
- GFRC as a material, however, is much more expensive than conventional concrete on a pound-for-pound basis. But since the cross sections can be so much thinner, that cost is overcome in most decorative elements.

VII. REFRENCES

1. S.Hemalatha1&Dr.A.Leema Rose2 M.E Student & Department of Civil Engineering, Adhiparasakthi Engineering College, Tamilnadu, India & Professor & Department of Civil Engineering, Adhiparasakthi Engineering College,Tamilnadu, India *"an experimental study of glass fibre reinforced concrete"* 4 April2016.
2. Sakshi Gupta1 , Abhimanyu Ramola2 , Anand Saini 3 ,Jatin Arora4 , Aakash 5 1Assistant Professor, 2,3,4,5 B. Tech Student Department of Civil Engineering, Amity University Haryana, Gurugram-122413, Haryana, India *" a review on glass fibres reinforced concrete for construction"* 8 august2018.
3. Eng. Pshtiwan N. Shakor*, Prof. S. S. Pimplikar**. *M.E. Civil (MIT) College, Sulaimaniyah International Airport,Iraq. **Head and Professor of Civil Eng. Dept., MIT College, Pune " *glass fibre reinforced concrete use in construction"* 6 june 2011
4. Komal Chawla and Bharti Tekwani *"studies of glass fibre reinforced concrete composites"* 3 august 2013.
5. T. Sai Kiran1 , Dr. K. Srinivasa Rao2 1 PG Scholar, Department of Civil Engineering, Andhra University, Visakhapatnam, Andhra Pradesh, India 2 Professor, HOD of Civil Engineering, Andhra University, Visakhapatnam, Andhra Pradesh, India " *mechanical properties of glass fibre reinforced concrete"* 10 october 2015
6. Muna M .Abdullah & Eman K.Jallo Dept.civil engineering *"mechanical properties of glass fibre reinforced concrete"* 21 december 2011
7. A. Upendra Varma1 &A.D. Kumar 2, 1 PG Student (Department of Civil Engineering, V.R. Siddhartha Engineering College, Vijayawada) 2Assistant Professor (Department of Civil Engineering, V.R. Siddhartha Engineering College, Vijayawada) *" glass fibre reinforced concrete"* 5 september 2013.
8. Dr.P.Srinivasa Rao, Chandra Mouli .K, Dr. T. Seshadri Sekhar(2012) Journal of Civil Engineering Science. "Durability Studies On Glass Fibre Reinforced Concrete" 2 january 2012.
9. Bartos P 1985 Proc. Symp. on Durability of Glass Fiber reinforced concrete ed S. Diamond (Chicago USA: PCI) Effects of changes in fibre strength and bond characteristics due to ageing on fracture mechanism of GRC
10. Gaurav Tuli1 , Ishan Garg2 1,2(Civil Engineering, College Of Engineering/University Of Petroleum And Energy Studies ,India) " structural properties of glass fibre reinforced concrete", 8 may 2016.
11. Pshtiwan N. Shakor & Prof. S.S.Pimplikar *"air resistance glass fibre reinforced concrete"*, 18 may 2017.