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Guidebook to GFRC

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INTRODUCTION TO GFRC

(Glass Fiber Reinforced Concrete, GFRC, GRC, FRC)

This is an introduction into the world of Glass Fiber Reinforced Concrete (GFRC), also referred to as Fiberglass Reinforced Concrete (FRC) and Glass Reinforced Concrete (GRC). Since its introduction, GFRC has become extremely popular among the Architect and Design industry. Along with this popularity came some concerns about the quality of the material, and how best to use GFRC. To eliminate these concerns, Stromberg compiled this information to better educate those interested in GFRC.

HISTORY OF THE PRODUCT

A new concept of material was brought from England to the United States in 1976; a product now known as Glass Fiber Reinforced Concrete. GFRC is composed of concrete, reinforced with glass fibers to produce a thin, lightweight, yet strong material. Stromberg, with its history of expertise in concrete and composites casting, was one of the first GFRC producers in the USA and continues to lead the industry. Stromberg developed many of the techniques and technology used in GFRC.

By late 1978, GFRC jobs were being sold and installed on construction projects in North America.

The material offered several benefits to architects and designers:

- GFRC has superior fire retardant properties.
- GFRC offers a variety of shapes (similar to what terra cotta, carved stone or precast concrete offer, but at a much reduced weight).
- GFRC is lightweight.
- GFRC can replicate Terra Cotta, granite, limestone, cast stone or other hard to use materials.

Glass fiber reinforced concrete (GFRC) also called GRC or FRC is a cementitious, composite material, cast in thin shell shapes for use in construction. Consisting of Portland cement, aggregate, water, alkali-resistant glass fibers, polymer and additives, the GFRC mix design is custom engineered depending on the requirements of the GFRC project and the GFRC part.

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COMPOSITION

Composition - GFRC is composed of:

- »Concrete- Portland cement
- »Aggregates – Selected crushed stone or silica sand
- »Glass Fibers- to provide tensile and flexural strength
- »Polymers- to improve toughness

GFRC can be used wherever a light, strong, weather resistant, attractive and fire retardant material is required.

GFRC can be used as wall panels, window surrounds, spandrels, column covers, soffits, cornices, brackets, quoins, railings, pilasters, copings, domes, etc. Landscape and hardscape uses include site furnishings, planters, bollards, urns, tables and fountains.

GFRC is used in historical restorations and renovations, for the replication of building ornaments of terra-cotta, carved stone and even wood

Stromberg has pioneered its use in other areas, including GFRC sandwich panels, bus shelters, security barriers, noise barriers, marine structures, cable ducts, floating pontoons, sun screens and storage tanks.

Relatively easy to form and lightweight, GFRC allows the designer the freedom to design with less restrictions and weight than most other materials.

Installation is easier, and there is less of a load imposed on the structure. GFRC will normally weigh between 5 to 25 pounds per square foot.

Glass fibers used in Stromberg GFRC have the following properties:

- »A high tensile strength (1700 N/mm^2), 3-4 times higher tensile strength than steel
- »High modulus (in other words not stretchy, 10 times that of polypropylene. Low modulus fibers on the other hand, stretch and allow concrete to crack).
- »Will never rust and so does not require a minimum cover
- »Inorganic with no health risk
- »Non combustible, so it will not burn

ADVANTAGES

GFRC (Glass Fiber Reinforced Concrete)

GFRC is made of minerals and will not burn. In addition, the nature of Concrete acts like 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.

Installation- GFRC is relatively light in weight compared to traditional stone or terra cotta ornaments. Its installation is quick and relatively easy.

GFRC can be cast to virtually any shape. We supply GFRC wall panels, GFRC columns, GFRC Bas Relief, GFRC domes, GFRC capitals, GFRC fireplace surrounds, GFRC moldings, GFRC medallions and all types of custom GFRC shapes.

Finish- GFRC is available either with a cast in integral color and texture: limestone, precast, acid wash, etc. or as paint grade that is easily finished with virtually any paint.

The strength of GFRC is determined by glass content, fiber size, fiber compaction, distribution and orientation as well as degree of cure.

Careful consideration must be given to the long term properties of GFRC. Extensive research has shown that some GFRC composites will lose strength and ductility over time. Testing, and real life examples, show that the aged flexural ultimate strength (AFU) of GFRC is at least equal to the early flexural yield strength (EFY), under normal environmental conditions.

Other stresses GFRC to be considered by the designer are: moisture and thermal induced stresses, tensile, in-plane shear and interlaminar shear,.

Tensile stresses should not exceed 40 percent of the flexural strength of the GFRC. On unusual shapes, shear stresses should be checked.

Moisture and thermal induced stresses can be minimized by allowing the glass fiber reinforced concrete composite the ability to shrink or expand without restraint.

1.05.C. Tolerances

Joint size and tolerance should take into account the volume changes to the GFRC and other materials caused by expansion and contraction, as well as initial drying shrinkage. Manufacturing and installation variables require a reasonable tolerance for GFRC.

In the shop drawing phase, GFRC (glass fiber reinforced concrete) piece length, depth, width, thickness, squareness, bowing, warpage and locations of openings or block outs is addressed.

PRODUCT TESTING CRITERIA

Most GFRC manufacturers have run tests which determine specific values for properties of glass reinforced Concrete. The following are recommended tests to determine physical properties of GFRC composites:

Physical Property Recommended Test Method

Surface Burning ASTM E 84-87

Characteristics

Impact Resistance ASTM D256-87

Flexural Strength ASTM C947

Compressive Strength ASTM C109-87

Hardness ASTM D2583-87 (Barcol) or ASTM D785 (Rockwell)

Thermal Expansion ASTM D696

Humidified Deflection ASTM C473

Manufacturer's test samples should be representative of actual production procedures and materials. Tests conducted by raw material suppliers or others should detail the procedures and processes used in the preparation of the test samples. The GFRC manufacturer should certify that the material is produced as tested. Test results can vary from GFRC manufacturer to manufacturer, and it is important to evaluate and compare the test results in relation to individual job requirements.

FABRICATION

GFRC is primarily composed of four raw materials: high density Concrete, glass fiber reinforcement, aggregate and polymer.

GFRC products are custom made thin shell shapes and forms manufactured in a plant by either one of two methods, both of which center around how the glass fiber reinforcement is introduced into the product. One method, known as the hand lay-up method, simply means that once the molds have been made and are ready, various layers of continuous glass fiber mat and Concrete are manually placed during the "lay-up" process. Another method, the "chopped-strand-spray" method, introduces glass fiber strands into the concrete mix as it is being sprayed into the mold. Both methods will produce high quality products.

GFRC products are made in molds which are customized for a particular job or from the manufacturer's standard line of molds. Molds should be manufactured in a manner so as not to adversely affect the finished product with respect to shape and finish. The molds should be fabricated to exact dimension and shape specified by approved shop drawings.

After the GFRC has set, the glass fiber reinforced concrete product is carefully removed from the mold, finished, cured and stored until adequately cured for shipment.

TOLERANCES

Fabrication tolerances for glass fiber reinforced concrete may vary depending on shape,

particular uses, desired finishes, and lighting. Generally speaking the glass fiber reinforced concrete product should be fabricated to a tolerance suitable to each particular GFRC component.

All glass fiber reinforced concrete manufacturers' tolerances should be expressed in fractions of an inch or metric equivalent. Measurement of any length or any dimension given on the GFRC shop drawings should be:

Straightness - at any point on a line generally along a plain, an edge, or a surface, the material should not vary from straight + __or - __.

Overall Length +___ or - ___.

Dimensions within the overall length + __ or - __.

Dimensions width + __ or - __.

Dimensions within the overall width + __ or - __.

Dimensions of chords, radius, diameters + __ or - __.

Measurement of dimensions not given or drawings such as square + __ or - __.

Tolerances should be shown on glass fiber reinforced concrete shop drawings. Next to any dimension where tolerance is critical, it should be marked with a "T".

DESIGN CRITERIA

An understanding of basic molding and casting constraints of glass fiber reinforced concrete as well as standard tolerances for GFRC will provide a better understanding for the architect and engineer of how GFRC design shapes and forms are to be manufactured. Here are some design considerations that may affect the cost of GFRC used in your project:

The amount of detail. GFRC can reproduce intricate details or smooth sweeping curves. Details and undercuts require rubber mold liners. Simple smooth flats and curves can be cast in rigid molds of fiberglass. While rubber molds are slightly more expensive, the cost may be minimal if the casting is repeated several times.

Number of repetitive pieces of glass fiber reinforced concrete. Numerous casts of a GFRC shape are more economical per piece, than one-time-only casts.

Size. GFRC can be cast in pieces up to 28′ in length. However, the longer the length, the more difficult it is to handle and ship the GFRC casting. We recommend a maximum length of 12′ for most moldings. If longer lengths are required, pieces can be field joined. Contact us for GFRC jointing details.

Surface Finish. GFRC can be cast with a limestone or precast finish, such as sandblasting, acid etching or retarding or the GFRC can be painted. The lowest priced finish is usually a plain smooth GFRC.

Special Reinforcements. Some specific design considerations are corners, draft angles, reveals, and finishes. All GFRC corners should have a radius of between 1/16″ and 1/8″ unless otherwise noted.

Draft Angles and Reveals Draft angles are designed bevels which allow the mold to release the GFRC parts and/or pieces. Reveals incorporated in a design should have draft angles present.

SHIPPING

There are two common means of shipping and transporting the finished GFRC products. The first is to crate every piece of GFRC in a "wooden box or form" and ship the entire glass fiber reinforced concrete "package" to the jobsite. The second way eliminates "crating" and utilizes air-ride suspension trailers and trucks. Regardless of how it is shipped care and caution is used to ensure the product arrives at the jobsite in good condition. In overseas shipments, the GFRC is wrapped, crated and shipped by container.

CHECKING MEASUREMENTS

Listed below are four categories for field checking measurements of GFRC. First are the tools required for taking the measurements and then the actual method of checking.

For Straightness:

Tools Required: Using a string line and ¼″ shims or equivalent; an absolutely flat surface is also acceptable.

Method: To check for straightness, place string line and shims over the glass fiber reinforced concrete (GFRC) surface to be checked. Use a ¼″ shim at 1 foot intervals to determine any variation from straight that occurs. Measure this variation if it appears to be greater than tolerance with a folding rule having at least 1/16″ marks on it.

For Chords and Lengths:

Tools Required: Use standard tape measure.

Method: To check for chords and lengths, use a standard tape measure. Use a block to determine the edge or corner. "Tapered" edges on glass fiber reinforced concrete (GFRC) must be considered when establishing the measurement. Shop drawings should indicate whether they have been calculated or not. If "tapered" edges are not included in calculations, then a point or edge must be created by a block or other means

to measure to and from.

For Curvatures:

Tools Required: Use a plastic or hardboard template. Template should be cut ¼" larger than dimensions if it is outside radius or ¼" smaller than dimensions for an inside radius.

Method: To measure glass fiber reinforced concrete from a template, cut a piece of cardboard (or hardboard if many measurements are to be made) ¼" larger or smaller than the desired shape and use a ¼" x ¼" shim to check the dimension of the shape. Do not measure or check in "tapered" edge portion of the material. If deviation from the shape dimensions exist, then measure with a folding rule with 1/16" marks on it.

For Squareness:

Tools Required: Use a tape measure or a layout on a flat surface.

Method: To measure for a square, a corner to corner measure should be taken if possible. If corner to corner is not appropriate, lay out on a flat surface, the shape of the part and use squares to determine the measurements.

JOBSITE INSTALLATION

Receiving and Storage of Materials

Once the glass fiber reinforced concrete product has been fabricated and shipped properly to the jobsite, the installer must, upon receipt, inspect and store the glass fiber reinforced concrete product correctly to avoid warping, twisting, or bowing. All GFRC pieces, crates, or cartons should be carefully examined for visible damage at time of receiving. Any visible defects to the GFRC must be noted on the bill of lading at the delivery site and Stromberg should be notified. Upon receipt of the product , the GFRC must be placed on a level surface in an upright position. Individual glass fiber reinforced concrete parts and pieces should never be stacked on top of one another. GFRC products should be stored and installed under favorable jobsite conditions.

INSTALLATION PROCEDURES

Using shop drawings and Stromberg recommendations, GFRC components should be installed plumb and level to required planes as designed and indicated.

If attachments to a framing system are required, it should be by stainless steel or corrosion resistant screws, adhesive, or hanging in accordance with manufacturer's recommendations. All FRC assemblies should have no deflection greater than L/240.

Large GFRC (glass fiber reinforced concrete) units are usually connected to the structure by

means of cast in metal frames constructed of metal studs or metal tubing. Metal studs are generally galvanized per ASTM A525 and conform to ASTM A446 . Tubes are ASTM A500 Grade B. These frames are connected to the GFRC skin by flex anchors. Smaller GFRC units may have cast in straps, wires, or inserts as needed. These are typically detailed in the glass fiber reinforced concrete shop drawing process.

Large GFRC units are erected with similar hoisting equipment to that used to erect precast concrete, except it can be smaller in capacity. Many smaller pieces of GFRC are typically installed by hand. Care should be taken when using straps, to not overly stress the GFRC units during installation.

Usually, GFRC units that have steel framing can be picked directly from the steel back up frame. In some cases jigs for lifting the GFRC may be needed.

AUXILIARY MATERIALS

In addition to the basic materials in all Glass Fiber Reinforced Concrete products, materials necessary for proper installation vary depending on the project. The list of materials range from stainless steel screws to stainless hanger wire and depends greatly on the particular application. The most common materials used in joining and supporting GFRC are as follows:

Steel studs, track and angles, for alignment and attachment of GFRC

Bolts and various screws as necessary for attachment of framing members and GFRC component attachment.

Adhesives as required for bonding GFRC panels together and to the substrate.

Blocks and shims as necessary for attachment or alignment of GFRC products.

JOINTS

1.05.D. Joints

Joints in GFRC (glass fiber reinforced concrete) serve an aesthetic and functional purpose.

Typically, GFRC joints are sealed with an elastomeric sealant such as silicone, urethanes or polysulfides. Sealants should be able to withstand dimensional changes, both within the product, and due to building movement.

Good joint design should direct water away from the joints, protect the sealant from direct exposure to sunlight and, if economically feasible, provide a secondary line of defense and a drainage method.

Preparation of joints, including primers, backer rods and application of sealant should follow

manufacturers recommendations.

For smaller ornamental GFRC shapes, a 3/8″ to 1/2″ joint width is typical. Larger surfaces, such as wall panels should be designed to have minimum 3/4″ wide joints.

For seismic reasons, some GFRC corner conditions can require larger joints.

Weathering

GFRC is tested for freeze-thaw resistance under ASTM C666.

In this extremely severe test, samples are subjected to accelerated aging. Next, the GFRC endures up to 300 freezing-thawing cycles and finally is tested for flexural strength. Stromberg High performance GFRC shows either no damage or only minor flaking on the back side, after 300 cycles, much better than most cementitious materials. GFRC performs as well or better than most cementitious materials. To reduce the stress on the GFRC from freeze thaw, horizontal surfaces should be sloped to shed water.

GFRC's thermal conductivity ranges from 3.5 to 7.0 BTU/in./hr./ft.2/deg.F. depending on the composite density and moisture content.

Permeability of GFRC depends on the mix design and compaction, and is equal to or better than most cementitious materials.

Erection Tolerances

It should be the contractor's responsibility to ensure that all components of the FRC (glass fiber reinforced concrete) system are installed reasonably level, plumb, straight, or curved as designed and specified. All lines, planes and joints should be uniform and comply with following the tolerances:

Plane alignment (panel to panel) 1/16″ Variation from plumb + or - 1/8″ per 10 ft. Variation from straightness + or - ¼″ per 15 ft

CLEANING AND REPAIRS

It is always better to avoid getting dirt or staining materials on the GFRC to begin with. A little care is keeping the GFRC material clean before and during installation will be worthwhile. Stains from handling GFRC can generally be removed with common household cleaners such as dishwashing detergent and water.

Repairs of chips, damaged edges or minor blemishes to GFRC are allowed. See instructions for patching GFRC (glass fiber reinforced concrete). Properly made GFRC repairs will last the life of the GFRC material.

QUALITY ASSURANCE

The success of any GFRC system depends on a

coordinated effort by the designer, manufacturer and installer. Sequence, deliveries and manufacturing tolerances are critical to the success of the project and should be mutually agreed upon by all parties. Submittals and shop drawings should be utilized extensively to familiarize the designer and installer with the method of attachment, reinforcement and fabrication. This process alerts the designer to any possible conflicts. The GFRC shop drawings should be complete in every detail to allow the installing contractor a complete inventory of parts and pieces, as well as expected tolerances.

CONCLUSION

A properly designed, manufactured and installed GFRC system will provide an innovative and aesthetically pleasing appearance, while often reducing overall cost, onsite labor requirements and shortening construction schedules. Glass fiber reinforced concrete (GFRC) offers an endless variety of decorative and ornamental shapes and forms at affordable prices.

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Glossary of GFRC terms

Admixture A material added to a GFRC mortar or to a GFRC cement slurry to modify its properties.

Alkali resistant glass fiber (AR) A glass fiber that is formulated to improve its resistance to attack by the aqueous alkaline solutions found in concrete. The most common alkali resistant glass fiber used in glass fiber reinforced concrete is a high zirconia glass (> 16% zirconia) .

Accelerated aging A controlled environment in which test specimens are exposed to exaggerated conditions in order to simulate exposure to natural weathering, and to accelerate any aging effects. In this way GFRC (glass fiber reinforced concrete) can be tested for its durability in harsh environments.

Backup mix The GFRC (glass fiber reinforced concrete) mixture that is cast into the mold behind the face mix.

Bondbreaker The material used to prevent the fresh GFRC mixture from bonding to another material.

Bonding agent Material used to increase adhesion between an existing piece of GFRC (glass fiber reinforced concrete) and another application of GFRC, like a patch.

Chopped glass Glass fiber strands, that are chopped into sections and mixed with the concrete slurry during the spray a process of GFRC (glass fiber reinforced concrete)

Cladding A GFRC (glass fiber reinforced concrete) exterior wall panel material.

Course aggregate Aggregate that is retained (too big to pass through) in the US standard number four sieve (4.75 mm).

Compaction In GFRC (glass fiber reinforced concrete) compaction refers to the process compressing the GFRC mix as much as practical through vibration, rolling or other means.

Curing Process in GFRC,glass fiber reinforced concrete, (similar to the process in traditional concrete), of the cement mixture gaining strength over time through the maintenance of proper moisture in temperature.

Draft The process of adding a slight slope to the mold surfaces, so that the GFRC, glass fiber reinforced concrete, element can be removed from the mold.

Efflorescence A powdery white deposit of salts, it may form on the surface of the GFRC, glass fiber reinforced concrete, or most other masonry materials. Naturally occurring salts in the aggregate or cement may dissolve in water and can be carried to the surface of the GFRC, where they are deposited when the water evaporates.

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Efflorescence typically appears on new masonry, and usually goes away on its on after a few months.

Erection drawings Set drawings that describes the location of the GFRC elements, and assembly details of the GFRC, glass fiber and first concrete, elements.

Face mix The mortar or concrete exposed face of the GFRC (glass fiber reinforced concrete).

Fiber content The ratio or percentage of glass fiber to the total GFRC compost. Fiber content may be expressed by either weight or volume. As a general rule, the higher the percentage of glass fiber in the GFRC (glass fiber reinforced concrete) the stronger the GFRC

Flex anchor A rod or bar of metal, typically stainless steel, which connects the GFRC skin of a panel to the metal panel frame.
Fine aggregate. The fine sand or crushed stone used in a GFRC, glass fiber reinforced concrete, mix. Aggregate that passes through the number four (4.75) sieve and is mostly retained on the number 200 sieve.

Form release agent The material used to prevent GFRC from sticking to the molds.

GFRC Glass fiber reinforced concrete. Composites mixture of glass fibers, Portland cement, fine aggregate, polymers and water.

GRC Glass reinforced concrete is synonymous with glass fiber reinforced concrete.

Matrix The cement and water paste the fill voids between aggregates and between glass fibers, in a GFRC composite.

Rib A stiffening member cast into the back the GFRC panel.

Shop drawings Shop drawings for glass fiber reinforced concrete include erection drawings and production drawings.

Skin The exterior shell of a glass fiber reinforced concrete product.

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