GLASS FIBRE REINFORCED CONCRETE

A SEMINAR REPORT

Submitted by

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Glass Fibre Reinforced Concrete

A Complete Study

Glass Fibre Reinforced Concrete is a recent introduction in the field of concrete technology. It has been used extensively in over 100 countries since its introduction in 1980's. This product is covered by international standards and has been practiced all over the world. GFRC has an advantage of being light weight and there by reducing the overall cost of construction thereby bringing economy in construction. This work is only an accumulation of information about GFRC from all over the internet and some text books.

About GFRC

GFRC is concrete that uses glass fibres for reinforcement instead of steel. It is typically cast in a thin section of around 1/2" to 3/4". Since the fibres cannot rust like steel, there is no need for a protective concrete cover thickness to prevent rusting. With the thin, hollow construction of GFRC products, they can weigh a fraction of the weight of traditional precast concrete

Introduction

Plain concrete processes a very low tensile strength, limited ductility, and little resistance to cracking. Internal micro cracks are inherently present in the concrete and its poor tensile strength is due to the propagation of such micro cracks, eventually leading to brittle failure of the concrete.

The most widely accepted remedy to this flexural weakness of concrete is the conventional reinforcement with high strength steel. Restraining techniques are also used to. Although these methods provide tensile strength to members, they however do not increase the inherent tensile strength of concrete itself. Also the reinforcement placing and efficient compaction of RCC is very difficult if the concrete is of low workable especially in the case of heavy concrete

(M35-M60). In plain concrete and similar brittle materials, structural cracks (micro-cracks) develop even before loading, particularly due to drying shrinkage or other causes of volume change. The width of these cracks seldom exceeds a few microns, but their two dimensions may be of higher magnitude.

When loaded, the micro cracks propagate and open up, and owing to the effects of stress concentration, additional cracks form in places of minor defects. The structural cracks proceed slowly or by tiny jumps because they are retarded by various obstacles, changes of direction in bypassing the more resistant grains in the matrix. The development of such micro crack is the main cause of inelastic deformation in concrete.

It has been recognised that the addition of small, closely spaced and uniformly dispersed fibres to concrete would act as crack arrester and would substantially improve its static and dynamic properties. This type of concrete is known as fibre reinforced concrete. Glass fibres do the same effect and perform better than any other fibres.

Glass Reinforced Concrete can be define as a composite material consisting of mixtures of cement, mortar or concrete and dis-continuous, discrete, uniformly dispersed fibres. Continuous meshes, woven fabrics and long wires or rods are not considered to be discrete fibres.

How Glass Fibre Reinforced Concrete Can Be Used

GFRC can be used wherever a light, strong, weather resistant, attractive and fire retardant material is required.
GFRC can be used in manufacturing architectural products such as wall panels, window surrounds, column covers, soffits, cornices, brackets, quoins, railings, pilasters, copings, domes, site furnishings, planters, bollards, urns and tables.

Glass Fibre Reinforced Concrete Strength

As an engineered material, the properties of GFRC can vary depending upon mix design, glass content and production methods. Glass fiber used in quality GFRC has a higher tensile strength than steel. As a general rule, the higher the fiber content, the higher the strength. A typical mix with 5% glass fiber has a compressive strength of 6,000 to 8,000 psi.

Glass Fibre Reinforced Concrete Durability

Glass fibre reinforced concrete has been tested both by accelerated aging tests in the laboratory and in real life installations. GFRC can be expected to last as long as pre-cast concrete. In many environments, as when exposed to salt spray or high moisture, the GFRC can be expected to perform better, as there is no steel reinforcement to corrode. Since the surface of GFRC is a Portland concrete, it weathers much as a quality architectural pre-cast concrete would.

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Properties of GFRC

Glass Fibre Reinforced Concrete (GFRC) is a cement-based material that is becoming a popular material because of its many advantages over its counterparts. Some of these advantages include easy customization, water resistance, and lightweight. GFRC can also be customized depending on the requirements of the project by modifying the materials used and their corresponding amount.

The following properties are essential in the performance of any GFRC material: tensile and flexural strengths, modulus of elasticity, compressive strength, impact resistance, shear strength, shrinkage and moisture movement, fire endurance, acoustical properties, thermal conductivity, permeability and moisture absorption.

There is no specific standard for each of these properties; their values depend on the particular need of the project. Each manufacturer or designer must test the composites used to establish the physical properties for the design. These values will depend on different factors like mix design, quality of materials used, manufacturing process and type of curing among others.

There are several factors affecting the physical properties of the GFRC. These factors include the following: fiber content, porosity, water-cement ratio, composite density, sand content, fiber orientation and length, and type of cure. Understanding these factors and their corresponding effects on the properties is essential in the design of GFRC materials.

Fibre length, fiber content and orientation affect tensile strength, flexural strength and impact strength. Basically higher fiber length and fiber content result to higher ultimate tensile, flexural and impact strengths. The fiber orientation also affects the performance of the GFRC material. Most GFRC have random two-dimensional fiber orientation. This factor can be regulated while spraying the GFRC. The fiber orientation determines the fiber resistance to loads.

Density and porosity are affected by the degree of compaction of GFRC. Composite density also affects the flexural strength and tensile strength. The modulus of elasticity also varies directly with the composite density. Lower composite density results to lower ultimate strengths. This is because at lower densities, air trapped in the GFRC reduces the bond between the fiber material and concrete. Thus, proper compaction is necessary to ensure that GFRC has high ultimate strengths.

The type of curing process performed on the GFRC manufacturing also affects the properties of GFRC. Adequate curing is necessary for the hydration of the cement, resulting to a good bond between the fiber and the cement matrix. This improves the fiber and matrix-dependent properties of GFRC like ultimate strengths.

The following properties are essential in the performance of any GFRC material:

- Tensile and flexural strengths,
- Modulus of elasticity,
- Compressive strength,
- Impact resistance,
- Shear strength,
- Shrinkage and moisture movement,
- Fire endurance,
- Acoustical properties,
- Thermal conductivity,
- Permeability and moisture absorption.
- Water resistant
- Light weight

Structural Properties of GFRC

GFRC derives its strength from a high dosage of AR glass fibres and a high dosage of acrylic polymer. While compressive strength of GFRC can be quite high (due to low water to cement ratios 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 fibres carries the tensile loads and the high polymer content makes the concrete flexible without cracking.

GFRC is analogous to the kind of chopped fibre glass used to form objects like boat hulls and other complex three-dimensional shapes. The manufacturing process is similar, but GFRC is far weaker than fibre glass.

While the structural properties of GFRC itself are superior to unreinforced concrete, properly designed steel reinforcing will significantly increase the strength of objects cast 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.

The table below shows various physical and structural properties of atypical GFRC mix.

Property	Hand or Machine Spray GRC	Vibration Cast Premix GRC
Glassfibre Content by Weight of Mix	5%	3%
Bending:		
Ultimate Strength (Modulus of Rupture – MOR) MPa	20-30	10–14
Elastic Limit (Limit of Proportionality – LOP) MPa	7–11	5-8
Tension:		
Ultimate Strength (Ultimate Tensile Strength – UTS) MPa	8–11	4-7
Elastic Limit (Bend Over Point – BOP) MPa	5–7	4-6
Shear:		
Interlaminar Shear Strength MPa	3-5	N.A.
In-plane Shear Strength MPa	8–11	4-7
Compressive Strength MPa	50-80	40-60
Impact Strength kJ/m²	10-25	10–15
Elastic Modulus GPa	10-20	10-20
Strain to Failure %	0.6–1.2	0.1–0.2
Dry Density Tonne/m³	1.9–2.1	1.8–2.0

Properties of GFRC

Components of GFRC

GFRC is a composite of cement, glass fibres, aggregates and polymers. The main components of GFRC are:

1. **Cement**: - The cement used in the GFRC should be ordinary Portland cement.

2. **Aggregates**: - Usually in GFRC only fine aggregates are only used fine aggregates are of silica sand. If used, coarse aggregates may be of crushed stones.

3. **Glass fibres**: - Glass fibre shall be an alkali resistant, continuous filament fibre developed and to have high strength retention in ordinary Portland cement environments.

4. **Polymers**: - Polymers are used in the GFRC mix to give toughness to the mix and give a curing effect to the mix after hardening due to its high water content. Acrylic polymers having low solid content is used usually.

5. **Admixtures**: - Addition of glass fibres reduces the workability of the concrete mix to a great extend, for making the concrete workable plasticizers can be used in required dosage.

Alkali Resistant Glass Fibres for GFRC

The glass used in GFRC is of alkali resistant and the alkali resistance of AR glass fibres is a result of adding zirconia (zirconium oxide) to the glasses. The best fibres have zirconia contents of 19% or higher. More the amount of zirconia in glass, more will be the alkali resistance. Figure 1 shows the relationship between Zirconia content and the alkali resistance of glass fibres.

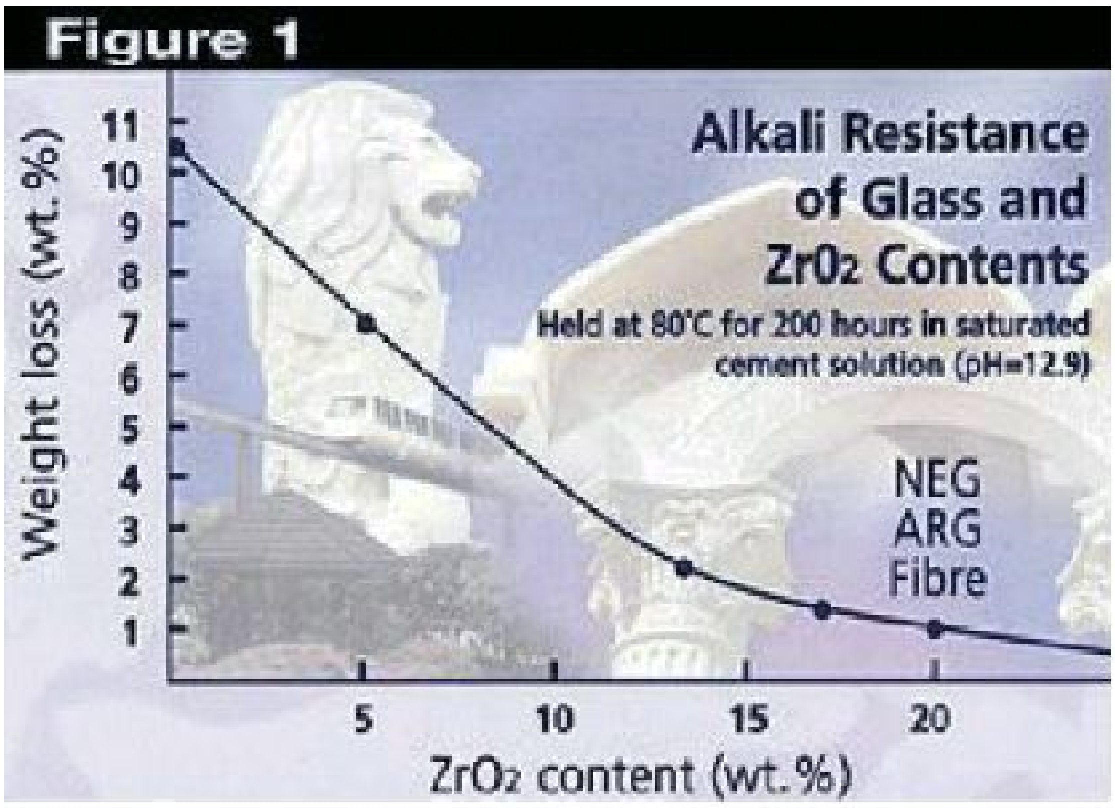
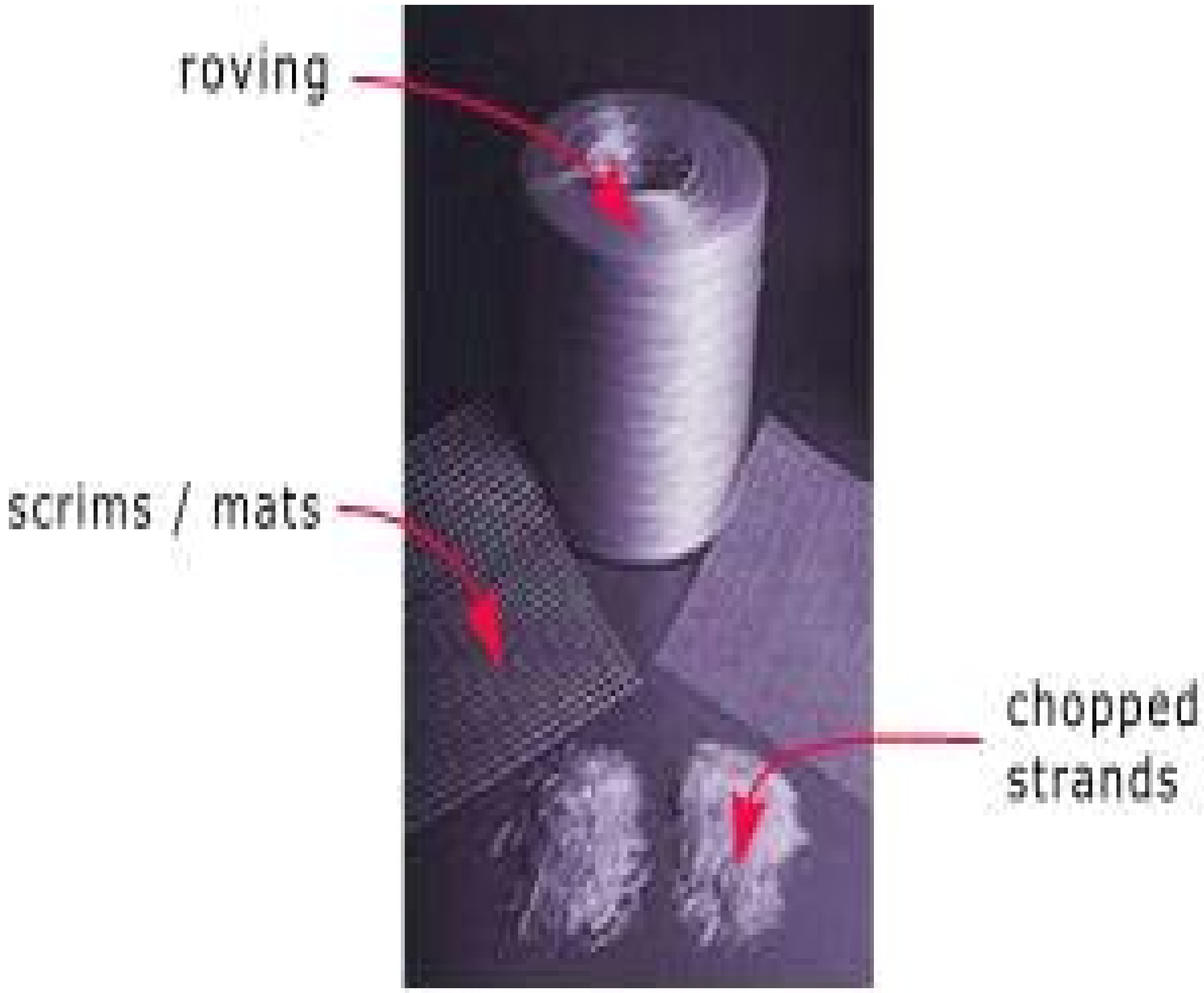


Figure 1: Alkali resistance of Glass and ZrO^2 Content

The fibres used for countertops, fireplace surrounds, and other decorative applications have high integrity (meaning the strands don't break down into individual filaments) and are usually ½-inch (13-mm) long or a combination of 13, 19, and 25 mm. AR-glass fibres are also available as roving, which is a spool of a continuous length of multiple strands of glass fibre twisted together (typically 28 strands in a roving with 200 filaments per strand). Glass fibre is also available as a scrim, which is a fibre fabric. This is placed into areas that might have a tendency to crack.

There are several manufacturers of AR glass fibre, including NEG America, Nycon, Rich Fibres & Systems, and Owens Corning. Owens Corning recently bought Saint-Gobain's Vortex glass fibre business

(Cem-FIL) and has transferred sales and marketing of its concrete-reinforcing fibres (including AR glass fibres) to Continental Marketing's Rich Fibres & Systems.



Different forms of AR glass fibres

How The Fibres Work?

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

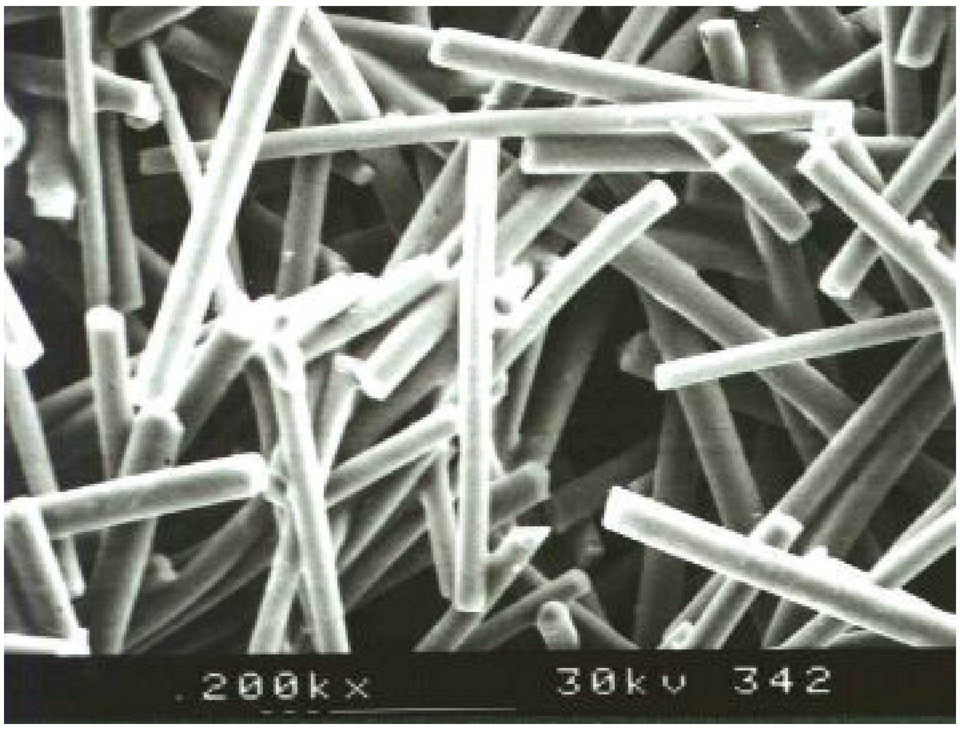
In order to resist tensile loads (and thus prevent the GFRC piece from breaking or cracking), there needs to be a sufficient amount of fibre present. Additionally, the orientation of the fibre determines how effective that fibre resists the load. Finally, the fibre needs to be stiff and strong enough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

Typical GFRC mix uses a high loading of glass fibres to provide sufficient material cross-sectional area to resist the anticipated tensile loads. Often a loading of 5% fibre by weight of cementitious material is used. So for every 100 Kg of cementitious material in the GFRC mix, 5 Kg of glass fibres are added.

Finally, the orientation of the fibres is important. The more random the orientation, the more fibres are needed to resist the load. That's because on average, only a small fraction of randomly oriented fibres are oriented in the right direction.

There are 3 levels of reinforcement that are used in general concrete, including GFRC. The first is random, three-dimensional (3D) reinforcing. This occurs when fibres are mixed into the concrete and the concrete is poured into forms. The fibres are distributed evenly throughout the concrete and point in all different directions. This describes ordinary concrete with fibres. Because of the random and 3D orientation, very few of the fibres actually are able to resist tensile loads that develop in a specific direction. This level of fibre reinforcing is very inefficient, requiring very high loads of fibres.

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



3D Fibres

2D Fibres

This orients them in the plane that the tensile loads develop in. While more efficient than 3D,2D reinforcing is still inefficient because of the highly variable fibre orientation within a horizontal plane. Additionally, most of the fibres 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), this zone is always at the bottom surface of a beam (or at the top in the case of a cantilever).

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. The middle of a countertop slab is such a zone.

GFRC Mix Design

Traditional spray-up GFRC is a low water-cement ratio mix. Most decorative GFRC products, other than artificial rocks, are made with a two-layer process with a very thin (1/8 to 3/16 inch) face coat and a thicker backing layer.
Sand and cement are typically used at a ratio of about 1:1, although some mix designs call for slightly higher cementitious materials content. With its high cement content and low water-cement ratio (0.33 to 0.38), GFRC can dry out quickly and not gain full strength. Traditionally, GFRC panels were cured in a moist-room for 7 days. Today, more commonly, this is overcome by using an Acrylic Polymer additive which serves as a curing compound to prevent the mix water from evaporating. The acrylic is typically in liquid form. Using 5% acrylic solids by weight of cement will result in the same strength you would get from a 7-day wet cure. The acrylic also gives you concrete that gains strength rapidly. GFRC panels and countertops are ready for use within 3 days. Acrylic used in the mix also gives water to the mix so that a typical mix we have to supply the water by taking into account, the water supplied by the polymer also. With a polymer solids content of 46%, 15 Kg of polymer plus 23 Kg of water are added for every 100 Kg of cement.

Fibre content varies, but is generally about 5% to 7% of the cementitious weight. Some mixes go up to 10% by weight of cement. Increased fibre content adds strength but decreases workability. Cem-Fil's Anti-Crack HP 12mm AR glass fibre is commonly used in premix applications.

In addition to the above components usually silica fume, metakaolin, or other Pozzolanas is also used in the mix, this reduces the permeability of the concrete, making it more water-resistant and also reduces the alkalinity of the concrete, which means it doesn't affect the glass fibres, and both of these factors mean increased concrete durability.

Typical GFRC mix

Chopped AR glass fibres	2 to 3% by weight for premixed; 4% to 6% for spray-up
Acrylic polymer emulsion	5% by weight of cement
Sand to cement ratio	1:1
Pozzolanas (silica fume, metakaolin)	10 to 25% cement replacement
Water cement ratio	0.30 to 0.38

Admixtures in GFRC

Now a day in all concrete construction admixtures is inevitable. In the GFRC also admixtures are used to a greater extent. The high dosage of glass fibres in the GFRC makes the mix very stiff and less workable, thus the use of plasticizers and super plasticizers.

i. **Plasticizers**: - For GFRC to flow more easily for a given water-cement ratio it is necessary to reduce the yield point(force needed to start the mix moving) of the mix. Plasticizers do this by absorbing on to the surface of the cement particles, reducing the flocculation, thus aiding the dispersion and reducing the drag, which increases the fluidity.

ii. **Viscosity modifying admixtures**: - Most VMA's are based on high weight polymers with a high affinity for water and built up a sort of three-dimensional structure in the liquid phase. Typically these are used at the rate of 0.1-1.5%. VMA's affect the plastic viscosity of the concrete without affecting the yield point. This helps in holding the constituents together thereby reducing the chance of bleeding and segregation this helps in reducing the friction in pumped mixes.

iii. **Polymers**: - Polymers used are mainly white latex, usually acrylic emulsion with approximately 50% solid content. The recommended dosage is 5-6%(10-12% latex) by weight of cement. The polymer must be resistant to alkali and UV stable. They function by forming a network of flexible polymer bridges between the brittle mineral ingredients, helping them to bind together

iv. **Anti efflorescence and water-repellent admixtures**: - GFRC has high cement content and so produce more lime during setting. This make it prone to efflorescence since lime is the primary cause of efflorescence. Usually Pozzolanas added at a rate of 15-20% cement replacement level will take care of this lime production and almost eliminates efflorescence. But in some cases a little amount is added according to the situation.

GFRC Manufacturing Process

Glass Fibre Reinforced Concrete or GFRC is a popular material used for exterior panels because of its property of being easily shaped. From its breakthrough introduction in the 1940s, GFRC has now become a common material in architectural and construction designs.

Composition of GFRC

GFRC is composed of the following materials: cement, aggregates, glass fibres, polymers and admixtures. Cement used for GFRC is just ordinary Type I or Type II Portland cement. Aggregates used are usually fine aggregates like silica sand. Course aggregates like crushed stones may also be used. Sand and cement ratio used is usually set to 1:1. In some cases, however, higher cement material is used; this usually depends on the purpose of the material.

Composition of glass fibres depends on the type of GFRC; for premixed 2%-3% chopped glass fibres are used while for spray-up 4% -6% chopped glass fibres are used. Polymers are usually about 5% of the cement weight. Polymers are used to make the mix tough and to give the mix a curing effect. Usually polymers with low solid contents are used in making GFRC. Admixtures like superplastirizers or high-range water reducers are used to make the mixture easy-to-shape. For cases where the mixtures need to be tough, no admixtures are used.

GFRC Manufacturing

Three methods may be used for manufacturing GFRC products. These are the traditional hand spray, sprayed mix and vibration casting.

Traditional hand spay method is done by hand spraying the GFRC mix into the mold. This method is still the best way to manufacture GFRC elements and this is how most panels and ornamental precast GFRC are made. In this method, a concentric chopper gun is used. However, since traditional hand spray method requires rigorous hard work, it requires experienced workers and strict quality control.

Sprayed mix method, on the other hand, requires a peristaltic pump with special spray head. Compared to the traditional hand spray method, this requires less expertise from the workers.

Lastly, vibration casting is done by pouring the GFRC mix into the mold and vibrating the GFRC for consolidation. Compared to the traditional hand spray method, vibration casting is a simpler method but it requires moulds which are water-tight.

GFRC - Two-Layer Approach

GFRC products are made using a two-layer process - a very thin face coat and a thick backing layer. The face coat acts as a decorative layer while the backing layer is the thicker layer containing the glass fibres. The face coat is usually sprayed into the mould through a hopper gun; this is usually just 1/8 to 3/16 inch thick. The GFRC backing coat is usually poured using a trowel; is usually just 3/4 to 1 inch. The thickness of these two layers may change depending on the size of the panel and the load that will be placed in them GFRC Casting Method

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

Spray-up

Spray-up is similar to shortcrete, in that the fluid concrete mixture (minus fibres) 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 fibres. The concrete and fibres mix when they hit the form surface. Glass fibre is fed off of a spool in a continuous thread into the gun, where blades cut it just before it is sprayed. Chopped fibre lengths tend to be much longer (about 1.5") than fibres that get mixed in, since long fibres would ball up if they were mixed into the concrete before spraying.

Hand spraying GFRC

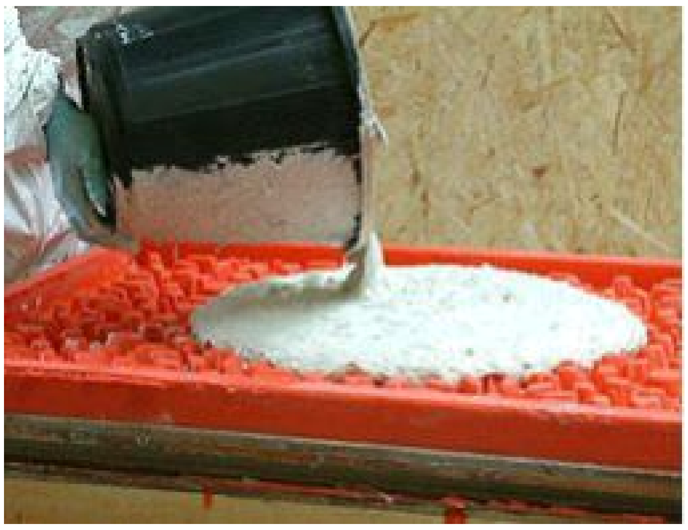
Typically Spray-up is applied in two layers. The first layer is the face coat, much like a gel-coat in fibreglass. This face coat usually has no fibres in it and is thin, often only about 1/8" thick. The second or backer layer has the fibre in it. The action of spraying on the fibres orients them in a thin layer, much like the layers in plywood.

Spray-up permits very high fibre loading using very long fibre length. GFRC made using the spray-up method the greatest strength. However, the equipment required to do spray-up is very expensive, often costing more than $20,000 (About Rs.1Lakh).

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

Premix

Premix, on the other hand, involves mixing shorter fibres 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 fibre 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 fibres and more random fibre orientation.



Premix GFRC pouring into moulds

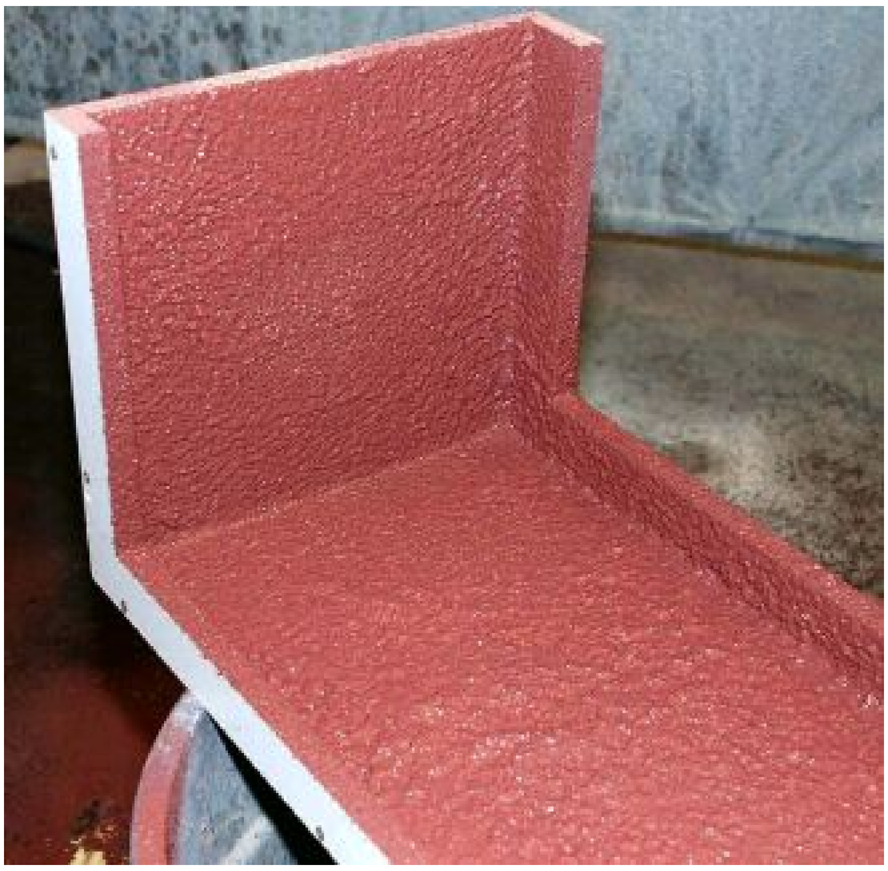
Hybrid

An alternative hybrid method uses an inexpensive hopper gun to spray the face coat. The fibre 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 can cost as little as $400-$500.

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

Spraying the face coat



Face coat ready for backer mix

Hand packing backer on upright

Advantages of GFRC

- Made of minerals and will not burn. In addition, the nature of concrete acts likes a thermal regulator when exposed to flame. GFRC not only will not burn, but it also protects the materials behind it from the heat of the flame.
- Relatively light in weight compared to traditional stone or terra cotta ornaments. Its installation is quick and relatively easy.
- Can be cast to virtually any shape. We supply wall panels, columns, bas relief, domes, column capitals, fireplace surrounds, mouldings, medallions and all types of custom GFRC shapes.
- Available either with a cast in integral colour and texture: limestone, precast, acid wash, etc. or as paint grade that is easily finished with virtually any paint

Lightweight

Stromberg GFRC, thin yet strong, weighs 80% to 95% less than solid concrete. This makes it easier and faster to install and reduces the load on the buildings structure. The lighter weight and stronger material also saves transport costs, allows more design freedom and, by using less material, reduces environmental impact.

Superior Strength

GFRC is strong. For GFRC panels, this means it has the proven ability to withstand seismic loads and hurricane winds. For architectural elements, stronger means less chance for damage, easier to install and longer lasting.

Durable

GFRC lasts. It is less susceptible to weather erosion and more freeze thaw resistant than conventional concrete. The use of glass fibres for reinforcement rather than steel means it cannot rust and can even be used under salt water and in marine environments.

Beautiful
GFRC provides the look and feel of natural stone, architectural precast concrete, terra cotta, wood or smooth panels. It allows the designer more freedom in shape, colour and texture than any material.

Naturally Friendly to the Environment
GFRC has a much lower environmental impact than conventional concrete, stone or other materials. Made with minerals: cement, aggregates, glass fibres and, in some cases mineral pigments and special polymers, GFRC is designed to be long lasting and earth friendly.

Disaster Resistant
Hurricanes, floods, fires and earthquakes are no match for GFRC. Over the years it has proven itself both in the lab and in the real world.

High strength
GFRC can have flexural strength as high as 4000 psi and it has a very high strength-to-weight ratio.

Reinforcement
Since GFRC is reinforced internally, there is no need for other kinds of reinforcement, which can be difficult to place into complex shapes.

Consolidation
For sprayed GFRC, no vibration is needed. For poured, GFRC, vibration or rollers are easy to use to achieve consolidation.

Toughness
GFRC doesn't crack easily-it can be cut without chipping.

Surface finish
Because it is sprayed on, the surface has no bug holes or voids.

Adaptability
Sprayed or poured into a mould, GFRC can adapt to nearly any complex shape, from rocks to fine ornamental details

Sustainable
Because it uses less cement than equivalent concrete and also often uses significant quantities of recycled materials (as a Pozzolanas), GFRC qualifies as sustainable

Cost
GFRC as a material, however, is much more expensive than conventional concrete on a m^2basis. But since the cross sections can be so much thinner, that cost is overcome in most decorative elements.

Fire resistant
GFRC structures are not only resistant to fire but also it insulates the heat from surroundings entering through it. It is an excellent heat insulator.

Disadvantages of GFRC

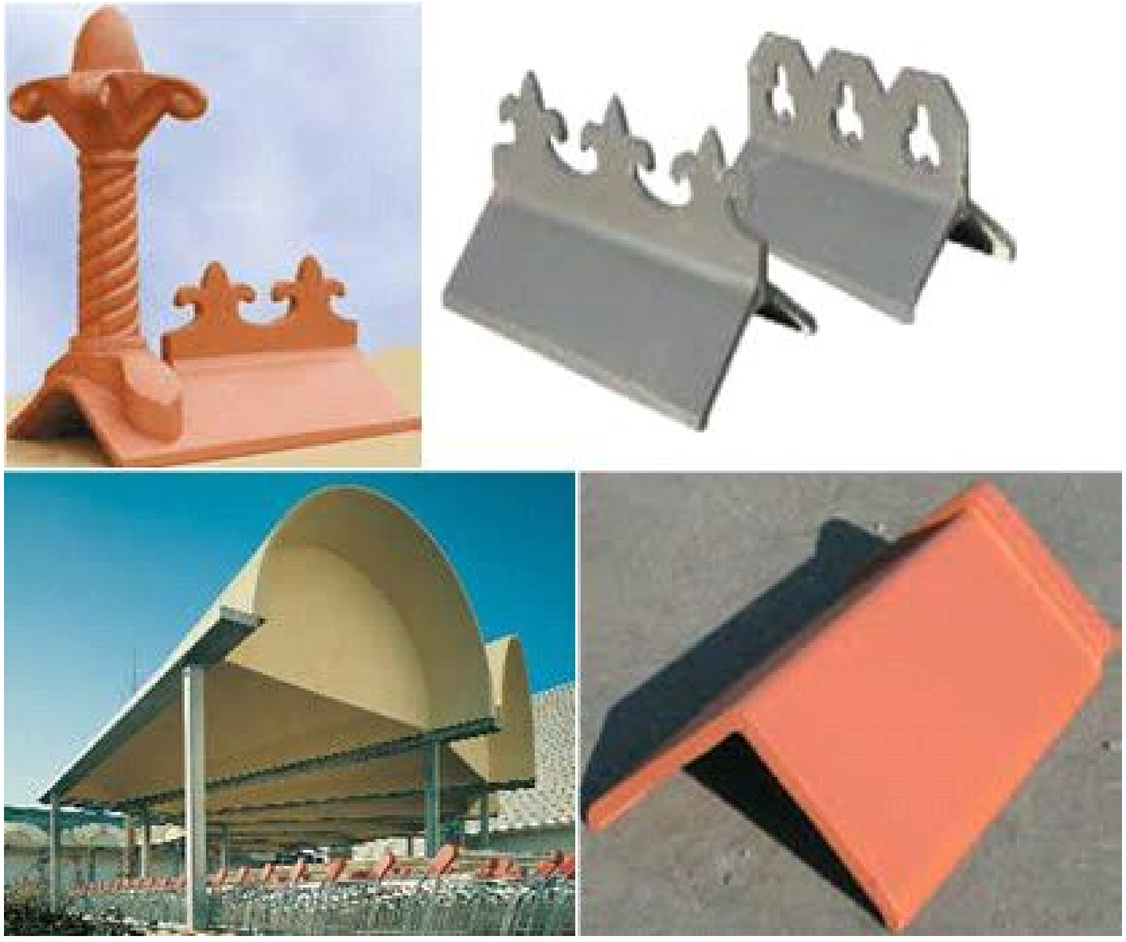
- Used as Non-load bearing only
- Requires separate anchorage system for installation
- Large panels must be reinforced
- Color additives may fade with sunlight
- May have different absorption rate than adjacent historic material

Applications of GFRC

Since its introduction in 1970 GFRC has gained much popularity among civil engineers, particularly among architects due to its flexibility of casting it in any desired shape. GFRC presents architects and engineers with a material from which the most ambitious designs can be created. It can be moulded to form modern futuristic designs or to replicate traditional historic features. GFRC can be painted, faced with fine aggregates, coloured or simply left with a natural white or grey, smooth or textured finish. GFRC provides the designer with a complete technology that few other materials can match for versatility. They are as follows

1. **GFRC claddings: -**
   GFRC is one of the most popular materials used for creative prefabricated architectural cladding. GFRC's ability to be moulded into thin, lightweight panels with a wide variety of shapes, forms and surface finishes make the materials suitable for making beautiful claddings for the buildings. GFRC cladding panels are generally manufactured by the 'Hand Spray' technique.
2. **GFRC Landscaping:-**
   Landscaping features such as Seating, planters, receptacles, kiosks, bollards, signs, statues and fountains are being made in GFRC with its ability to tailor shape, form and surface finish and to be aesthetically compatible with the chosen environment. GFRC is used to create rock spaces, replica buildings, simulated environments for animals, and much more
3. **GFRC Roofing**:-
   GFRC is an ideal material to use on a variety of roofing structures. It is lightweight but tough, easy to fix and unaffected by environmental conditions. It can imitate traditional roofing materials such as slate, natural stone or clay products but unlike these materials it is neither heavy nor brittle. GFRC can be moulded into complex shapes for roofing accessories such as

finials, ridges and chimneys. It is non-combustible with a high impact strength and can be used on all types of roof.



GFRC Roofing's

4. **GFRC Renovation**:-

GFRC is an ideal material for use in renovation. Thin lightweight panels are easy to fix and minimise the weight imposed on the existing structure. In many cases the opportunity is taken not only to improve the aesthetics of the building but also to improve the thermal and acoustic properties. GFRC's ability to be moulded and finished with natural materials means that traditional architectural forms can be maintained when required.

5. **GFRC Flooring**:-

GFRC can provide practical solutions in the construction of foundations and floors. As permanent formwork under suspended, in-situ concrete floors it can give economic benefits together with excellent appearance. In balcony slab construction, GFRC can provide a pre-finished moulded edge while simplifying construction. On ground floor concrete slabs, insulated GFRC edge formwork can help in minimising heat loss from the building in cold climates. Similarly, in wall construction insulated GFRC base course and sill units can be incorporated, which contribute to the overall wall insulation performance. On the construction site, forms of glass fibre-modified concrete can be used in floor screeding, both in relatively thick concrete screeds and in thin self-levelling overlays.

GFRC Flooring

6. **GFRC Modular buildings:-**

The qualities of GFRC are shown to great advantage in the area of modular building. GFRC panels are light and easily transported but also resistant to damage. Small units such as modular bathrooms or telecommunications equipment housings can be shipped in one piece and rapidly lifted into position. The strength of GFRC is sufficient so that, even in thin skin construction, small modular buildings can be designed without heavy structural frames. GFRC walls can incorporate thermal insulation if required, while the absence of steel reinforcement can be a benefit in electrical or telecommunications applications.

7. **GFRC Permanent formwork**:-

GFRC has been using for making permanent formwork for concrete construction for years. The most popular application is in bridge construction. Small (1-2 m span) GFRC panels are fitted between precast concrete beams before steel reinforcement and concrete are placed. GFRC permanent formwork panels are not only fast to install, they also provide extra corrosion protection to the steel reinforcement. GFRC carbonates very slowly and has low permeability providing a barrier to the ingress of de-icing salts. GFRC permanent formwork has also proved to be an efficient solution to the world's ageing sewers. In the UK, France, Holland and elsewhere thousands of kilometres of brick-built sewers have been lined with GFRC permanent formwork and grouted in place. Not only does this safeguard the structural integrity of the sewer but also the smooth surface of the GFRC enhances the hydraulic performance.

GFRC Permanent Form Work

8. **GFRC for earthquake resistant structures**:-

In areas that receive earthquakes, GFRC can be effectively used in the construction to reduce the effect of earthquake. There are three main reasons why architectural concrete is particularly well suited for seismic design applications. First, Glass Fibre Reinforced Concrete is lighter than many other commonly used construction materials, including brick, stone, cast stone, terra cotta, and traditional precast concrete. Lighter weight means a reduced seismic load on the structure and simplified connection details. Second, GFRC is reinforced throughout. Because the glass fibre is integral to the product, there are no unreinforced areas in a GFRC panel or GFRC element. Since the reinforcing is continuous, there are no fragile, unreinforced sections in GFRC. Lastly, fibre reinforced concrete is capable of flexing without breaking, making it ideally suited for use in seismic zones. Unlike rigid masonry or precast concrete, Glass Fibre Reinforced Concrete can withstand a considerable amount of bending forces and shaking and still remain intact.

Fibre reinforced concrete is increasingly used on account of the advantages of increased static and dynamic tensile strength, energy absorbing characteristic and better fatigue strength. The uniform dispersion provide throughout the concrete provides isotropic properties not common to the conventionally reinforced concrete. Fibre reinforced concrete has been tried on

1.Overlays of air-field
2.Road pavements
3.Industrial floorings
4.Bridge decks
5.Canal lining
6.Explosive refractory lining etc.

Design Freedom with GFRC

Name your colour.

"It can be matched"

Colour is one of the most basic elements of architectural design. GFRC colour options include:

- Cast-in colours
- Stains:
- Glazes
- Paint

Name your texture

"*It can be prepared"*

- Smooth
- Sandblasted
- Honed
- Exposed Aggregate
- Coral Stone
- Wood Grain
- Brick
- Terra Cotta
- Carved details

Name your shape

"Your design, any shape and it can be a reality".

- Flats, squares and rectangles, but we also produce sweeping curves, dramatic angles, spheres, domes, waves, intricate detail and complex geometries

Featured Product

Conclusion

GFRC as an engineered material has excellent properties that can be conveniently used for many construction works and it is a suitable material for architects to give life to their imaginations as structures by properly using this flexible material.

A properly designed, manufactured and installed GFRC system will provide an innovative and aesthetically pleasing appearance, while often reducing overall cost, onsite labour requirements and shortening construction schedules.

Glass fibre reinforced concrete (GFRC) offers an endless variety of decorative and ornamental shapes and forms at affordable prices.

Bibliography

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2. **Scribd.com**