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Using Glass Fiber Reinsforced Concrete As construction Material

AUTHORS-

1. **Mo. Kamil Raza** , Student , RGPV Bhopal
2. **Arshad Siddique** , Student , RGPV Bhopal
3. **Ankit Pawar**, Student , RGPV Bhopal
4. **Mo. Uzer Quraishi** , Student , RGPV Bhopal
5. **Proff. Mohit verma** , Professor, RGPV Bhopal

Civil Engineering , RGPV Bhopal, INDIA

ABSTRACT

Glass- fiber reinforced concrete (GFRC) is a material made up of a cementations matrix composed of smaller sized coarse aggregates, fine aggregates, rebars, cement, water mixtures, in which glass fiber are dispersed. GFRC exhibits many characteristics such as being lightweight, durable, aesthetically pleasing with adequate strength. An investigative report backed by existing experimental findings is presented to showcase the various applications of GFRC as a viable alternative construction material. Undoubtedly one of the most important materials vastly used in the global construction industries Concrete, thanks to the hardened uniform structure, the ability to take any shape and most importantly the capability of quality improvement by incorporating composites and ad-mixtures. One such form of modified concrete is Glass Fiber Reinforced Concrete whose constituent material properties, production technologies, resulting matrix properties and field applications are dealt in.

INTRODUCTION

General

The following is an article about what GFRC is, how it works, its properties and how itis made, including mix designs, casting techniques and finishing techniques.

Glass- fiber reinforced concrete (GFRC) is a material made up of a cementatious matrix composed of smaller sized coarse aggregates, fine aggregates, rebars, cement, water added mixtures, in which glass fibers are dispersed. GFRC exhibits many fav-rable characteristics such as being lightweight, durable, aesthetically pleasing with adequate strength.

Glass fiber reinforced composite materials consist of high strength glass fibere bedded in a cementitious matrix. In this form, both fibers and matrix retaintheir physical and chemical identities, yet they produce a combination of properties thatcannot be achieved with either of the components acting alone. In general fiberthe principal loadcarrying members, while the surrounding matrix keeps them in thedesired locations and orientation, acting as a load transfer medium between them, and protects them from environmental damage."

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

GFRC History and Application

GFRC was originally developed in the 1940's in Russia, but it wasn't until the1970's that the current form came into widespread use.

Commercially, GFRC is used to make large, lightweight panels that are often used as facades. These panels are considered non-structural, in that they are designed to support their own weight plus seismic.

and wind loadings, much in the way glass window curtain walls are designed. The panels are considered light weight because of the thinness of the material, not because GFRC concrete h as a significantly lower density than normal concrte .On average it weighs about the same as ordinary concrete on a volume basis.

Façade panels are normally bonded to a structural steel frame which supports the panel and provides connection points for hanging.
A balcony for room no-257 at hotel Taj Heritage was replaced by GFRC work. Originally in RCC same old finish (100 years old) was achieved with same style.

Properties of GFRC

High tensile strength (1700N/mm
Impact Resistance.
Water resistant.
Low thermal expansion.
Less creep with increase with time.
Light weight
Resistance to cracks in concrete.
Resistance to corrosion.
Improve homogeneity of fresh concrete.
Improve durability of structure.

Structural characteristics of GFRC

GFRC derives its strength from a high dosage of AR glass fibers and a high dosage of acrylic polymer.
While compressive strength of GFRC can be quite high (due to low water to cement and high cement contents), it is the very high flexural and tensile strengths that make it superior to ordinary concrete. Essentially the high dose of fibers carries the tensile loads and the high polymer content makes the concrete flexible without cracking. GFRC is analogous to the kind of chopped fiberglass used to form objects like boat hull sand other

complex three-dimensional shapes. The manufacturing process is similar, but GFRC is far weaker than Fiber glass.

While the structural properties of GFRC itself are superior to unreinforced concrete, properly designed steel reinforcing will significantly increase the strength of objectscast with either ordinary concrete or GFRC. This is important when dependable strength is required, such as with cantilever overhangs, and other critical members where visible cracks are not tolerable.

GFRC does not replace reinforced concrete when true load carrying capacity is
required. It’s best used for complex, three dimensional shells where loads are light.
Applications where GFRC makes the most sense are fireplace surrounds, wall panels, vanity tops and other similar elements. GFRC’s advantage is minimized when ordinary
flat countertop-shaped pieces are being made. While the weight savings due to reduced thickness is maintained, the effort of forming, mixing and casting are similar or the same.

Factors effecting properties of GFRC

Volume of fiber.
Orientation of fiber.
Workability.
Compaction of concrete.
Mixing.
Size of coarse aggregate
Water cement ratio.

How the fibers work

GFRC uses alkali resistant glass fibers as the principle tensile-load carrying member. The polymer and concrete matrix serves to bind the fibers together and transfer loads fromone fiber to another via shear stresses through the matrix.

Fiber reinforcement in concrete is a topic that frequently causes confusion and misunderstanding. CCI has written articles on fiber reinforcement in ordinary concrete. However, the role of structural fibers and the importance of their dosage and orientation will be discussed here.

Fiber reinforcement is a common method to increase the mechanical properties of materials. It is an important topic that is taught to many engineers interested in material science. As mentioned before, fiberglass is perhaps the most common and widely recognized form of fiber reinforcement.

In order to resist tensile loads (and thus prevent the GFRC piece from breaking or cracking), there needs to be a sufficient amount of fiber present. Additionally, the orientation of the fiber determines how effective that fiber resists the load. Finally, the fiber needs to be stiff and strong enough to provide the necessary tensile strength. Glass fibers have long been the fiber of choice due to their physical properties and the irrelatively low cost.

Typical GFRC mix uses a high loading of glass fibers to provide sufficient material cross-sectional area to resist the anticipated tensile loads. Often a loading of 5% fiber by weight of cementitious material is used. This means that 100 lbs of GFRC mix includes5 lbs of glass fibers.

Finally, the orientation of the fibers is important. The more random the orientation, the more fibers are needed to resist the load. That's because on average, only a small fraction of randomly oriented fibers are oriented in the right direction.
There are three levels of reinforcement that are used in general concrete, including GFRC.

The first is random, three-dimensional (3D) reinforcing. This occurs when fibers are mixed into the concrete and the concrete is poured into forms. The fibers are distributed evenly throughout the concrete and point in all different directions. This describes ordinary concrete with fibers. Because of the random and 3D orientation, very few of the fibers actually are able to resist tensile loads that develop in a specific direction. This level of fiber reinforcing is very inefficient, requiring very high loads of fibers. Typically only about 15% of the fibers are oriented correctly.

Glass has an amorphous structure; its properties are the same along the fiber and across the fiber. Humidity is also an important factor in the tensile strength. Moisture is easily adsorbed and can worsen microscopic cracks and surface defects, and lessen tenacity.

Fig. Random 3D fibers

The second level is random, two-dimensional (2D) reinforcing. This is what is in spray-up GFRC. The fibers are oriented randomly within a thin plane. As the fibers are sprayed into the forms, they lay flat, conforming to the shape of the form. Typically 30% to 50%of the fibers are optimally oriented

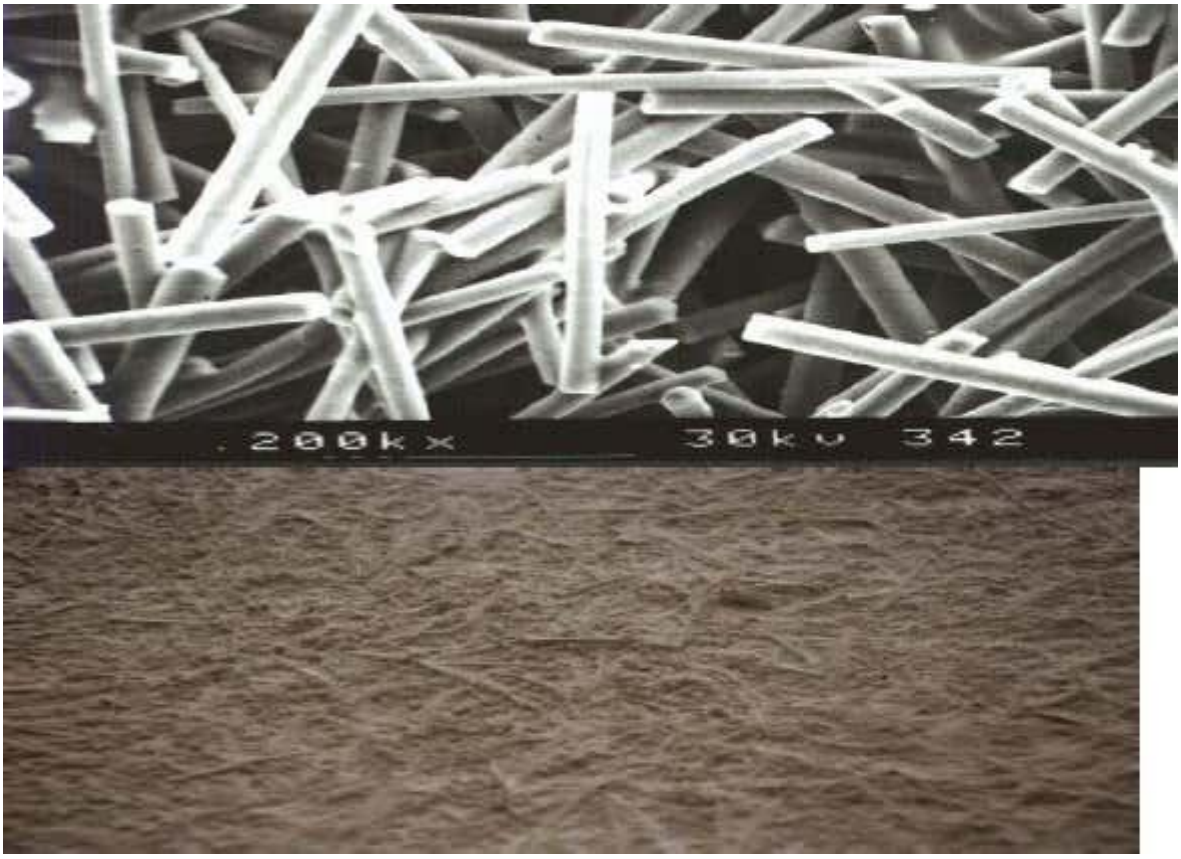

Fig. 2D reinforcing with Glass fiber

This orients them in the plane that the tensile loads develop in. While more efficient than3D, 2D reinforcing is still inefficient because of the highly variable fiber orientation within a horizontal plane. Additionally, most of the fibers lie outside the zone where the tensile loads are the greatest (which is the best location to place reinforcing so as to resist those tensile loads). As mentioned in other CCI articles on reinforcing, this zone is always at the bottom surface of a countertop (or at the top in the case of a cantilever).Structural engineers are very aware of this, which is why beams have their reinforcing near the bottom.

Fig. I section

The third level of reinforcement is one-dimensional (1D) reinforcing. This is how structural beams are designed using steel reinforcing. It is the most efficient form of reinforcing because it uses the least amount of material to resist the tensile loads. The reinforcing is placed entirely within the tensile zone, thereby maximizing the effectiveness without wasting reinforcing in
areas that don’t generate tensile loads.

GFRC mix designs

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

Fiber content varies, but is generally about 5% to 7% of the cementitious weight. Some mixes go up to10% by weight of cement. Increased fiber content adds strength but decreases workability. Cem-Fil's Anti- Crack HP 12mm AR glass fiber is commonly used in premix applications.

Common water to cement ratios used rang from 0.3 to 0.35. However, acrylic polymer is being added, so some of the mix water comes from the acrylic polymer. This makesaccurate w/c ratio calculations difficult unless the solids content of the polymer is known. With a polymer solids content of 46%, 15 lbs of polymer plus 23 lbs of water are added for every 100 lbs of cement.

□

Acrylic is the polymer of choice over EVA or SBR polymers. Acrylic is non-rewetable, so once it dries out it won't soften or dissolve, nor will it yellow from exposure to sunlight. Most acrylic polymers used in GFRC have solids content ranging from 46% to over 50%. Two reliable acrylic polymers are Smooth-On's duo Matrix C and Forton's VF-774.

Sand used in GFRC should have an average size passing a #50 sieve to #30 sieve (0.3mm to 0.6mm). Finer sand tends to inhibit flowability while coarser material tends to run off of vertical sections and bounce back when being sprayed. Pozzolans such as silica fume, metakaolin and VCAS can be used to improve the properties of GFRC.
VCAS will improve workability, while metakaolin and especially silica fume will decrease workability due to their higher water demand. Typically VCAS is used at a20% cement replacement level. Superplasticizers are often used to increase fluidity. However very stronge superplasticizers will make spraying vertical surfaces difficult since the material will no thang on the vertical surfaces.

GFRC Casting Methods

Commercial GFRC commonly uses two different methods for casting GFRC. One is called spray-up, the other is called premix.

Spray-up process

Spray-up is similar to shotcrete in that the fluid concrete mixture (minus fibers) is sprayed into the forms. The concrete is sprayed out of a gun-like nozzle that also chops and sprays a separate stream of long fibers. The concrete and fibers mix when they hit the form surface. Glass fiber is fed off of a spool in a continuous thread into the gun, where blades cut it just before it is sprayed. Chopped fiber lengths tend to be much longer than fibers that get mixed in, since long fibers would ball up if they were mixed into the concrete before spraying.

Chopped glass fibers and cement slurry are sprayed simultaneously on to the form surface, to produce thin sheets. With this technique, substantially higher fiber volumes, up to about 6%, can be incorporated. (Note: Coarse aggregates are not used). Typically Spray-up is applied in two layers. The first layer is the face coat, much like angel-coat in fiberglass. This face coat usually has no fibers in it and is thin, often only about 1/8" thick. The second or backer layer has the fiber in it. The action of spraying on the fibers orients them in a thin layer, much like the layers in plywood.

Premix process

Premix, on the other hand, involves mixing shorter fibers in lower doses into the fluid concrete. This mixture is either poured into moulds or sprayed. While the spray guns used don't have a fiber chopper, they are nonetheless costly and require a pump to feed them (the same pump used with spray-up). Premix tends to be less strong than spray-up due to the shorter fibers and more random fiber orientation.

GFRC used for concrete countertops in large shops tends to be made using the spray-up method. However, the high equipment cost puts this out of the reach of most people. However, the high equipment cost puts this out of the reach of most people.

Hybrid Method

In this method, layers of fiber in the form of mats or fabrics can be placed in moulds , impregnated with cement slurry, and then vibrated or compressed, to produce dense materials with very high fiber contents. This technique can also be used with glass fiber ravings' already impregnated with cement slurry An alternative hybrid method uses an inexpensive hopper gun to spray the face coat. The fiber loaded backer mix is often poured or hand packed, just like ordinary concrete. Once the thin face mix is sprayed into the forms it is allowed to stiffen up before the backer mix is applied. This prevents the backer mix from being pushed through the thin face mix.

Hopper guns are often used to spray acoustic ceilings, cementitious overlays or other knock-down surfaces. They are inexpensive and run off of larger air compressors. A very effective combination of a hopper gun and a 60 gallon air compressor .

The face mix and the backer mix are applied at different times, so the makeup and consistency can be different. It is always important to ensure the gross makeup is similar, and w/c ratios and polymer contents should be the same to prevent curling. However the heavy dose of fibers in the backer mix often precludes spraying, so hand placement or conventional pouring of an SCC version is required.

Fig. - Spraying the face coat

Fig. Face coat ready for backer mix

Fig. Hand packing backer on upright

Fig. SCC backer in bottom

Fig. Edge closeup

GFRC

Thickness

Typical countertop thickness ranges from ¾" to 1" thick. This represents the minimum thickness that a long, flat countertop can be made so that it doesn't break when handled or transported. Smaller wall tiles can be made much thinner.

Curing And Stripping

Because of the high polymer content, long term moist curing is often unnecessary. It is important to cover the freshly cast piece with plastic overnight, but once the piece has gained enough strength, it can be uncovered and processed. Generally GFRC pieces are stripped the next day, usually 16 and 24 hours after casting. Longer curing will always yield better concrete, but the general tendency is strip soon after casting.

Processing

GFRC, depending upon the mix, the spray method and the skill of the caster may or may not require grouting to fill bug holes or surface imperfections. Often the blowback (sand and concrete that doesn't stick to the forms) collects in the corners of the formwork, and if it's not cleaned out before getting covered the concrete's finished surface will be open and granular.

Fig. Sand buildup in corner
Fig. Surface Variations from Inconsistent Spraying

Out of the mould, GFRC can have the wet cast look. While not impossible, reliably achieving a perfect out-of- the- mould piece requires extensive skill, experience and a lot of luck. Often the surface is honed, which eliminates many casting variations. GFRC in this case is indistinguishable from a honed sand-mix. Since air bubbles tend to get trapped in the mix, there usually are small pinholes that need to be grouted, just like regular concrete.

Looks

GFRC is, after all another form of concrete. So acid staining, dying and integral pigmentation are all possible. Embedment's
, decorative aggregates, veining and all other forms of decorative treatments are possible. GFRC can be etched, polished, sandblasted. If you can imagine it, you can do it.

Is GFRC green?

GFRC is roughly on par with other forms of concrete countertops in terms of the "green-ness". In comparing 1.5" thick concrete countertops to ¾" GFRC countertops, the same amount of cement is used, since GFRC tends to use about twice as much cement as ordinary concrete. This sets them equal to each other. The use of

polymers and the need to truck them does make GFRC less green than using ordinary water, which could be recycled from shop use. Both traditional cast and GFRC can use recycled aggregates, and steel reinforcing is greener than AR glass-fibers , since steel is the most recycled material, so its use in concrete of all forms boosts the
concrete's green-ness.

COMPOSITION OF GFRC

GFRC is composed of:

Concrete-typically Portland cement, type I.

Aggregates, (crushed stone or silica sand).

Glass fibers-to provide tensile and flexural strength.

Polymers in some cases-to improve toughness.

Plasticizers to enhance workability of concrete where it is necessary. Generally, higher cement ratios are used in GFRC mixtures and concretes that contain glass fiber reinforcement. In fact, the more the fibers, the more the
cement. Normally used fiber lengths are 0.5, 1, 1.5 and 2 inches. Because using shorter fibers makedistributi on easier but experiences show that the 1 inch length provides optimum strength. In spray head mixing which results better physical and mechanical properties often 1.5-inch fibers are used. Mixing longer fibers in concrete or cement bother the process of consolidation and decrease density and subsequently mechanical strength. In most glass fibers products the content of glass fibers differ from 3 to 7 percent by weight however, when the fiber ratio goes up density declines and this is because of poor compaction. Samples made of ordinary glass fibers are initially strong but a loss of strength is shown when they age, and it causes from high alkaline environment of Portland cement. In special cases if using typical glass fibers are required due to lower cost or accessibility it is possible to replace micro silica or nano silica by cement weight to reduce alkaline effects but when the issue of difficult environment is imposed it's highly recommended to use AR glass fibers. Samples were made of ordinary glass fibers were initially strong but the strength dropped off as the sample saged because the highly alkaline environment of Portland cement attacked surfaces of glass fibers.

AR Glass Fiber Chopped Strands

Fig Continuous AR GlassFibers

Moreover, it seems very unique to reinforce rural buildings (typically made of clay and bricks or mud and straw) with glass fiber meshes to increase their flexural strength and durability. This solution is an innovative idea to rebuild and repair masonry buildings especially in rural museums and heritages or even in true cases because buildings must be stable in harsh environments and stand different stresses. This idea came to our mind to reinforce mud-ricestraw paste with AR chopped glass fibers to improve its durability, tensile strength, compressive strength and flexural strength and permeability as well as all above. Despite all structural benefits of this solution it has several architectural benefits for example the building scan maintain their original external view but stronger and thinner than before. III.

Physical and Mechanical Properties of GFRCGFRC does not fail immediately under load but yields gradually nevertheless in cement and concrete tensile failure begins with micro cracks and they propagate quickly and caused destruction. The key of this accepted behaviour of GFRC is due to randomly distribution of tiny glass fibers in it, uniformed distributed fibers expand the loads in a wide range and let the matrix to behave cohesive.[Figures] shows randomly distribution of AR glass fibers in the matrix in a large scale.

The existence of glass fibers provides crack arresting system for example we can imagine a concrete beam with numerous ties or reinforcement in different directions. It is clear when the first crack occurs in the beam the strong fibers pick the loads so that this characteristic allows the beam to withstand more loads. More loading impose, only new cracks appear rather than causing first cracks to develop which occurs in steel reinforced concrete especially in the tension area. Therefore, failure in GFRC develops as a gradual plastic-like yielding and in the end, fracture happens when fibers are broken. The schematic diagram below shows the process of crack arresting.

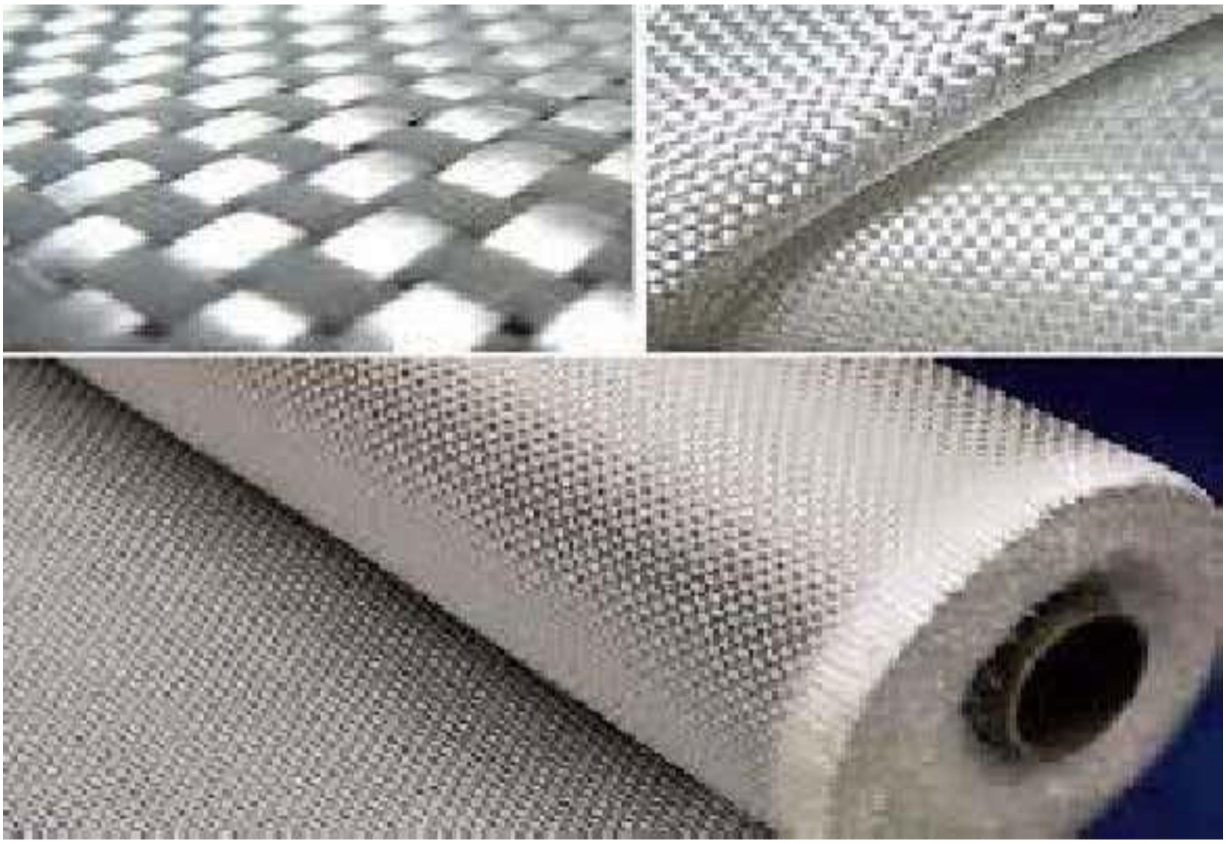

fig. - Glass Fiber Meshes.

GFRC has a higher tensile strength than steel. [Generally, the higher the fiber content, the higher the strength. A typical mix with 5% glass fiber has a compressive strength of 6000 to 8000 [psi] or 4.21 to5.62 [Kg/mm].

MATERIALS USED

Portland Pozzolana Cement-

Cements of different grades are available in market. We are usingPortland pozzolona cement of43 Grade available in local market has been used in the project andof specific gravity 3.15.Itmust be kept in mind either we use low alkali cement or use Alkali resistance glass fiber toreduce alkali content in the concrete.

Coarse Aggregates

Coarse aggregate of size 20mm of specific gravity and of size 10mm are used in 60:40 ratio;

Fine Aggregates-

Sand was used as fine aggregate of specific gravity 2.86.

Alkali Resistance Glass Fiber-

We are using alkali resistance glass fiber of size 12mm and 14(micron) µm.

We are mixing glass fiber used in concrete 0.5% to 3% of the weight of cement.

Admixture-

Super plasticizer is used 5% of the cement weight as admixture to reduce setting time andimpart plasticity in concrete.

Glass fiber

The glass fiber used is of Cem-FIL Anti-Crack HD with modulus of elasticity 72GPA, Filament diameter 14 microns, specific gravity 2.68, length 12 mm.

Water

Locally available portable water is used.

Grade of Concrete-

We are using M20 grade of concrete for whole project. The ratio is 1:1.5:3 as per IS-Code specifications. GFR Concrete comparing with plane concrete mix.

METHODOLOGY

Comparison Of Compressive Strength Of GFRC At Different PercentageOf Glass Fiber (by weight of Cement)

Compressive Strength of concrete is defined as the Characteristic strength of 150mmsize concrete cubes tested at 28 days.

Why Do We Test At 7, 14 & 28 Days?

Concrete is a macro content with Sand, Cement, & Coarse aggregate as its micro ingredient(Mix Ratio) and gains its 100% strength over time at the hardened state.

CONCRETE

STRENGTH

OVERTIME:-

DAYS AFTER CASTING

STRENGTH GAIN

Day 1

16%Day 3 40%
Day 7

65%
Day 14

90%
Day 28

99%As you can see the concrete gains its strength rapidly till 7th & 14th Days. Then gradually increases from there. So we can't predict the strength until the concrete comes to that stable state.

Grade of Concrete

Grade of Concrete

Minimum compressive strength (N/mm2) at 7 days

Specified characteristics compressive strength (N/mm2) at 28 days M15 10 15M20 13

20M25 17 25M30 20 30M35 23.5 35M40 27 40M45 30 45

3.3 Compressive Strength of Concrete Lab Test

Required Equipment & Apparatus

150 mm Cube Moulds (with IS Mark)

Electronic Weighing Balance

G.I Sheet (For Making Concrete)

Vibrating Needle & other tools

Compressions Testing Machine

Procedure

Cube Casting

1. Measure the dry proportion of ingredients (Cement, Sand & Coarse Aggregate) as perthe design requirements. The Ingredients should be sufficient enough to cast test cubes.

2. Thoroughly mix the dry ingredients to obtain the uniform mixture.
   Add design quantity of water to the dry proportion (water-cement ratio) and mix well toobtain uniform texture.

3. Fill the concrete to the mould with the help of vibrator for thorough compaction.
   Finish the top of the concrete by trowel & tapped well till the cement slurry comes to thetop of the cubes.

4. After some time the mould should be covered with red gunny bag and putundisturbed for 24 hours at a temperature of 27 ° Celsius ± 2

5. After 24 hours remove the specimen from the mould.

6. Keep the specimen submerged under fresh water at 27 ° Celsius. The specimen should bekept for 7 or 28 days. Every 7 days the water should be renewed.

7. The specimen should be removed from the water 30 minutes prior to the testing.
8. The specimen should be in dry condition before conducting the testing.

9. The Cube weight should not be less than 8.1 Kgs.

Testing

Now place the concrete cubes into the testing machine. (centrally)
The cubes should be placed correctly to the machine plate (check the circle marks on themachine). Carefully align the specimen to the spherically seated plate.
The load will be applied to the specimen axially.
Now slowly apply the load at the rate of 140kg/cm2 per minute till the cube collapse.

The maximum load at which the specimen breaks is taken as a compressive load.

Calculation

Compressive Strength of concrete = Maximum compressive load / Cross Sectional Area

Flexural Strength of GFRC

Flexural test evaluates the tensile strength of concrete indirectly. It tests the ability of unreinforced concrete beam or slab to withstand failure in bending. The results of flexural test on concrete expressed as a modulus of rupture which denotes as (MR) in MPa or psi. The flexural test on concrete can be conducted using either three point load test (ASTM C78) or center point load test (ASTM C293). The configuration of each test is shown in Figure-2 and Figure-3,respectively. Test method described in this article is according to ASTM C78.

three-point load test (ASTM C78)

It should be noticed that, the modulus of rupture value obtained by center point load test arrangement is smaller than three-point load test configuration by around 15 percent.

Moreover, it is observed that low modulus of rupture is achieved when larger size concrete specimen is considered.

Furthermore, modulus of rupture is about 10 to 15 percent of compressive strength of concrete. It is influenced by mixture proportions, size and coarse aggregate volume used for specimen construction.

Finally, the following equation can be used to compute modulus of rupture, but it must be determined through laboratory test if it is significant for the design : fct: Modulus of rupture
fc‘: concrete compressive strength

Figure : Compression test on Concrete Cube

According to ASTM the size of the specimen is 150mm width, 150mm depth and thelength should not be at least three times the depth of the specimen.

Indian standard determined the size of the concrete specimen as 150mm width, 150mmdepth, and span of 700mm.

It also states that a size of 100mm width, 100mm depth, and span of 500mm can be usedif the maximum aggregate size used is not greater than 19mm.

British standard specifies square specimen cross section with 100mm or 150mmdimension and the span ranges from four to five times specimen depth.

However, it preferred 150mm width, 150mm depth, and span of 750mm for thespecimen.

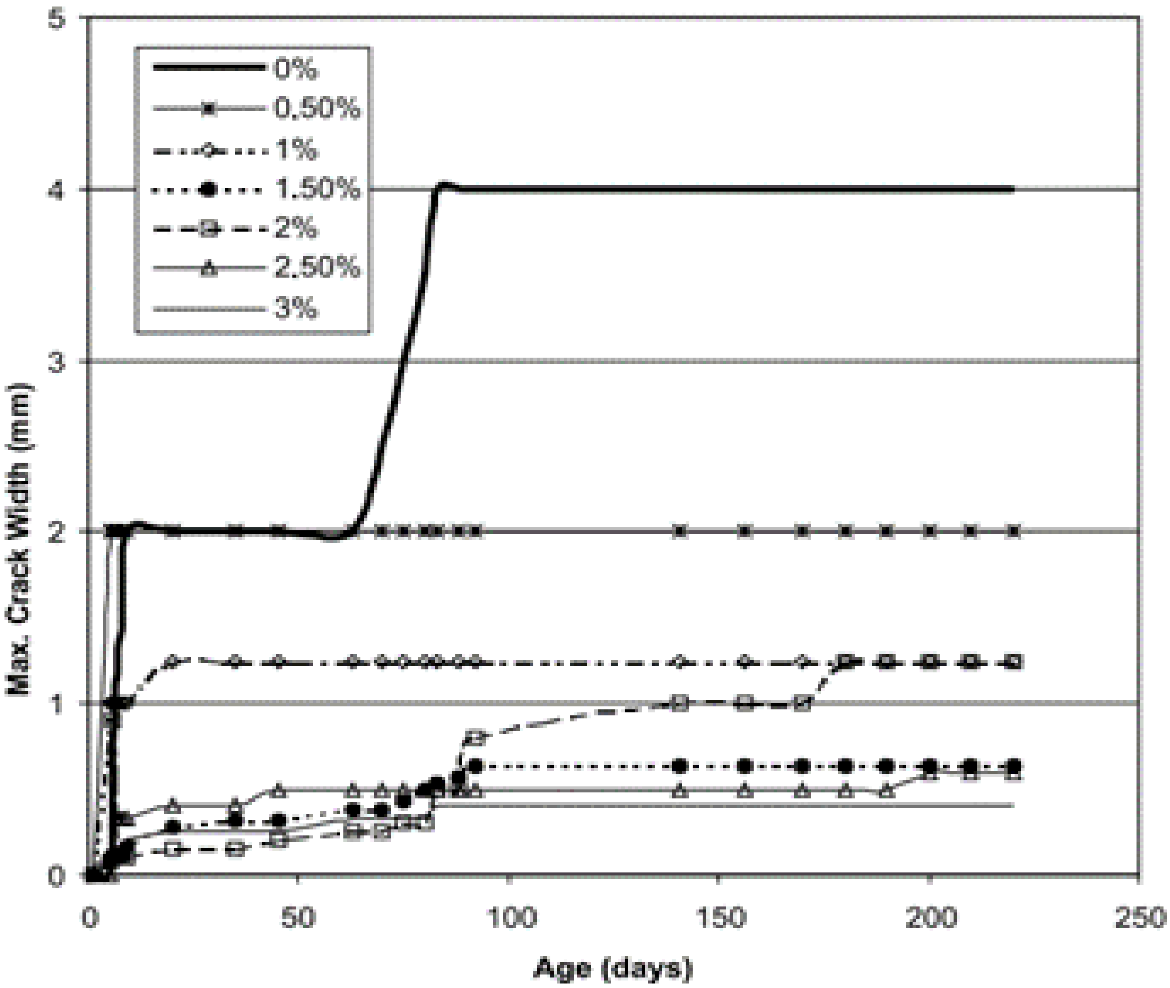

Fig. Restrained shrinkage test results for GFRC with different glass fibre contents.

Apparatus for Flexural Test on Concrete

Steel, iron cast, or other non absorbent material moulds with size of (150mmX150mmX750mm)

Tamping rods: ASTM specify large rode (16mm diameter and 600mm long) and small rode (10mm diameter and 300mm long)

Testing machine capable of applying loads at a uniform rate without interruption of shocks

Scoop

Trowel

Balance with accuracy of 1g

Power driven concrete mixer

Table vibration in the case of using vibration to compact concrete in moulds

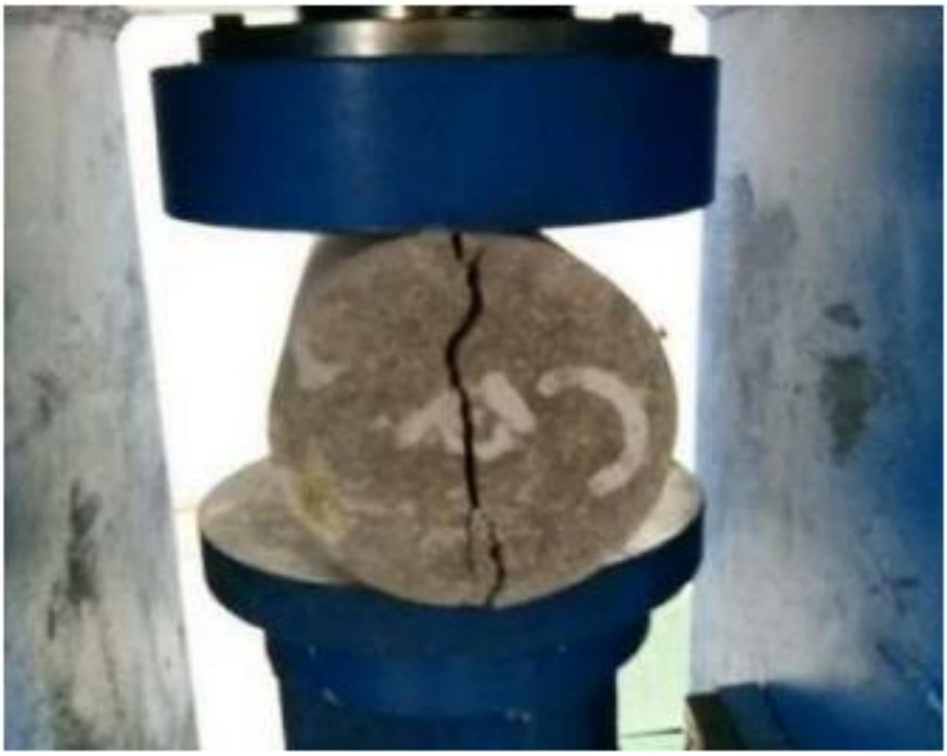

Figure : Split Tensile test on Concrete

Sample Preparation of Concrete

Determine proportions of materials including cement, sand, aggregate and water.

Mix the materials using either by hand or using suitable mixing machine in batches with size of 10 percent greater than moulding test specimen.

Measure the slump of each concrete batch after blending.

Place moulds on horizontal surface and lubricate inside surface with proper lubricant material and excessive lubrication should be prevented.

Pour fresh concrete into the moulds in three layers.

Compact each layer with 16mm rode and apply 25 strokes for each layer or fill the mould completely and compact concrete using vibration table.

Remove excess concrete from the top of the mould and smoothen it without imposing pressure on it.

Cover top of specimens in the moulds and store them in a temperature room for 24 hours.

Remove the moulds and moist cure specimens at 23+/-2 C till the time of testing.

The age of the test is 14 days and 28 days and three specimens for each test should be prepared

Procedure of Flexural Test on Concrete

The test should be conducted on the specimen immediately after taken out of thecuring condition so as to prevent surface drying which decline flexural strength.

Place the specimen on the loading points. The hand finished surface of the specimenshould not be in contact with loading points. This will ensure an acceptable contact between the specimen and loading points.

Center the loading system in relation to the applied force.

Bring the block applying force in contact with the specimen surface at the loading points.

Applying loads between 2 to 6 percent of the computed ultimate load.

Employing 0.10 mm and 0.38 mm leaf-type feeler gages, specify whether any space between the specimen and the load-applying or support blocks is greater or less thaneach of the gages over a length of 25 mm or more.

Eliminate any gap greater than 0.10mm using leather shims (6.4mm thick and 25 to50mm long) and it should extend the full width of the specimen.

Capping or grinding should be considered to remove gaps in excess of 0.38mm.

Load the specimen continuously without shock till the point of failure at a constant rate(Indian standard specified loading rate of 400 Kg/min for 150mm specimen and180kg/min for 100mm specimen, stress increase rate 0.06+/-0.04N/mm .s according toBritish standard).The loading rate as per ASTM standard can be computed based on the following equation:

$$r = sbd^2/L$$

Where:r: loading rateS: rate of increase of extreme fiber b: average specimen widthd: average specimen depthL: span lengthFinally, measure the cross section of the tested specimen at each end and at center tocalculate average depth and height.

Computation of Modulus of Rupture

The following expression is used for estimation of modulus of rupture:
Where:
MR: modulus of ruptureP: ultimate applied load indicated by
testing
machineL: span length b: average width of the specimen at the fracture d: average depth of the specimen at the fracture

Tensile Strength of GFRC-

Tests shall be made at recognized ages of the test specimens, the most usual being 7 and 28 days. Where it may be necessary to obtain the early strengths, tests may bemade at the ages of 24 hours ± ½ hour and72 hours ± 2 hours. The ages shall be calculated from the time of the addition of water to thedry ingredients. Number of Specimens
At least three specimens, preferably from different batches, shall be made for testing at each selected age.

Apparatus

Testing Machine

The testing machine may be of any reliable type, of sufficient capacity for the tests and capable of applying the load at the rate specified
in 5.5. The permissible error shall be not greater than ± 2

percent of the maximum load. Cylinders. The cylindrical mould shall be of 150 mm diameter and 300 mm height conforming toIS: 10086-1982. Weights and weighing device, Tools and containers for mixing, Tamper(square in cross section) etc.

Procedure:-

Sampling of Materials

Samples of aggregates for each batch of concrete shall be of the desired grading and shall be in an air-dried condition. The cement samples, on arrival at the laboratory, shall be thoroughly mixed dry either by hand or in a suitable mixer in such a manner as to ensure the greatest possible blending and uniformity in the material.

Proportioning

The proportions of the materials, including water, in concrete mixes used for determining the suitability of the materials available, shall be similar in all respects to those to be employed in the work.

Weighing

The quantities of cement, each size of aggregate, and water for each batch shall be determined by weight, to an accuracy of 0.1 percent of the total weight of the batch.

Mixing Concrete

The concrete shall be mixed by hand, or preferably, in a laboratory batch mixer, in such amanner as to avoid loss of water or other materials. Each batch of concrete shall be of such asize as to leave about 10 percent excess after moulding the desired number of test specimens

Figure 3. Pre–mixture and casting process

Mould

The cylindrical mould shall be of 150 mm diameter and 300 mm height conforming to IS:10086-1982.

Compacting

The test specimens shall be made as soon as practicable after mixing, and in such a way as to produce full compaction of the concrete with neither segregation nor excessive laitance.

Curing

The test specimens shall be stored in a place, free from vibration, in moist air of atleast 90 percent relative humidity and at a temperature of 27° ± 2°C for 24 hours ± ½ hour from thetime of addition of water to the dry ingredients.

Placing The Specimen In The Testing Machine

The bearing surfaces of the supporting and loading rollers shall be wiped clean, and anyloose sand or other material removed from the surfaces of the specimen where they are tomake contact with the rollers.

Calculation:-

Calculate the splitting tensile strength of the specimen as follows:

$$\mathbf{T} = 2P/\pi LD$$

Where T = Splitting tensile strength P = Maximum applied load L = Length, mD = Diameter

Workability

Workability of concrete is defined as the ease and homogeneity with which a freshly mixed concrete or mortar can be mixed, placed, compacted and finished.

Concrete slump test:-

The concrete slump test measures the consistency of fresh concrete before it sets. Itis performed to check the workability of freshly made concrete, and therefore the ease withwhich concrete flows. It can also be used as an indicator of an improperly mixed batch. The test is popular due to the simplicity of apparatus used and simple procedure. The slump testis used to ensure uniformity for different loads of concrete under field conditions.

A separate test, known as the flow table, or slump-flow, test, is used for concrete that is too fluid to be measured using the standard slump test, because the concrete will not retain its shape when the cone is removed.

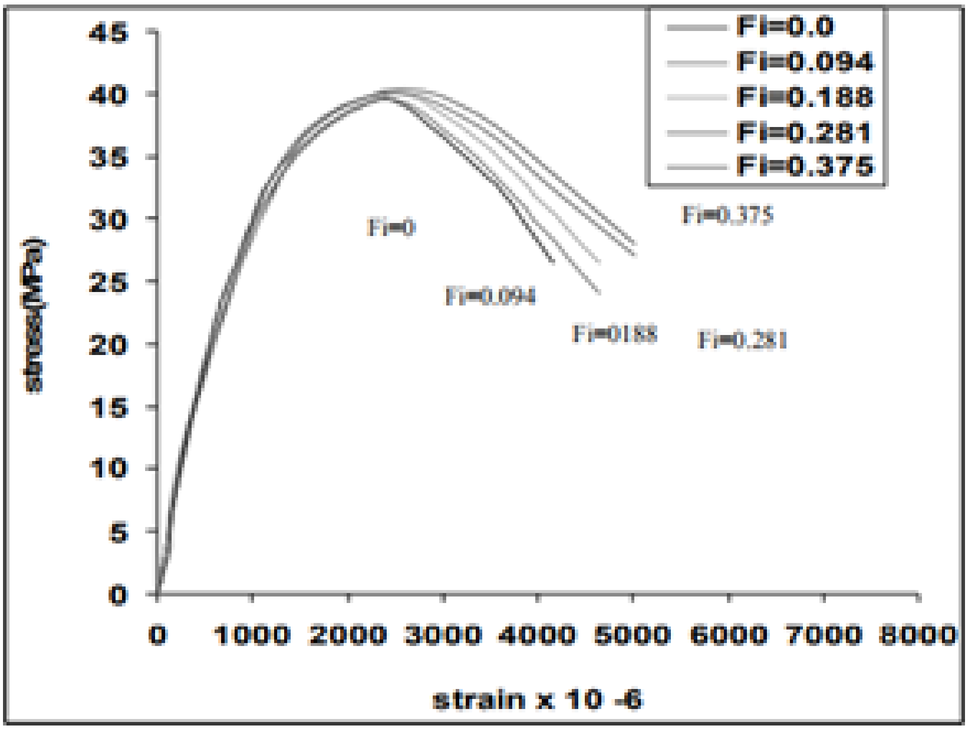

Fig. - Stress–Strain diagram with differences at fibre ratios.

Procedure:-

Mixing with concrete for Slump cone

Height measurement

The test is carried out using a metal mould in the shape of a conical frustum known as a slump cone or **Abrams cone**, that is open at both ends and has attached handles. The tool typically has an internal diameter of 100 millimetres (3.9 in) at the top and of 200 millimetres (7.9 in) at the bottom with a height of 305 millimetres (12.0 in).The cone is placed on a hard non-absorbent surface. This cone is filled with fresh concrete in three stages. Each time, each layer, is tamped25 times with a 2 ft (600 mm)-long bullet-nosed metal rod measuring 5/8 in (16 mm) in diameter. At the end of the third stage, the concrete is struck off flush with the top of the mould. The mould carefully lifted vertically upwards, so as not to disturb the concrete cone. The concrete then slumps (subsides). The slump of the concrete of the measured by measuring the distance from the top of the slump concrete to the level of the top of the slump cone.

Interpretation of Results

The slumped concrete takes various shapes and according to the profile of slumped concrete, the slump is termed as true slump, shear slump or collapse slump. If a shear or collapse slump is achieved, a fresh sample should be taken and the test repeated. A collapse slump is an indication that the mix is too wet. Only a true slump is of any use in the test. A collapse slump will generally mean that the mix is too wet or that it is a high work ability mix, for which the slump test is not appropriate. Very dry mixes having slump 0
25 mm are typically used in road making, low workability mixes having slump 10, 40 mm are

typically used for foundations with light reinforcement, medium workability mixes with slump 50
mm, are typically used for normal reinforced concrete placed with vibration,high workability concrete with slump > 100 mm is typically used where reinforcing has tight spacing, and/or the concrete has to flow a great distance.

Comparison, collapse, Shear

In a collapse slump the concrete collapses completely. In a shear slump the top portion of the concrete shears off and slips sideways. In a true slump the concrete simply subsides, keeping more or less to shape.

Limitations of Slump Test

The slump test is suitable for slumps of medium to low workability, slump in the range of 5

260 mm; the test fails to determine the difference in workability in stiff mixes which have zero slumps, or for wet mixes that give a collapse slump. It is limited to concrete formed of aggregates of less than 38 mm (1.5 inch).

Other Tests:-

There are many tests for evaluating slump in concrete: the flow table test (DIN 1048-1) uses similar, but differently-sized, apparatus, but the table on which the slump cone is placed is dropped several times after the slump cone is removed, and the measurement is of the diameter of the sample, not the height. one example is the K-Slump Test (ASTM International C1362-09 Standard Test Method for Flow of Freshly Mixed Hydraulic Cement

Concrete). Other tests evaluating consistency are the British compacting factor test, the consist meter for roller-compacted concrete (ASTM C1170).Another way of determining slump is to use an automated slump meter. Sensors and controls the meters to measure and display slump. Their reliability has by now earned them acceptance in various standard codes such as ASTM International. Some automated slump meters, such as the one by Verify also can add water to the concrete mix in the delivery truck while in transit. In 2013 ASTM C94/C94M was revised to allow water additions during transit for trucks equipped with automated slump monitoring and measurement systems.

Factors Affecting Workability

Workable concrete shows very less internal friction between particles and overcomes the frictional resistance with just the amount of compacting efforts provided. Workability of the concrete depends on a number of interrelating factors. Water content, aggregate properties, use of admixtures, fineness of cement are the factors affecting workability.

Water content:

The increase in water content increases the fluidity of the concrete thus providing greater lubrication. This helps to increase the workability ofthe concrete. Increasing the water content should be the last resort to improve theworkability in the concrete as this will seriously affect the strength of the concrete. Even if more amount of water is to be added, more cement also should be added so that the water/ cement ratio remains the same and hence the strength of the concrete remains unaffected.

Size of aggregates:

The surface area of bigger aggregates is less and hence lessamount of water is required for lubricating the surface to reduce the friction. Thus the concrete having large sized aggregate is more workable (of course, within certain limits).

Mix proportions:

Aggregate/ cement ratio is the measure of how lean or rich the concrete is. If aggregate/ cement ratio is higher, the concrete becomes leaner. In lean concrete less paste is available for the lubrication of the aggregate, while in rich concrete with low a/c ratio, more paste is available which makes the mix more cohesive and hence provides better workability.

Shape of aggregates:

Rounded aggregates have considerably less surface areaand less voids in comparison to angular or flaky aggregates which provide better possibility of overcoming the frictional resistance. Further, angular and flakyaggregates make concrete very harsh.

Surface texture of aggregates:

The aggregates having smooth or glossy texture haveless surface area compared to rough textured aggregates. This provides betterworkability as less amount of water is required for lubricating effect. But, taking into account the poor interlocking action provided by the glossy textured aggregate, its use is generally discouraged in high strength concrete.

Grading of aggregates:

Well graded aggregate is the one with least amount of voids in a given volume. If the grading of aggregate is good, the voids will be less and hence higher the workability.

Use of admixtures:

Use of admixtures in concrete is the major factor that affects the workability. The use of plasticizers and super-plasticizers amply increase theworkability of the concrete. Air entraining agents produce air bubbles which act asrollers between particles and provide better mobility thus improving the workability.

Time and temperature:

Fresh concrete gets stiffened as the time flows. This is because some of the water used to mix the concrete gets evaporated and some gets absorbed by the aggregates. Thus the workability of concrete reduces withtime. This loss of workability with time is known as slump loss. The effect of temperature on workability of concrete is noteworthy. As the temperature increases, the workability of the mix reduces.

DISCUSSIONS AND RESULTS

Compressive Strength

M20+Glass Fibre

Compressive Strength (N/Mm 2) (7 Days)

(28 Days)

0.5% 17.70- 27.062. ,
1% 20.76- 28.463.
2% 19.64 -26.984.
3% 18.4 -26.108

Flexural Strength

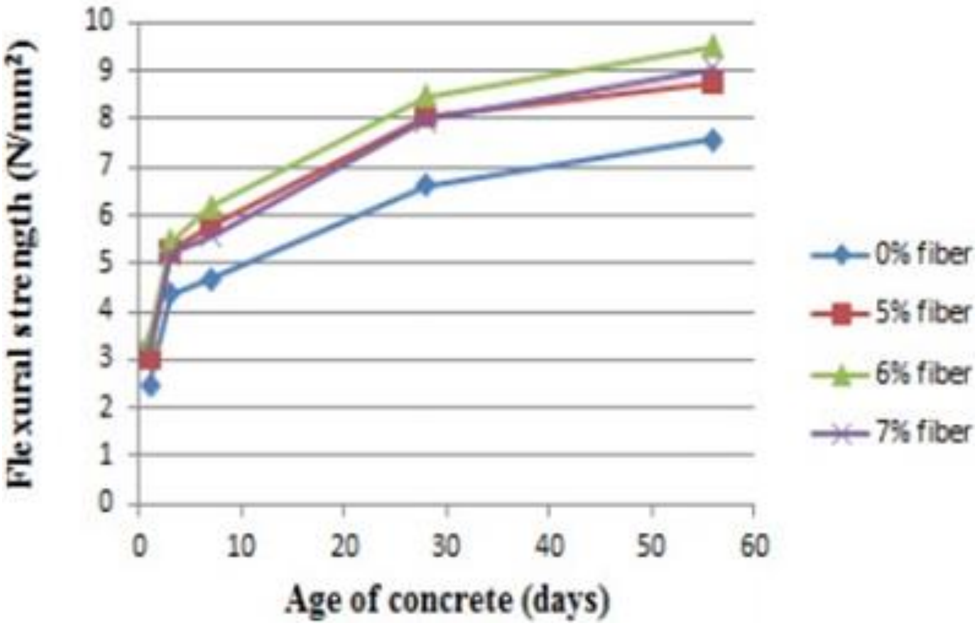

Fig. - Variation of flexural strength with the age of concrete.

M20+Glass Fibre Flexural
Strengt (N/Mm 2)

(7 DAYS) 1% 1.47 -2.943.

(14 DAYS) 2% 1.30 2.604

(28 Days)3% 1.28- 2.45

Split Tensile Strength

M20+Glass Fibre Split Tensile Strength
(N/Mm2) (7 Days) (28 Days)

1. 0.5% 1.41 - 3.402.
2. 1% 2.83 - 3.923.
3. 2% 2.62 - 3.57
4. 4. 3% 2.43 - 3.42

Comparisons Between Gfrc And Plain Concrete

Plain concrete GFRC Compressive strength (N/mm2)
Compressive strength N/mm2)
7DAYS 28 DAYS % G.F. 7DAYS 28DAYS

0.5 17.70 - 27.062.
1 20.76 - 28.463.
1 19.64 - 26.984
2 3 18.4 - 26.108

Effect of Compressive Strength on Glass Fiber Concrete:

This figure represents the graph between the Compressive strength vs % of glass fiber. The glass fiber 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 is28.46N/mm2

Compressive Strength vs. % of Glass fiber
Effect of Flexural Strength on Glass Fiber Concrete:

This figure represents the graph between the Compressive strength vs % of glass fiber. The glass fiber 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/mm2

Split Tensile Strength V/S % Of Gf
Advantages And Disadvantages
The main advantages of GFRC in comparison to concrete are as follows:

Higher flexural strength, tensile strength and Impact Strength than plain concrete due to the presence of the glass fibers.

No cover requirement to be provided thus resulting in thinner sections.

Fibers are lightweight that minimizes the load added to existing structures.

Improved Chemical Resistance, for example GFRC exhibits better chloride penetration resistance than steel.

It does not rust or corrode.

Good acoustic properties.

Low permeability that increases water or air pollution resistance.

It is Recyclable and Eco friendly.

Good surface finish is obtain, without voids, since it is sprayed and defect do not appear. Some of the main disadvantages of GRC are:

It is more expensive than plain concrete.

GRC can lose some of its initial strength over long periods of time and this has to betaken into consideration during the design stage.

At present in the Indian market only a couple of suppliers are available and the awareness regarding field applications of GFRC is relatively low.

APPLICATION OF GFRC

Decorative Architectural Panels or Cladding

Due to the light weight of GFRC panels, thinner structural members provide enough stability. Transportation costs are also reduced. GFRC panels also provide good resistance to fire and extreme weather conditions thereby making it an ideal material for exterior use. Also GFRC isa versatile material that provides great design flexibility by offering a plethora of colours, textures, patterns and surface finishes. Spray-up and pulp type production are the commonly used methods of production.2.

Noise Protection Barriers

GFRC has been used for making noise protection barriers. The main reason is that theoretical values have suggested that GFRC panels with a thickness of 10mm and surface mass of 20kg/m 2
will achieve a sound reduction of about 30dB. Production technology is the same as in Architectural cladding.3.

Interior usage:

GFRC is more stain resistant than granite and more scratch resistant than marble. Kitchen counter tops, Commercial and Industrial tops etc. Premix method is best suited for these purposes.4.

Column Strengthening by GFRC layers:

Retrofitting of existing compression members to improve ductility. Also the strength is increased by confining the columns in Glass Fiber Reinforced Polymer wrapping. Spray up is the preferred method of execution.5.

Retrofitting of Masonry walls with Glass Fiber mesh

Since masonry walls offer poor resistance to dynamic forces, existing masonry construction are strengthened by application of Glass fiber mesh beneath a layer of mortar or cement slurry by spray up or Hybrid Method.6.

Ducts, Channels and Sewer lining:

GFRC offers good resistance against impact, acid, salt, lime and water. The major problems encountered in channels and sewers are abrasion due to flow of liquid, corrosion due to chemicals present in wastewater, temperature of water and humid conditions. Hence GFRC provides a safe composite that serves well in many environmental issues related to concrete and its poor strength in extreme conditions. All,types of Production technologies are used depending on the site requirement..

Exact Replicas of historical buildings:

The versatility of GFRC in terms of colours, textures, patterns and surface finishes make it a good choice for the repair and rehabilitation of historical structures and extensions to old buildings using the same design features.

CONCLUSION:

The following conclusions can be summarized:-

GFRC can be used wherever a light, strong, weather resistant, attractive, fire retardant, impermeable material is required. It is characterized by many useful properties.

GFRC possesses Higher tensile strength than that of steel. Modulus of elasticity is higher in steel bars but low modulus glass fibers stretch and allow concrete to crack, but nevertheless do not allow the crack to propagate hence, a new crack in different position appears.

Use of fiber produces more closely spaced cracks and reduces crack width. Fibers bridge cracks to resist deformation.

Fiber addition improves ductility of concrete and its post-cracking load-carrying capacity.

Like most composites GFRC properties are dependent on the quality of materials and accuracy of production method.

Fracture energy of cement based materials is significantly increased by adding glass fiber to the mix composition

LITERATURE REVIEW

General

Glass fiber reinforced composite materials consist of high strength glass fiber embedded in a cementitious matrix. In this form, both fibers and matrix retain their physical and chemical identities, yet they produce a combination of properties that can't be achieved with either of the components acting alone. In general fibers are the principal load-carrying members, while the surrounding matrix keeps them in the desired locations and orientation, acting as a load transfer medium between them, and protects them from environmental damage. GFRC is a form of concrete that uses fine sand, cement, polymer (usually an acrylic polymer), water, other admixtures and alkali-resistant (AR) glass fibers. Many mix designs are freely available on various websites, but all share similarities in ingredient proportions.

2.2 Aim Of Work

To determine tensile strength of GFRC.
To determine compressive strength of GFRC.
To determine flexural strength of GFRC.
To compare strength of GFRC at different percentage of glass fiber.

To determine workability of GFRC

Glass fiber reinforced concrete:

Review By P J M Bartos (2017) PJM Bartos had reviewed the use of GRC over the past 40 years. He had discussed the use, compatibility and procedure of using glass fiber as reinforcement material.

PJM Bartos had reviewed the use of GRC over the past 40 years. He had discussed the use, compatibility and procedure of using glass fiber as reinforcement material. He also reviewed type of fiber used and modes of failure of GRC are also discussed. He provides a widened knowledge and history of GRC as a construction material. We concluded that GRC is light weight, economical, compatible or different structures and environment friendly.

An Experimental Study on Glass Fiber Reinforced concrete

By S.Hemalathal , Dr .A. Leema Rose(2016)They have discussed the mechanical strength as well as chemical resistance of GRC. They have experimented on different percentage of glass fiber used in GRC and comparedtheir flexural, tensile, compressive and resistance to acid attack. They concluded that maximum tensile strength is attained at 1% addition of glass fiber and after exceeding a certain limit the addition of glass fiber leads to decrease in strength of concrete.

Studies of Glass Fiber Reinforced Concrete composites

Komal Chawla and Bharti Tekwani had discussed the future scope of GRC .They have done experiments regarding strength of GRC after increasing percentage of fibering Steel reinforced concrete and compared them. They have concluded that toughness, flexural strength, compressive strength is increased as compared to the normal reinforcement provided.

A study on glass Fiber As An Additive In Concrete To Increase Concrete Tensile Strength

by Ronak Prakash Kumar Patel Jayraj Vinod Singh Solanki & Jayesh Kumar Pitroda:-

In this paper they have discussed type of glass fiber used in GRC and effect of their propertieson GRC.They have experimented with glass fiber reinforcement in RigidPavements & concluded that Glass Fiber reinforcement is economical have high strength require low cost equipments develop no cracks on applying on rigid pavement & are easily compacted. They have also discussed the effect of glass fiber on tensile Strength of concrete.

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