Study and Experimentation on A.R. Glass Fibre for R.C.C. Road

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Abstract - In this way, glass fibre reinforced concrete (GFRC) was started for the fulfilment of the different demands. Different studies and tests on the GFRC have shown that the physical and mechanical property of the GFRC change depends on the quality of the materials and the accuracy of the production methods. As technological advances, it is possibly expected to build the whole building and complex freeform with low cost. Concrete is relatively brittle, and its tensile strength is typically only about one tenths of its compressive strength Regular concrete is therefore normally reinforced with steel reinforcing bars. The present work has compared the compressive strength, strain and stress curve. GFRC can be used where a Strong, weather resistant, attractive, fire retardant, impermeable material is required it has many physical and mechanical remarkable assets. The high tensile strength that is higher than that of steel. In this project work, glass fibre is being used accordingly in the range of 1% and 2% and the concrete used is of M20 grade.

***Key Words*: ** Glass, Fiber, Reinforcement, Concrete, Properties, strength

I. INTRODUCTION

Glass fibre reinforced concrete (GFRC) is a material that set ups a significant contribution for the economy, technologies of the construction industry worldwide is about from 40 years. GFRC is one of the most manifold building materials available to the architects and engineers. Compared to traditional concrete, it has complex characters because of its special structure. Many types of parameters such as water–cement ratio, porosity, composite density, inter filler content, fibre content, orientation and length, type of cure influence properties and behavior of GFRC as well as accuracy of production method .GFRC can be produced as thin as 6 mm so its weight is much less than the traditional pre–cast concrete products. Progressing of 3D–printing technology with glass fibre reinforced ink can construct a whole building and complex architecture forms with the high reliability as well as by the use of premix, spray–up, hybrid methods of GFRC. MSelf– cleaning environmental friendly panels for industrial construction had contributed to the GFRC both in terms of its cost and its popularity. The use of glass fibre in the High Performance Concrete (HPC) class, being a class with extremely high mechanical performance,durability, workability and aesthetics, has gained momentum in recent years. The design and manufacture of the GFRC products is covered by international standards, which have been processed in Europe, America, Asia and Australia. GFRC is processed in over 100 countries . It is prepared by the combined mixture of a fine sand, cement, water, other admixtures and alkali-resistant (AR) glass fibres. Many mixed designs are available in online sites, but you will find that all share similarities in the ingredients and proportions are used. Glass fiber-reinforced concrete is consisted of high-strength, alkali-resistant fibre in a concrete matrix. Glass fibres must be incorporated into a matrix either in continuous or discontinuous lengths. The glass fibres used in GFRC since the 1970s are Alkali- Resistant glass and the durability problem has mostly gone away. AR glass fibres are mainly 13 or 14 microns in diameter. Our fibres are mostly 9mm in length. so that when we put stress on the concrete system the glass absorbs its energy and would not allow it to crack. AR Glass Fibres are designed are mostly used in concrete. AR glass fibres have high tensile Strength and modulus, it does not rust like steel, and are easily used in concrete mixtures. Alkali Resistant (AR) Glass fibres are manufactured from special formulated glass composition with an optimum level of Zirconium (ZrO_2) is suitable to use in concrete.

Types of fiber

1. SFRC - Steel Fiber Reinforced Concrete
2. GFRC - Glass Fiber Reinforced Concrete
3. SNFRC - Synthetic Fiber Reinforced Concrete
4. NFRC - Natural fibers Reinforced Concrete

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Area use for GFRC

- Thin sheets
- Roof tiles
- Pipes
- Prefabricated shapes
- Panels
- Curtain walls
- Slabs on grade
- Precast elements

Advantages of Fibre glass Reinforced Concrete

- Its a great material for restoration of old buildings and it is used for the exterior of the buildings. It is also being used extensively for walls and ceilings. Landscape artists have came on board and discovered the versatility of GFRC.
- GFRC is lightweight and it is about 75% lighter than traditional concrete.
  The flexural strength gives it a high strength to weight ratio.
- The concrete is internal for the reinforcement and does not need any additional reinforcements.
- Heavy duty or expensive equipment is not important when pouring or spraying GFRC.
- It is easy to cut and also very difficult to crack.

GFRC is mostly adaptable in that it can be poured or sprayed.Benefit of FRC

- Workability of concrete increases by using A.R. glass fibre with same water cement ratio.
- Compressive strength increases by using A.R. glass fibre for same grade of conventional concrete mix.
- Durability increases by using A.R. glass fibre for same grade of conventional concrete mix.
- Improving mix cohesion, improving pump ability over long distances
- Improvement in freeze-thaw resistance
- Improvement in resistance to explosive spelling in case of a severe fire
- Improvement in impact resistance
- Increase resistance of the plastic shrinkage during the time of curing

II. Materials & Their Properties

The materials used in the preparation of Concrete are:

- 1. Cement
- 2. Fine aggregate i.e., Natural Sand
- 3. Coarse aggregate
- 4. Water
- 5. Glass Fibers

To produce good quality of concrete we need good quality ingredients which satisfy the Standards. Hence tests on different ingredients mentioned above are conducted as per IS standards which are presented below. Properties are represented in the form of Tables for every material used in the production of Concrete.

1. Cement

Portland Pozzolana Cement of 43 grade of AMBUJA brand confirming to I.S is used in the present work. The cement is tested for its various properties as per IS: 4031 – 1988 and found to be confirming to the requirements as per IS: 1489-1999 Part-1.

In order to avoid the possible variation in the properties of cement from various batches all the specimens are prepared from the same batch of cement.

The results of tests concluded on cement are as follows. Cement - Portland Pozzolana Cement

Brand Name - Birla gold cement

Specific Gravity - 3.1

Table 1.1 : Properties of Cement

S.NO	PROPERTY	VALUE	REQUIREMENT AS PER IS:1489-1
1	Fineness	2%	<10%
2	Soundness	1mm	<10mm
3	Standard Consistency	32%	Within the Code Provisions
4	Initial Setting Time	63min	>30min
5	Final Setting Time	360min	<600min

2. Fine Aggregate – Natural Sand:

Sand which is passed on 4.75mm sieve & retained on 150µ sieve are used.

Table 2.1 : Physical Properties of Natural Sand

S.NO	PROPERTY	VALUE	REQUIREMENTS AS PER IS 383
1	Fine Aggregate	Sand	As per Indian Standards
2	Specific Gravity	2.65	2.6-2.8
3	Water Absorption	0.25%	Should not be > 1% for construction
4	Density	1450 gm/cc	Within the Code Provisions
5	Fineness Modulus	2.74	2.6-2.9

Table 2.2: Sieve Analysis of Natural Sand

4.	600 µ	448	1411	70.55	29.45
5.	300 µ	430	1841	92.05	7.95
6.	150µ	149	1990	99.5	0.5
7.	75 µ	8	1998	99.90	0.1

Table- 3: Grading Limits of Coarse Aggregate as per IS 383:1970

I.S. Sieve Designation	Percentage passing by weight			
	Grading Zone-I	Grading Zone-II	Grading Zone-III	Grading Zone-IV
10mm	100	100	100	100
4.75mm	90-100	90-100	90-100	95-100
2.36mm	60-95	75-100	85-100	95-100
1.18mm	30-70	55-90	75-100	90-100
600 µ	15-34	35-54	60-79	80-100
300 µ	5-20	8-30	12-40	15-50
150 µ	0-10	0-10	0-10	0-15

4. Coarse Aggregate:

The Coarse aggregate is free from clay matter, silt and organic impurities etc. the coarse aggregate is also tested for specific gravity and it is 2.82, fineness modulus of coarse aggregate is 4.07. Aggregate of normal size 20 mm downgraded 60% passed on 20.0 mm sieve and remaining 40% is taken from the sieve 10.0 mm (passing) and 4.75 mm (retained) is mostly used in the experimental works, which is acceptable according to IS: 383– 1970.

Table 4.1 :- Properties of Coarse Aggregate

S. N.	I.S sieve	Weight retained (gm)	Cumulative Wt retained (gm)	Cumulative Percentage Weight Retained	Cumulative Percentage Weight Passing
1.	4.75	90	90	4.5	95.5
2.	2.36	234	324	16.2	83.8
3.	1.18	639	963	48.15	51.85

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4. Water:

About 38% of cement

At Normal Room Temperature = 550ml

5. Glass Fibre

Table 5.1 : Properties of Glass Fibre

S. No.	CHARACTER	GLASS FIBERS
1	Number of fibres	212 million/kg
2	Aspect ratio	857:1
3	Typical addition rate	0.6 to 1.0 kg/m3 of concrete
4	Tensile strength	1700 Mpa
5	Modulus of elasticity	72 Gpa
6	Corrosion resistance	Excellent
7	Specific gravity	2.7
8	Density	26 KN/m3
9	Filament diameter	13-14 μ
1o	Filament length	9 mm

III. LITERATURE REVIEW

1. Authors: Kumar J.D.

Discussion: In his studies he found that the addition of glass fibres at 0.5%, 1%, 2% and 3% of cement decreases the cracks under different loading conditions. It has been observed that the workability of the 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 much at 1%. We can likewise make use of the waste product of glass as fibre.

Discussion: This study has carried out using an M20 grade of concrete and glass fibre has been added as 0.5%, 1%, 2%, 3%. And the specimens are thrown for a compressive and tensile test of the concrete. In this experiment, the concrete attains strength when the 2% of the fibre is added to the concrete and when 3% fibre is added to the concrete the strength of the concrete declines. When the fibre is added 2% the strength of the concrete attains 26.98Mpa of the compressive strength, 2.94Mpa of Flexural Strength and 3.57Mpa of the Tensile strength of the concrete after 28 days of curing. In this experiment, the author mentioned that the workability of the concrete is increased and thus the glass fibre decreases the crack under the different loading.

4. Authors: Kannan, 2010.

Discussion: In this paper, the authors has carried out the experimental study on permeability and the compressive strength of super plasticized concrete by adding the AR glass Fibre in proportions up to 1% and super plasticizer by the weight of the cement. An attempt has made in this paper to develop a new concrete with the good workability and the better resistant against permeability with the help of A.R glass fibre and super plasticizer. M20 grade GFRC mix design is used in this paper and A.R Glass Fibers are added at 0.2%, 0.4%, 0.6%, 0.8 % and 1.0% by weight of cement to reference mix and allowed the test specimens for 28 days of curing to test the workability, compressive strength and permeability. The permeability was determinate by Steady flow method. Based on research, the authors have drawn following conclusions:

The addition of 0.2% fibre gives much compressive strength and makes the concrete impermeable with good workability.

The maximum compressive strength got at the added by 1% fibre and 0.8% super plasticizer when compare to the reference mix.

5. Authors: Ghugal, Y.M., Deshmukh, S.B., 2006.

Discussion: In this paper, the authors has carried out an experimental examination on the effect of A.R glass fibres on workability, density, compressive, flexural and split tensile strength of the M20 grade concrete.M-20 grade of concrete is applied in this paper having mix proportions of 1:1.59: 3.70 i.e., cement: fine aggregate: coarse aggregate with w/c ratio of 0.51. Fibres were added in the wet state of concrete and it is again mixed thoroughly. A.R glass fibres were added in varying percentage 0 to 4.5% at the interval of 0.5% by the weight of cement and the specimens were cast for curing for 28 days. The test for strength properties are carried out for the fresh and hardened concrete. Based on the researches, the authors have made the following conclusions:

(a) The A.R glass fibre were decreases the workability in the terms of slump method and reached 44.44% when 4.5% fibres were added in the concrete and the wet density of concrete increases with the addition of glass fibres. When it is compare to the reference mix at 28 days.

(b) The average compressive strength, flexural strength and split tensile strength are observed 28.46 N/mm2, 50.08 N/mm2 and 48.68 N/mm2when A.R glass fibres were added in the various proportions respectively.

(c) The flexural member increases the load carrying capacity with the addition of glass fibre in the concrete as compare to reference mix and this shows that the ductility and flexural stiffness has increased due to glass fibres.

6. Authors: Kiran, T. S., Rao, D. K., 2016.

Discussion: In this paper, the authors have carried out the experimental investigation on the behavior of the Glass Fibre Reinforcement concrete (GFRC) on compressive, split-tensile and flexural strength of M30 grade concrete with and without the Alkaline Resistant Glass Fibre (ARGF).M-30 grade concrete is used having an mix proportions 1:1.70: 3.06 i.e., cement: fine aggregate: coarse aggregate with w/c ratio of 0.45. Fibres were added in wet state of concrete and it is again mixed thoroughly. The fibres are added in varying percentage 0%, 5%, 6%, and 7% by the weight of the cement and specimens were cast for curing 1,3, 7, 28 and 56 days. Based on the research, The authors have made the following conclusions:

- The maximum compressive strength obtains at the addition of 7% of the glass fiber.
- The maximum split tensile and flexural strength obtained at the addition of 6% glass fiber.

7. Authors: C. Selin Ravikumar and T.S. Thandavamoorthy.

Discussion: The study there has a significant increase in the use of fibres in concrete for the improvement on its properties such as tensile strength and ductility. The fibre concrete is also used in the retrofitting existing concrete structures. Among many different types of fibers are available today, glass fibre is a recent introduction on the field of concrete technology.

8. Authors: S. S. Pimplikar

Discussion: Conducted an experiment as the Glass-fiber reinforced concrete (GRC) It is a material made of a cementations matrix composed of a cement, sand, water and admixtures, in which the short length glass fibres are dispersed.

IV. EXPERIMENTAL PROGRESS

Test Speciments

Test specimens consisting of 150mm*150mm* 150mm cubes (8 Kg Weight)

Concrete Mix

The M20 grade (1:1.5:3) en quantities is used per cubic meter and water-cement ratio has been fixed to 0.38 .

Cement
Birla Gold Cement (Grade 43)=1.45 Kg

Aggregates
(a) Fine Aggregate- Sand (IS 4.75mm-150micron SIEVE) = 2.18 Kg
(b) Coarse Aggregate-Gravel (IS 20-4.75mm SIEVE) = 4.36 Kg

Water

(about 38% of cement)
Locally available portal water is used

Fibre

(about 0% and 0.5% and 1% of cement) Glass Fibre (AR Type) = 15 gm and 30 gm

Curing
Time for curing = 28 Days

Table 3.1 : Mix Proportion of Material

S. No	Material	Quantity per in kg and percentage
1	cement 42 grade ppc	1.45 kg
2	fine aggregate (IS 4.75mm-150Sieve)	2.18kg
3	coarse aggregate (IS 20-4.75mm sieve)	4.36 kg
4	Water	0.38%
5	Fibre	0-1% by total weight of mix

Mixing of GFRC:- Concrete Mix:-

The M20 grade (1:1.5:3) in quantities are used per cubic meter and water-cement ratio has been fixed to 0.50 with Grade 43 Cement (1.45 Kg).

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Fig- 3: Fine Aggregate

(b) Coarse Aggregate – The machine crushed angular granite metal of maximum size of 20mm retained on 4.75mm I.S. sieve. The IS 383-1970 was used. The total amount of coarse aggregate is worked in project 4.36 Kg.

Fig-4: Coarse Aggregate

Water - As per IS 456-2000 recommendations, potable water was used for mixing concrete. (about 50% Of cement) , At Normal Room Temperature=550ml.

Fibre - Added concrete 1% and 2% of cement. Glass fibre (AR Type) = The glass fibre mix design of concrete is 15 gm and 30 gm.

Curing- The curing time of mixed concrete = 28 Days.

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(a) Fine Aggregate- The gradation of sand is given by sieve analysis. The sieve analysis is done by passing through a set of standard sieves and finding out of passing percentage through each sieve. The IS 383-1970, When the aggregate sieved of 4.75mm sieve the aggregate passed through it called as fine aggregate. The total amount of aggregate showed in project 2.18 Kg.

S.NO.	Addings Glass Fiber %	28 DAYSCOMPRESSIVE STRENGTH OF CUBES	
		WITHOUT FIBER	WITH GLASS FIBER
1	Plan concrete (Nill)	3	

Table 3.2 : Experimentation Details of Project

Test On Mould For Cube Specimen

- Take random samples from the mix in a concreting.
- Pour concrete in the cubes in all 3 layers.
- Compact each layer with 35 Nos. of strokes with the temping rod.
- Finish the top surface by trowel after compaction of the last layer.
- Each specimen should be taken from the different locations of the proposed concreting.
- After 24 hours, reshuffle the specimen from the mold.
- While removing it, take care to avoid breaking of the edges.
- Code the cube with paint of marker. Coding should be self explanatory, building no. and the date of casting.
- Submerge the specimen in clear, fresh water until the time of tensing.
- Test 4 specimens for 7 days & 4 specimen for 28 days curing.

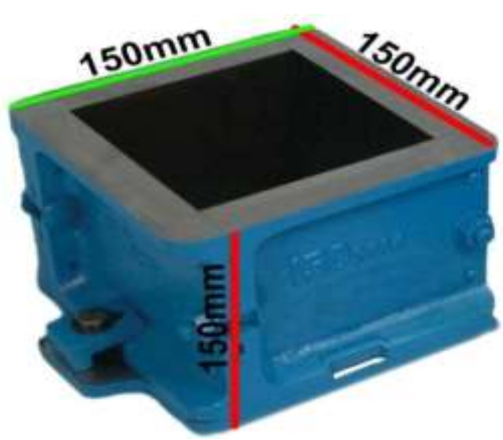

Fig-5: Mould for Cube Specimen

Test on Slump Test Apparatus Definition :-

Concrete Slump Test is a measurement of concrete's workability, or its fluidity. It's an unmarked measurement of concrete consistency or stiffness. A slump test is a method used to judge the consistency of concrete. The consistency, or stiffness, shows how much water has been used in the mix. The stiffness of the concrete mix should be matched for the requirements for the finished product quality concrete slump test.

Principle of Slump Test

The slump test result is a measure of the behavior of a compacted inverted cone of the concrete under the action of a gravity. It measures the consistency or the wetness of concrete which gives an idea about the workability condition of the concrete mix.

Slump Test Apparatus

- Slump cone,
- Scale for measurement,
- Temping rod (steel)

Procedure of Concrete Slump test :-

1. The mould for the concrete slump test is a frustum of a cone, 300 mm of height. The base is 200 mm in a diameter and it has a smaller opening at the top of 100 mm.
2. The base is placed on its smooth surface and the container is fully filled with concrete in three layers, whose workability is to be tested .
3. Each layer is temped 25 times with the standard 16 mm diameter steel rod, rounded on its end.
4. When the mould is perfectly filled with the concrete, the top surface is struck off (levelled with mould top opening) by means of screening and rolling motion of the temping rod.
5. The mould must be firmly held against its base while the entire operation, so that it could not move due to the pouring of concrete and this can be done by means of handles or foot - rests brazed to the mould.
6. Immediately after filling is totally completed and then the concrete is levelled, the cone is slowly and carefully lifted vertically, an unsupported concrete will be now slumped.
7. The reduction in the height of the centre of the slumped concrete is called slump.
8. The slump is measured by placing the cone just beside the slump concrete and then the temping rod is placed over the cone so that it can also come over the area of slumped concrete.
9. The decrease in height of concrete to that of mould is noted with the help of scale. (usually measured to the nearest 5 mm

Types of Concrete Slump

The slump concrete takes various shapes, and according to the profile of the slumped concrete, the slump is termed as:

1. Collapse Slump
2. Shear Slump
3. True Slump

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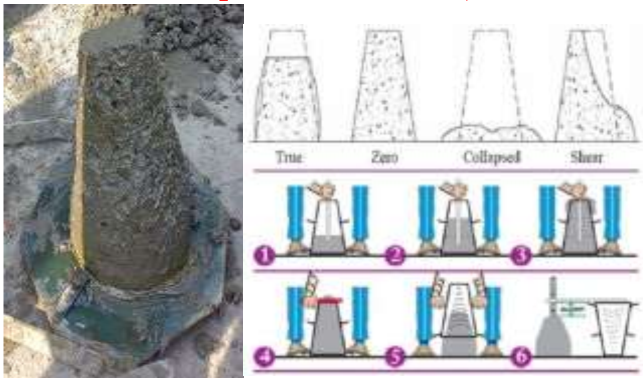

Fig-6: Slump Test Apparatus

Test of Compression Test Definition

Compressive strength is an ability of material or structure to carry the loads on its surface without any crack or deflection. A material under compression tends to make the size smaller, while in tension, size elongates.

Compressive Strength Formula

Compressive strength formula for any material is the load applied at the point of failure to its cross-section area of the face on which load was applied.

Compressive Strength = Load / Cross-sectional Area

Apparatus Required

1. Compression Testing Machine

The testing machine can be of any reliable type, of enough capacity for the tests and capable of applying the loads at the specified rate. The permissible error should be not greater than ± 2 percent of the maximum load.

2. Moulds/ Cubes for Testing

The mould shall be of 150 mm size conforming to IS: 10086-1982.

Fig-7: Moulds/ Cubes for Testing

Specimen

12 cubes of 15 cm size Mix. M20 Grade of Concrete.

Sampling of Cubes for Test

1. Clean the mounds and apply oil on it.

2. Fill the concrete on the moulds in layers approximately 5 cm thick.

3. Compact each layers with not less than 35 strokes per layer using a tamping rod (steel bar 16mm diameter and 60cm long, bullet-pointed at lower end).

4. Level the top surface and smoothen it with a trowel.

Curing of Cubes

The test specimens are stored in humid air for 24 hours and after this term the specimens are marked and removed from the molds and kept submerged in clear freshwater until taken out prior to the test.

Precautions for Tests

The water for curing should be tested after every 7 days and the temperature of the water must be at 27+-2oC.

Procedure for Concrete Cube Test

1. Remove the specimen from the water after some specified curing time and wipe out excess water from the surface.

2. Take dimension of the specimen to the nearest 0.2m

3. Clean it's bearing surface clearly of the testing machine.

4. Place the specimen on the machine in manner that the load should be applied to the opposite sides of the cube cast.

5. Align the specimen on the centre of the base plate of the machine.

6. Rotate the movable portion carefully by hand so that it touches the top surface of the specimen.

7. Apply the load carefully without shock and continuously at the rate of 140 kg/cm^2/minute till the specimen fails

8. Record the maximum load and note any unusual features in the type of failure you have observed.

Fig- 8: Compression testing machine

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Fig-9: fibre concrete cube

(A) Workability of Slump Test :-

Slump for the given sample = 28 mm

(B) Compression Test of Concrete :-

Table 4.1 : (a) Compressive Strength of Plain Concrete after 28 days

Specimens		Wt (kg)	Avg wt (kg)	Max Load (kN)	Avg. load (kN)	Compressive strength (N/mm2)
CC1	0% (Nil)	8.5	8.25	430	440	20
CC2		8.12		450		
CC3		8.15		440		

Table 4.2 : Test Result of Without Fibre Load applied on cubes:

Compression load	440 KN

Compressive Strength of cubes:

Compressive Strength	20 N/mm2

Table 4.3 : (b) Compressive Strength of GFRC having different of Glass Fibre after 28 days

Specimens		Wt (kg)	Avg . wt (kg)	Max Load (kN)	Avg. load (kN)	Compres--sive strength (N/mm2)
CC1	0%	8.5	8.27	470	460	22
CC2		8.12		450		
CC3		8.20		460		
GFC1	0.5%	8.30	8.32	590	590	26.6
GFC2		8.35		595		
GFC3		8.32		585		
GFC1	1%	8.36	8.38	610	630	28
GFC2		8.40		630		
GFC3		8.38		650		

Table 4.4 : Test Results of With Fibre Load applied on cubes:

% of fibre	0%	0.5%	1%
Compression load	460 KN	590 KN	630 KN

Compressive Strength of cubes:

% of fibre	0%	0.5%	1%
Compressive Strength	22 N/mm2	26.2 N/mm2	28 N/mm2

V. CONCLUSIONS

The percentage increase of compressive strength of grades on glass fiber concrete mixes compared with 28 days compressive strength is increased 29% for 0.5% fiber of concrete and 37% for 1% fiber of concrete.GFRC should be used wherever a light, strong, weather resistant, attractive, fire resistant, impermeable materials are required.Steels are removed in the GFRC so that, no corrosion will occur and minimum cover is needed.GFRC industries suggest

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many new applications like: water storage tanks, coastal and marine structures, water and wastewater pipelines and etc.A reduction in bleeding is observed by addition of glass fibers in the concrete mixes.The high tensile strength that is higher than that of steel. Modulus of elasticity commonly is higher in steel bars but tow modulus dispersed glass fibers stretch and allow concrete to crack, when the concrete cracks strong glass fibers plays their role and did not allow the crack to propagate and a new crack in different position appears.GFRC properties are mostly dependent on the quality of the materials and accuracy of the production methods. AR glass fiber may stand acid, alkaline the main reasons of erosion. Accelerated ageing has tested developed and proved the durability of GFRC products and stability in different weather conditions during the long years.Results showed that the passage of time and effects of different weather conditions and freeze- thaw cycles had very little effects on tensile ultimate strength and flexural ultimate strength. GFRC products had been used for many architectural purposes form many years.

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