

Glass Fibre Reinforced Concrete Use in Construction

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.

*pshtiwann@yahoo.com, **sunil_pimplikar@rediffmail.com

Abstract— Glass-fibre reinforced concrete (GRC) is a material made of a cementitious matrix composed of cement, sand, water and admixtures, in which short length glass fibres are dispersed. It has been widely used in the construction industry for non-structural elements, like façade panels, piping and channels. GRC offers many advantages, such as being lightweight, fire resistance, good appearance and strength. In this study trial tests for concrete with glass fibre and without glass fibre are conducted to indicate the differences in compressive strength and flexural strength by using cubes of varying sizes. Various applications of GFRC shown in the study, the experimental test results, techno-economic comparison with other types, as well as the financial calculations presented, indicate the tremendous potential of GFRC as an alternative construction material.

Keywords – Glass Fibre, RCC, GRC, Construction

I. INTRODUCTION

Glass Fiber Reinforced Concrete (GFRC) or (GRC) is a type of fiber reinforced concrete. Glass fiber concretes are mainly used in exterior building façade panels and as architectural precast concrete. This material is very good in making shapes on the front of any building and it is less dense than steel.

GFRC is a form of concrete that uses fine sand, cement, polymer (usually an acrylic polymer), water, other admixtures and alkali-resistant glass fibers. Many mix designs are freely available on various websites, but all share similarities in ingredient proportions.

Glass fibre reinforced cementitious composites have been developed mainly for the production of thin sheet components, with a paste or mortar matrix, and ~5% fibre content. Other applications have been considered, either by making reinforcing bars with continuous glass fibres joined together and impregnated with plastics, or by making similar short, rigid units, impregnated with epoxy, to be dispersed in

the concrete during mixing.

Glass fibres are produced in a process in which molten glass is drawn in the form of filaments, through the bottom of a heated platinum tank or bushing. Usually, 204 filaments are drawn simultaneously and 123

consisting of the 204 filaments. Prior to winding, the filaments are coated with a sizing which protects the filaments against weather and abrasion effects, as well as binding them together in the strand [2].

II. FINDING FROM LITERATURE REVIEW

There are some points figured out from above review:

1. 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 [4].
2. 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[9].
3. 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 [6].
4. 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 [1].

5. 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 [10].
6. 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 [7].
7. 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 [5].
8. 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 [3].
9. 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 be

5.76% 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 [8].

III. OBJECTIVES OF THE STUDY

In the study, the following objectives are envisaged:

- i) Study the mix design aspects of the GRC.
- ii) Understand the various applications involving GRC.
- iii) Compare GRC with alternatives such as stone, aluminum, wood, glass, steel, marble and granite.
- iv) Perform laboratory tests that are related to compressive, tensile and flexure by use of glass fibre in the concrete pour.

IV. METHODOLOGY OF THE STUDY

In order to achieve the objectives set, data was collected from the field practices which are being followed in the building construction and from the factory manufacturing GRC. Data has been collected from different project sites and from different locations.

The data is collected from these resources:

- Yogi Group
- Grasim Company
- Durocrete Laboratory
- J. Kumar Infraproject Company
- Some project sites like, Della Tower, Sharad Pawar International School, Holakar Bridge...etc.

The type of data collected is to make comparison between GRC with other cladding materials aspect to costs, quality and techniques.

Other type of data is related to experimental work at laboratory. Some test research on concrete with Glass fibre are collected so as to gain differences between them, when using different ratios of glass fibre.

The test is carried out on the cube specimen 150x150x150mm and 100mm x100mmx100m. Cast iron moulds are used to cast the cubes having leak proof metal base plate. The joints between the section of moulds are thinly coated with the mould oil to prevent adhesion of concrete to the mould surface.

All materials should be thoroughly mixed, for (2-3) minutes, before adding the glass fibres. After mixing glass fibre, for 1 minute, the cubes are casted.

Curing

After moulding, the specimens are stored on the site free from vibration under damp matting, sack or other similar material for 24 hours from the time of addition of water to the other ingredients.

The temperature of place of storage was within the range of 22°C to 32°C . After a period of 24 hours cubes were marked. After removing from the moulds, cubes were stored in clean potable water at a temperature of 24°C to 30°C until they were transported to the testing laboratory.

In flexural test the beam specimen is placed in the machine in such a manner that the load is applied to the upper most surface as cast in the mould. All beams are tested under two points in Universal testing machine of 60 tones capacity. The load is applied at a rate loading 10cm x 10cm x 50cm specimens. The load is increased until the specimen failed and the failure load is recorded.

The flexural strength is calculated from the equation.

$$F_b = PL/bd^2$$

When 'a' is greater than 20cms or

$$F_b = 3Pa/bd^2$$

When 'a' is less than 20cms but greater than 17cms

TABLE (1)
GRC RAW MATERIAL COST

S. No.	Materials	Unit Price
1	White Cement	Rs. 11.50 per Kg
2	Silica Sand	Rs. 3.00 per Kg
3	AR- Glass fibre	Rs. 260 per Kg
4	Hardener 'A' (Cemplast) Black liquid plasticizer	Rs. 95 per litre
5	(SBR-Styrene butadiene rubber)	Rs. 160 per Kg

*Mix of 100 kg GRC (Typical)

**TABLE (2) THE DATA SHOWN BELOW IS OBTAINED
FROM YOGI COMPANY WITH RESPECT TO YEAR 2010**

Property	GRC	Stone	Aluminu m	Glas s	Wood
Manufacturi ng per sq.ft	115 Rs.	60 Rs.	100 Rs.	130 Rs.	-
Transportati on per sq.ft	15 Rs.	25 Rs.	10 Rs.	20 Rs.	-

Installation per sq.ft	40 Rs.	35 Rs.	55Rs.	45 Rs.	-
Materials per sq.ft	6 Rs.	6 Rs.	20 Rs.	20 Rs.	-
Maintenance routine per sq.ft	Nil	10 Rs.	15 Rs.	15 Rs.	-
Propert y	GRC	Stone	Aluminu m	Wood	Glass
Color	Uniform	Un Uniform	Unifor m	Un Uniform	Unifor m
Color choice	Wide range	Limited	Limited	No choice	Limi te d
Quality	Consiste nt	Non Consisten t	Consist ent	Non Consisten t	Non Consisten t
Thickness	Uniform	Non-Uniform	Unifor m	Non-Uniform	Unifor m
Shape	Availabl e in any shape	Limited shapes	Limited shapes	Limited shapes	Limi te d shapes
Sizes	Availabl e in any size	Limited size	Limited size	Limited size	Limi te d size
Dry Bulk density	1.8 to 2.0 t/m3	2.2 to 2.5 t/m3	2.5 t/m3	0.4 to 0.7 t/m3	2.5 t/m3
Maintenance periodical per sq.ft	5 Rs.	5 Rs.	15 Rs.	15 Rs.	-
Total Cost	181 Rs.	141 Rs.	215 Rs.	245 Rs.	100- 1000 Rs.

** Rs.: It is meaning Indian Rupees, according to date
1/1/2010 / 1 USD = 47.50

125

TCFT

PROPERTIES IN GRC WITH OTHER CLADDING MATERIALS

➤ Yogi Project-----GRC Work-----Taj Heritage Hotel—Mumbai

A balcony for room no.257 at hotel Taj Heritage was replaced by GRC. Original in RCC same old finish (100 years old) was achieved with same style. Balcony weight: 800 Kg. Cost: cost 250,000 Rs. Duration for replacement: 30 days.



FIGURE (1) BEFORE REPLACING GRC BALCONY (TAJ HERITAGE)

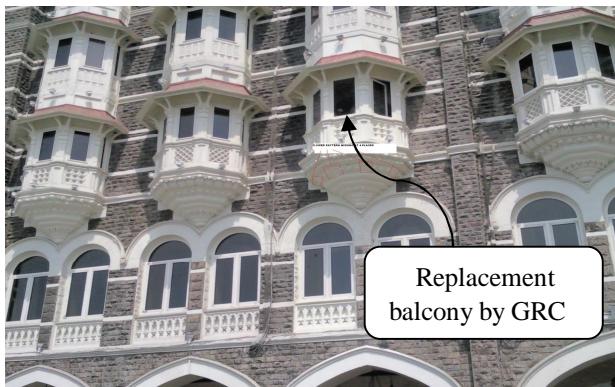


FIGURE (2) AFTER REPLACING GRC BALCONY (TAJ HERITAGE)

➤ Casting at J.KUMAR INFRAPROJECTS
Name of project: Holakar Bridge, Pune. Location:
RMC plant, Holakar Bridge

Date of casting: 17/4/2010

Type of casting: normal concrete mixed with AR-glass fibre.

Mix proportion ratio:

W/C- 0.16

Cement- 400 kg/m³

Micro silica (Silica fume) - 40 kg/m³

Standard sand- 1000 kg/m³

Glass fibre- 1% by weight of cement

Coarse aggregate- Nil

Mater	Casting concrete with glass fibre	stur %	Absorp tion in %	Correc tion Mix Absorp tion in (kg.)	Correc ted Mix for 1 m ³ (kg.)										
					W/C	Cement	Fly ash	Micro Silica	Glass	R. Sand	C. Sand	10 mm	20 mm	Net Weight	Water
W/C	0.26	-	-	-											-
Cement	400	-	-	-											400
Fly ash	100	-	-	-											100
Micro Silica	40	-	-	-											40
Glass	0.6	-	-	-											0.6
R. Sand	748	0.00	0.00	0.000											748
C. Sand	0	0.00	0.00	0.000											0
10 mm	448	0.00	1.30	5.824											442
20 mm	674	0.00	1.30	8.762											665
Net Weight	-	-	-	14.586											0
Water	140	-	-	-											155
Admixtu	5.4	-	-	-											5.4
Total	2556	-	-	-											2556



FIGURE (3) CASTING CONCRETE WITH GLASS FIBRE SURROUNDS PRESTRESS STRAND CABLE AT HOLAKAR BRIDGE

➤ Experimental program at J. Kumar concrete division

Table (4) Trial no. 1 With Glass Fibre: 0.024% of
gopalax Publications & TCET

Table (5) Results of tests

Table (6) Results of tests

Sample No.	% Of Glass Fibre	Flexural strength MPa (N/mm ²) 7 days	Average Flexural Strength MPa
No. 1	1.5%	5.80	5.55
No. 2		5.28	
No. 3		5.56	
No. 1	2.0%	4.98	5.17
No. 2		5.51	
No. 3		5.02	
Sample No.	% Of Glass Fibre	Flexural Strength MPa (N/mm ²) 28 days	Average Flexural strength MPa
No.4	1.5%	5.46	5.48
No.5		5.37	
No.6		5.62	
No.4	2.0%	5.49	6.15
No.5		6.40	
No.6		6.56	

➤ Discussion

Following points emerge from the test results:

- 1) As seen from table 5, the 7 days average compressive strength of concrete is maximum when 1.5 % of glass fibres are used. At lower or higher %, about 15% to 20% reduction in strength is observed nevertheless at 28 days, the reduction in strength reduced by 5% to 10%.
- 2) According to this result, increasing weight of glass fibre in normal concrete affects the cohesiveness between the particle of concrete and this results in degrading of compressive strength, flexural and tensile strength.
- 3) For (M60) mix, a percentage of glass fibre of 2% gave a flexural strength of (6.15 MPa), which is 10% more than that obtained at 1.5%.
- 4) Glass fibre does not effect on high performance concrete, if it especially contains big gradation of coarse concrete because it leaves more porosity and spaces between the particles and allows air to move between.
- 5) One should take care of glass fibre during mixing with concrete. It should be not allowed to mix more than 1 minute, otherwise it will be break to tiny pieces, and it cannot be worked with.

➤ GRC as a cladding material

Important points to be observed for GFRC to explained below use in cladding of buildings are :

- 1) The materials have a good resistance for tension. That is the reason why Glass fibre is chosen as reinforcement for concrete. Right now, is used

Sample No.	% Of Glass Fibre	Compressive strength MPa (N/mm ²) 7 days	Average compressive strength MPa
No.1	0.11%	53.33	53.037
No.2		48.00	
No.3		57.77	
No. 1	1.5%	64.44	65.18
No. 2		66.66	
No. 3		64.44	
No. 1	2.0%	56.44	56.74
No. 2		62.66	
No. 3		51.11	
Sample No.	% Of Glass Fibre	Compressive strength MPa (N/mm ²) 28 days	Average compressive strength MPa
No. 4	0.11%	71.55	72.593
No. 5		70.66	
No. 6		75.55	
No.4	1.5%	>80.00	>80.00 unbroken
No.5		>80.00	
No.6		>80.00	
No.4	2%	76.44	76.44
No.5		76.00	
No.6		76.88	

mostly for cladding buildings, lining, sewer pipe, shoulder of roads and etc...

- 2) Compatibility of glass fibre with concrete or mortar helps us to use it easily in our daily project especially for facade of buildings, as we said AR-glass fibre that have good resistance to alkalinity that contains in cement ($\text{pH} > 12.3$) with high level.
- 3) AR-glass fibre can control shrinkage cracks easily; it shows this property particularly in cladding purpose or rendering. Because of most important thing in GRC it is water: cement ratio maximum 0.35, which helps to control the shrinkage and bonding each other by glass fibre.
- 4) GRC can be used as alternative material of natural stone, especially in those countries where stone is less or unavailable. Also for those countries that favour stone only, the cost is higher, but because of less maintenance one can return back this money.
- 5) Changing GRC panel is very easy as compared to other cladding because of making GRC by panel and just installing on the site. Also if broken one panel can be repaired or removed and a new one can be put, but if stone or tile is broken, it is not easy to change.

- 6) This material is eco-friendly material because it consumes less energy during production; one can use to control pollution and carbon dioxide which is dangerous to human life.
- 7) GRC is a new growing industry in India, customer awareness is increasing and more projects have GFRC components.
- 8) GFRC industry in India can be started anywhere. Existing manufactures do not have their units in city industrial areas.
- 9) As of today GFRC cladding to building surface has emerged as main application on account of reasons as below;
 - * Alternative cladding materials like glass, aluminium have not performed well in Indian climate leading to leakages, warp pages, panels falling...etc.
 - * Granite, marble and PCC (Precast Cement Concrete) panels are very heavy compared to GFRC panels leading to site handling problems; there are major procurement problems with granite and marble.
 - * With GRC claddings building heat losses are minimum compared to aluminium and glass cladding. Civil aviation authorities have already taken decision to go for GRC claddings on their airport buildings.
 - * Facility to provide, indicate shapes, curves and profiles.

gopalax Publications &

aciu wasii, name naanen...etc on GRC
panels which is not possible in other
materials.

- * GFRC manufacturers work on turnkey basis from concept to installation, where as for other materials one needs more than one agency.
- * Suitability in earthquake prone areas.
- * By adding suitable additives, GRC panels can be made 'Green' which is not easily possible with other materials.

➤ Result and conclusion of glass fibre use in normal concrete

Based on the tests results which are obtained, following conclusions are made:

- 1) Glass fibre helps concrete to increase compressive strength until indicated limit. A limit exists to a

particular percentage from glass fibre mixed with concrete because increasing it affects on the bond of materials as is seen in the result. For 1.5% of cementitious weight gained best results are obtained as compared to other results.

- 2) Air entrainment affects the f_t/f_c (tensile strength to compressive strength) ratio because the presence of air lowers the compressive strength of concrete more than the tensile strength particularly in the case of rich and strong mixes.
- 3) By using 20 mm of coarse aggregate more air entraining is increased in the concrete:- only 10 mm coarse aggregate should be used to solve problem of reduced flexural strength.

REFERENCES

1. Alan J. Brookes, "Cladding of Buildings", Third Edition Published 2002, (pp 82).
2. Arnon Bentur and Sidney Mindess, "Fibre Reinforced Cementitious Composites", Second Edition 2007, Chapter 8, (pp 278).
3. J.G. Ferreira, F.A. Branco 2005, "Structural application of GRC in telecommunication towers", Construction and Building Materials Journal, Published August 2005.
4. Majumdar, A.J. (1974), "The role of the interface in glass fibre reinforced cement", Building Research Establishment, Published 1974, Current Paper (cp 57-74).
5. M. Levitt 1997 "Concrete materials problems and solutions", "GRC and Alkali-Glass reaction", First Edition 1997, (pp 22-24).
6. M.W. Fordyce and R.G. Wodehouse, "GRC and buildings", Published First Edition 1983.
7. Perumelsamy N. Balaguru and Surendra P. Shah, "Fibre reinforced cement composites" February 1992 Chapter gopalax Publications & TCET
- study on the effect of AR-Glass Fibre reinforced concrete", NBW & CW October 2006, (pp 174-180).
9. R .N. Swamy, "Testing and Test Methods of Fibre Cement Composites", Published 1978, (pp 42-43).
10. Surendra P. Shah, James I. Daniel, Darmawan Ludirdja, "Toughness of Glass Fiber reinforced concrete panels subjected to accelerated aging", PCI Journal, September-October 1987, (pp 83-88).
11. U. M. Ghare, "Manufacture of Glass Fibre Reinforced Concrete Products", Unit 1, Division of YOGI group-UAE, August 2008.