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# SECTION 08 11103 Facade

# GLASS FIBER REINFORCED CONCRETE CLADDING

## PART 1. GFRC PERFORMANCE REQUIREMENTS

This section describes minimum acceptable requirements for the GFRC cladding system.

### 1.1 General

1.1.1 Edges to incorporate rebates / surfaces to receive baffles and sealants

1.1.2 Joints to accommodate all movements

1.1.3 Calculate joint width/ design and sealant type/ (movement accommodation factor) so that full range of movement can occur without sealant failure

1.1.4 Openings and handed panels as indicated on drawings

1.1.5 Maximum panel size / weight to allow handling on site

1.1.6 Dowelled panels where required

### 1.2 StructuralThe design of GFRC panels and structural components shall be based upon a 50 years design life.

1.2.1 Structural Adequacy

1.2.1.1 Any facade system is to be structurally adequate to resist the loads that it will experience over its structural design life and have adequate structural stability and robustness to avoid progressive collapse.

1.2.2 GFRC Strengths

1.2.2.1 The ultimate strength of a GFRC composite is determined by the presence of glass fibers and consequently, it is dependent upon glass content, size, distribution and orientation of the fibers, degree of the cure and compaction of the fibers within the cement/ sand slurry.

1.2.2.2 Test data to determine the average of 28-days flexural yield strength and the average 28-day flexural ultimate strength of at least 20 consecutive tests (6 specimens each spray-up) performed by the GFRC manufacturer prior to design also being subject to accelerated age testing.

1.2.3 Dead loads

1.2.3.1 All systems are to support and transfer their own self-weight and other associated dead loads to the main building structure. GFRC Contractor will be required to identify, design, coordinate and supply all necessary sub-frames and secondary structure.

1.2.4 Impact Loading

 1.2.4.1 Panels to sustain impact load of following criteria:

a. Soft body impact of 50 kG - dropped at 3 M distance

b. Hard body impact of 25 kG - dropped at 1 m distance

1.2.5 Thermal Effects

1.2.5.1 The GFRC system shall accommodate all expected thermal effects in service including weather cycle, humidity and expansions/contractions during the service.

### 1.3 Durability

a. Facing mixes may be used provided they are integral to the panel and do not increase the water absorption or carbonation resistance.

b. Do not use carbon steel in locations subject to wetting or condensation or where this will result in corrosion; shortening their design life or compromising safety, however long-term; or, causing rust, staining; or, establishing a bimetallic cell with other metals or carbon.

c. Identify materials and components which under normal service conditions cannot meet the specified design life and design to allow their monitoring and replacement

d. Have sufficient durability to prevent the relevant limit states from being reached without the need for excessive maintenance, during the intended life of the structure

e. Resist the growth of algae on the surface of the cladding.

1.3.1 Surface Finishes

 1.3.1.1 The installation is to perform satisfactorily for the following periods:

a. 25 years with regular cleaning

b. 10 years no fading and colour changing

1.3.2 Fungi Resistance

1.3.2.1 The GFRC system shall not develop any flora and fauna/algae during humidity and wet weather cycle, through-out its life cycle. The Contractor has to adopt appropriate protection methods and applicants to retard the development of algae.

## PART 2. MATERIALS REQUIREMENT

Following are minimum requirements of materials used for the GFRC cladding panels manufacturing and erecting.

**2.1 AR Glass Fibre**

AR Glass Fibre shall be Cem-FIL or NEG (Nippon Electric Glass) alkali resistant having been specifically developed and formulated to have high strength retention in hydraulic cement environments. The GFRC Contractor shall provide certification from the manufacturer of the glass fibre for each batch supplied confirming the following properties:

1. Single filament tensile strength: 3.5 GN/mL
2. Strand tensile strength: 1.4 to 1. 7 GN/m -
3. Young's Modulus of Elasticity: 72 to 74 GN/mL
4. Specific Gravity: 2.68
5. Strain at breaking point (strand): 2 to 2.5%
6. Filament diameter: 13 to 20 μm ± 2 μm
7. Fibre length: 30mm to 50mm
8. Date of manufacture

2.1.1 Cement

 2.1.1.1 Portland white cements complying with ASTM C150

2.1.1.2 Cement should be provided from one manufacturer using one colour, brand and type throughout the project.

2.1.1.3 Cement used in face mixes or mist coats must be controlled for colour uniformity.

2.1.2 Aggregate

 2.1.2.1 Dense selected aggregate (fine and coarse): To BS EN 12620

 2.1.2.2 Aggregates shall be graded within the limits specified in BS EN 12620

2.1.2.3 The grading shall allow for a 1.2mm max particle size for sprayed GFRC and 2.4mm for premix GFRC. In both cases the tiny fraction i.e. passing 150um shall be less than 10%. Silica sands are widely used and shall conform to the following specification.

2.1.2.4 Chemical Composition

1. Silica > 96%
2. Moisture <2%
3. Soluble Salts <1%
4. Loss on Ignition <0.5%
5. SO3 4,000 ppm maximum
6. CI 600ppm maximum

2.1.2.5 Non silica sands may be used by the contractor who shall provide evidence of their suitability. Soft building sands shall not be used.

2.1.2.6 Metallurgical furnace slag aggregate: shall not be used.

2.1.2.7 Lightweight aggregate: shall not be used.

2.1.2.8 Aggregate containing breccias stone or ironstone shall not be used.

 2.1.3 Water

2.1.3.1 The water shall be clean and uncontaminated to comply with BS EN 1008. When so directed the Trade Contractor shall arrange for tests of the water to be carried out in accordance with BS EN 1008

 2.1.4 Admixtures

2.1.4.1 Admixtures may be permitted at the Construction Manager's discretion in designed mixes provided the details of the admixture and the associated mix design and trial results are approved.

2.1.4.2 Admixtures shall comply with BS EN 934-2 and shall be used in accordance with the manufacturer's specifications.

 2.1.5 Acrylic Polymers

2.1.5.1 Acrylic thermo plastic polymer dispersions shall be used according to the manufacturer's instructions and shall conform to the following specification.

1. Compound Type: Aqueous Thermoplastic polymer dispersion
2. Polymer Type: Acrylic Based% Solid 45-55%
3. Appearance: Milky white. Creamy. free from lumps Minimum film forming
4. Temperature: 5°C
5. Ultraviolet resistance: Good
6. Alkali resistance: Good
7. Freeze thaw stability: No gelation in a minimum of 5 cycles

2.1.5.2 Polymers with properties outside the above specification may only be used with the agreement of the Construction Manager.

 2.1.6 GFRC Mixes

2.1.6.1 GFRC mix proportions shall be calculated by the Trade Contractor. Complete details shall be submitted for approval as soon as they are available.

2.1.6.2 The proportions shall be chosen to achieve performance in accordance with the performance requirements. The following limitation to the mix design shall be observed.

1. Aggregate Cement Ratio: 0.5-1.0
2. Water Cement Ratio including polymer: 0.3 -0.375
3. Glass Fibre Content Polymer Content: 4.0-5.0%
4. Polymer Content: 5.0-7.0% Polymer
5. Solids by Weight of Cement

 2.1.7 Trial Mixes

2.1.7.1 Preliminary tests shall be made from test boards' surfaces in accordance with BS 6432 and GFRCA method of testing GFRC material Part

2.1.7.2 Results of all preliminary tests shall be sent to the Construction Manager as soon as they are available and before casting commences.

2.1.7.3 The Construction Manager may not accept the results of tests on laboratory produced trial mixes if he is not satisfied that they are representative of the quality of concrete which will be produced for the Works.

2.1.7.4 Salts: The total amount of soluble chloride content in the concrete from the aggregates, water and any admixtures shall not exceed the requirements of BS 1881.

 2.1.8 Integral Rib Formers

2.1.8.1 If integral rib formers are to be used to provide stiffness for GFRC panels the Contractor shall submit details of the material proposed to form the ribs to the Construction Manager for approval.

 2.1.9 Panel Frame and Flexible Anchors

2.1.9.1 If a steel panel frame is used for support of the GFRC, all steel work including flexible anchors shall be fabricated from hot dip galvanised elements to BS 729.

2.1.9.2 Cold formed or hot rolled steel sections shall comply with BS 5950 and BS 4848. Fabrication of the panels shall comply with the specification for Structural Steelwork.

2.1.10 Grouted Dowels

 2.1.10.1 Dowels

 2.1.10.2 Embedded dowels shall be Hot Dip galvanised MS

2.1.10.3 Cored Holes

2.1.10.4 Where grouted dowels are used the grout shall have a low shrinkage characteristic and should totally fill the core hole provided. Provide for GFRC cladding unit movement in dowel connections if necessary.

2.1.11 Embedment and Fixings

2.1.11.1 Embedment and fixings (including temporary fixings for handling purposes) shall be grade 304 stainless steel threaded inserts.

2.1.11.2 Fixing bolts, brackets, shims and the like shall be grade SS 304 stainless steel or mild steel hot dipped galvanised (Refer Schedule 4 -Materials).

2.1.11.3 Steel fixing brackets supporting the dead load of the units which are exposed within the building shall be fire protected to provide a two-hour rating. The material for fireproofing shall be submitted to the Construction Manager for approval.

2.1.11.4 The designed allowance for movement at fixing points shall be maintained.

2.1.11.5 Post drilled fixings inserted by drilling (including masonry anchors and the like), or by explosive tools, shall not be used except by approval of the Construction Manager.

 2.1.12 Weather Seals

2.1.12.1 Sealants shall be compatible, non-staining and fit for their intended purpose.

2.1.12.2 Non-structural sealants shall be either:

a. approved low modulus silicone ( exposed or concealed)

 b. approved polyurethane ( exposed or concealed)

2.1.12.3 Acrylic sealants are not acceptable.

2.1.12.4 Use open cell backing rods which do adhere to the sealant and are compatible with the substrate.

 2.1.13 Applied Finish

 2.1.13.1 Colour of Finishes to be approved by the Construction Manager.

a. The exposed face of GFRC cladding units shall be coated with a clear coating of silane or siloxane on the front and back surfaces of a panel to reduce moisture absorption and efflorescence.

b. The coating must be water vapour permeable to allow the panel to "breathe".

c. Manufacturers of coatings should be consulted for details of application, performance and testing of coatings with submission to Engineer for approval as shown in Schedule 4.

d. Surface has to be prepared to obtain good adhesion to the coating

e. The Trade Contactor may, if he wishes, submit an alternative to the Construction Manager for review. Technical Performances should be better than those indicated above.

## PART 3. FABRICATION & INSTALLATION

Following are minimum requirements of materials used for the GFRC cladding panels manufacturing and erecting.

**3.1 General**

3.1.1 Following are general requirements for fabrication but not limited to:

1. GFRC cladding units and associated elements shall be fabricated in strict accordance with approved Shop Drawings.
2. Trade Contractor shall comply as a minimum with all the relevant regulations and with the current edition of the relevant Standards and Codes.
3. The manufacture of GFRC cladding panels shall be by direct spray method or with premix GFRC in accordance with the requirements of the Glass Fibre Reinforced Cement Association recommended practice as set out below.

**3.2 Manufacturing Method**Following are general requirements for fabrication but not limited to:

 3.2.1 Concrete Face Mix

3.2.1.1 The concrete face mix shall be placed and vibrated in accordance with the procedures specified for precast concrete panels and nominated in the method statement submitted by the Trade Contractor. The delay between placing the face mix and commencement of placing the GFRC backing mix shall not exceed two hours or the time when sufficient set has taken place to form a cold joint at the interface.

3.2.2 Direct Spray Method for GFRC

3.2.2.1 Weigh/Batching - All dry ingredients shall be matched by weight using calibrated weighting equipment capable of any accuracy of ±2% of the stated batch weight. Liquids shall be weighted, volume batched or automatically dispensed. The manufacturer shall demonstrate that the method employed will give an accuracy of ±2%.

3.2.2.2 Mixing - The cementitious slurry shall be mixed in a "high shear mixer" in accordance with the manufacturer's instructions and using the stated mix design. The Trade Contractor shall demonstrate that he possesses this type of mixing system. The consistency of the mix shall be tested by measuring the slump. The test shall be performed at the start of each shift and then at agreed intervals.

3.2.2.3 Spraying - Spraying shall be carried out using specialist equipment which will allow the simultaneous deposition of known quantities of cementitious slurry and chopped glass fibre.

Prior to commencement of manufacture at the beginning of each shift the spray equipment shall be calibrated to ensure that the specified glass fibre percentage is achieved.

Bag and Bucket tests shall be carried out by the Contractor to measure the deposition rates of the glass fibre and cementitious slurry. The GFRC materials shall be sprayed and built up in thin layers of 3-4mm until the required thickness is achieved.

The GFRC shall be compacted by hand roller prior to tile spraying of the next layer. After the final layer is sprayed the

thickness of the GFRC shall be checked using a template or depth gauge and compared to the design thickness.

 3.2.3 Plant Facilities

3.2.3.1 The GFRC plant shall provide the following:

a. An enclosed area for the dry storage of raw materials, as necessary.

b. A storage area that maintains the temperature of acrylic thermoplastic copolymer dispersion above 32 deg. F (0 deg. C) and below 100 deg. F (38 deg. C).

c. Area for mould fabrication and storage.

d. Area for fabricating panel frames and other items of hardware.

e. An enclosed or covered area for the spray operation which is protected from wind, dust and direct sunlight.

f. An enclosed or protected area for curing of panels with the provision for mist spray curing if polymers are not being used.

g. Plan or yard space for finishing operations and adequate space for convenient and proper storage.

h. Area for sample preparation and laboratory testing including the necessary laboratory equipment.

 3.2.4 Moulds

3.2.4.1 Moulds shall be dimensionally stable to produce the required finish and tolerance. Repeated use of moulds shall not affect the dimensions or planes of the moulds beyond permissible tolerances.

3.2.4.2 Mould materials shall not warp or buckle due to temperature or moisture change. The mould materials shall be non-absorbent or sealed to prevent moisture absorption.

3.2.5 Storage Prior to Demoulding

3.2.5.1 Filled moulds shall be stored at temperature in excess of 10°C or 16°C if polymers are used and not exceeding 50°C.

3.2.5.2 Once the initial set has taken place the mould shall be covered with polythene of 500 gauges or above and shall not be moved until demoulding.

3.2.6 Application of Mist Coat

3.2.6.1 For GFRC panels without a face mix a mist coat shall be applied to the form to a thickness approximately 0.5mm after application of a form release agent and prior to application of the GFRC mix.

3.2.6.2 The GFRC backing shall be applied prior to the initial set of the mist coat. Details of the mist coat shall be submitted to the Construction Manager for approval. The mist coat shall have the same mortar formulation as the GFRC backing.

 3.2.7 Demoulding

3.2.7.1 The GFRC component shall not be demoulded until it has gained sufficient strength for removal and transportation without stressing the component beyond the elastic limit of the material. Demoulding shall be carried out in such a manner that no damage occurs to the component.

3.2.7.2 When a component is of a size that is too large to be demoulded by hand then special demoulding sockets or loops shall be embedded in the component and demoulding shall take place by means of a lifting frame.

3.2.7.3 The Trade Contractor shall document the specific procedure to be used for agreement with the Construction Manager prior to the commencement of production.

 3.2.8 Curing

Following are minimum requirements:

3.2.8.1 Moist Curing

1. Curing of GFRC components with concrete face mixes shall be at controlled temperature and humidity. This shall be for a period of 7 days.
2. The Contractor shall demonstrate that he has a curing procedure that enables the component to achieve the physical properties stated in the specification.
3. Ensures there is not excess shrinkage caused by too rapid drying of the product.
4. The panels are protected from direct sun and drying winds for a minimum period of 7 days.

3.2.8.2 Polymer Curing

1. Polymer grade GFRC components without face mixes shall not be moist cured as specified above.
2. Components shall be dry-cured after demoulding but shall not be exposed to temperatures above 30°C or below 16°C or the film formation temperature of the polymer for 3 hours after demoulding. The panels shall be protected from direct sun or drying winds in a covered area for a minimum period of 7 days.

 3.2.9 Fabrication Tolerances

 Following are the permissible tolerances while manufacturing GFRC panels:

| Aspects | Size of panels | Permissible Tolerance |
| --- | --- | --- |
| a. Length and height | < 3 m  | + / - 3 mm |
| b. Straightness/bow | < 3 m | + / - 5 mm |
| c. Thickness | Up to 50mm wall thick | + / - 2 mm |
| d. Twist at any corners | < 3 m | + / - 5 mm |
| e. Insert locations |  | + / - 2 mm |

 3.2.10 Installation Tolerances

Following are the permissible tolerances upon installation and completion of GFRC panels on its final position on to the building.

| Aspects | Size of panels | Permissible Tolerance |
| --- | --- | --- |
| a. Verticality within a floor | < 4 m  | + / - 2 mm |
| b. IN / out of building | < 3 m | + / - 5 mm |
| c. Joints sizes | Up to 50mm wall thick | + / - 2 mm |
| d. Joint gaps | Hairline Joints | + / - 1 mm |
|  | Expansion Joints up to 15mm | + / - 2mm |

**3.3 Installation**

3.3.1 Installation shall be carried out in accordance with approved Shop Drawings by personnel experienced in the handling and site installation of GFRC cladding units and associated elements.

3.3.2 Following are minimum requirements, site handling and installation methods are subject to approval by consultants/ project managers:

3.3.2.1 Handling and Hoisting

1. All units shall be carefully handled and hoisted, care being taken at all stages to ensure that edges and finishes are not damaged.
2. Hoisting at the site shall use safe lifting methods approved by the project manager.
3. Unsafe methods such as involving manual handling of GFRC panels for more than 4 floors are not acceptable.

3.3.2.2. Erection

1. Comply with the requirements of the Recommended Practice for GFRC Panels.
2. Adopt an erection procedure such that all members can be placed and fixed in position without distortion. Make safe during all handling, erection, and temporary conditions of the structure, against wind and all erection stresses and loading conditions, including those due to erection equipment.
3. Provide the cost of temporary erection bracing required and any of the Main Contractor's requirements in connection with such bracing.
4. Submit certification by a qualified structural engineer to verify the structural adequacy and stability of temporary work, erection cleats, brackets etc.

3.3.2.3 Protection

1. All GFRC cladding shall be adequately protected at all stages of delivery and installation.
2. The Trade Contractor shall be responsible for the protection of all installed works until handover of a completed floor. The method of protection shall be documented in the method statement. After hand over, the Main Contractor shall be responsible for protection of the completed installation from construction dust and falling cement slurry.
3. The use of applied adhesive materials is not recommended for this purpose.

3.3.2.4 Storage, Handling, Transport

The GFRC components shall be stored handled and transported in such a way that:

1. No part of the component is stressed beyond the elastic limit.
2. Bowing or twisting is not induced in the panel.
3. No damage is caused to any part of the component particularly edges and comers.
4. No permanent staining or discolouration is caused either by the storage conditions or the stacking/protection material.
5. For large components the method of handling, storage, loading and transporting shall be submitted to the Construction Manager for approval.

## PART 4. TESTING & VERIFICATION

**4.1 General**

4.1.1 The testing authority, and the personnel engaged in sampling, preparing, and handling test specimens shall be subject to the approval of the Construction Manager.

4.1.2 Record the result of each specimen test. Include the information listed under the heading Records in the relevant part of BS 6432:1984 and GFRC a Method of Testing GFRC Material Part 1. Make the records available on request.

4.1.3 Prior to supplying GFRC cladding units, furnish test certificates based on samples for the most recent production or from stockpiles for the project.

**4.2 Sampling**

4.2.1 Sample boards shall be prepared for testing the GFRC. The sample boards shall be representative of the actual material quality and thickness. The board size shall be 600mm x 600mm from which coupons shall be cut for testing.

4.2.2 Preliminary testing shall be carried out on a minimum of 5 test boards. Note that an average of 3 results can be recorded per test.

4.2.3 Following preliminary testing a minimum of 2 test boards per day per production team shall be taken.

**4.3 Curing and Coupons**

4.3.1 All coupons cut from test boards shall be cured for 28 days prior to testing. Curing shall be representative of the actual curing proposed for the material.

**4.4 Testing of GFRC**

4.4.1 GFRC panels for vertical and horizontal fins to be tested for the following requirements.

4.4.2 The testing shall be in accordance with BS 6432 and GFRC. A Method of Testing GFRC Material Part 1.

4.4.3 All these tests to be carried out at an approved third party laboratory to consultant's approvals.

4.4.4 The test Compliance and acceptable criteria has to be as followed:

4.4.4.1 Impact test

Largest panels used on the project, shall be tested for the impact test for:

1. Soft body impact- 50 Kg cushion rapped and dropped from 3m distance
2. Hard Body Impact- 25 Kg metal ball dropped from Im distance

4.4.4.2 Bending

Minimum 3 samples of size 300mm length shall be tested in Third party laboratories

 4.4.4.3 Rilem Test (Lab Test)

300x300 size panels shall be tested for the water absorption test as per Water Absorption ASTMC97

 4.4.4.4 Pull-out Test

Embedded Anchor/ Cast-inn channel pull out test: Minimum 3 samples of size 300x300 along with embeds shall be tested for pull out load tests in the Third party laboratories

 4.4.4.5 Beading Test

Visual Test

4.5 Acceptance criteria for GFRC Tests

 4.5.1 Glass Content - As per mix design but not to exceed 6.3% by weight

 4.5.2 Modulus of Rupture (MOR) - 18 Mpa (Min)

 4.5.3 Limit of Proportionality - 7 Mpa (Min)

 4.5.4 Wet Bulk Density - 2 tonnes/m3 (Max)

 4.5.5 Dry Bulk Density - 1.8 tonnes/m3 (Min)

 4.5.6 Water Absorption - After 30 minutes water absorption should be less than 10%

## PART 5. APPENDIX: MATERIAL TABLE - MINIMUM REQUIREMENTS

**5.1 GFRC Materials**

Following are minimum requirements for materials, this table will take precedence in case of any contradiction within any clauses of this specification. Contractor to submit technical data and material samples for approval.

| **Components**  | **Material & Grade** | **Comments and basic requirements** |
| --- | --- | --- |
| Glass fibre | Alkali Resistant Cem-Fil Glass Fibres Have min. Strength of retention 300mpa.  | Shall be Alkali Resistant.Suppliers: Saint Gobain/Vetrotex and NEG ARG Fibre manufactured by Nippon Electric Glass any other suppliers are subjected toreview and approval. |
| Cement | Ordinary Portland cement (white) | Cement shall be correctly stored and kept dry to avoid deterioration. Shall be from reputed suppliers assessed for capability to AS 3972 or Equivalent Indian standards. |
| Admixtures | Admixtures/Retarders are permitted; however, their use should only enhance improve the properties of GFRC | Add mixture shall comply with AS 14 78 or any Equivalent Indian standards.Do not have any harmful effects on the GFRC products and are used in accordance with the manufactures requirements. |
| Aggregates | Fine aggregate, with the particle size 1.2mm for premix GFRC.Maximum particle size shall be 2.4mm with 150micron with escape ratio 10% by weight of the total sand. | Should be silica sand. Confirm to clause 3.1.2 values in the GFRC specification.Sand other than silica may be used but the producer should provide evidence of their suitability.Burnt ashes, roasted aggregates and by-products of foundry are not acceptable. |
| Sealers | Use Silicone based sealers. Sealer is applicable for pigmented GFRC finish, and not applicable in case of paint finish. | Acceptable suppliers: DC IE-6694/ DC IE-6683 / Wacker SILRES® BS290.Compatibility and adhesion tests should be carried out with actual materials. |
| Finishes | Product should be harmless to the GFRC set and strengthShould be added in the mix of the GFRC while mix design | Provide final finish coat as per architectural requirements. Final coat warranty should be min. 5 years.Finishes achieved through the natural pigments along with spray/ brush method as per supplier recommendation.Should be UV and Alkali resistant.To be stable at High temperature. |
| Steel Stiffeners | Hot Dip Galvanised Mild Steel with Min. Yield stress of 275 MPa. | Structural steel specifications apply. Concealed elements. |
| Steel frame finishes | Hot dip galvanised | Cold galvanising or paint applications are not acceptable. |
| Screws & Bolts | SS 304 grade for all connections | Bolts: Min. size MIO for all structural connections with min. 2 nos. / fixing. |

**END OF SECTION**