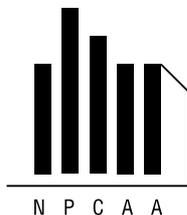


Recommended Specification for Manufacture, Curing and Testing of Glassfibre Reinforced Concrete (GRC) Products

This specification refers to the manufacture of Glassfibre Reinforced Concrete (GRC) products by the spray process. This process involves the simultaneous spraying of fibre and slurry onto a mould by manual or mechanical means. It is the commonly-used method of manufacture for relatively large GRC elements (eg cladding panels, noise barriers, permanent formwork) and other elements which are required to be thin in section and of high flexural strength.



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**GRC Industry Group of
National Precast Concrete Association Australia**

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GRC Industry Group manufacturers and suppliers:

Asurco Contracting Pty Ltd
Huntsman Composites
Nippon Electric Glass Co Ltd
Precast Concrete Pty Ltd
Saint-Gobain Vetrotex(Cem-FIL)

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1 GENERAL

1.1 SPECIALIST CONTRACTOR

The work specified in this section is to be undertaken by a Manufacturer who is a Member of the National Precast Concrete Association Australia, GRC Industry Group with experience in the GRC industry, which includes the production of architectural panels (or other products for which this specification is being used). With his tender, the contractor shall submit to the construction manager written evidence indicating his capability of producing panels of a reliable and consistent quality.

1.2 STANDARDS AND CODES

AS 3972	<i>Portland and blended cements.</i>
BS 12	<i>Portland Cement.</i>
BS 3892	<i>Pulverised Fuel Ash for use in Concrete.</i>
BS 476 Part 8	<i>Test Methods and Criteria for the Fire Resistance of Elements of Building Construction.</i>
-	GRC Industry Group of National Precast Concrete Association Australia, <i>A Recommended Practice - Design, Manufacture and Installation of Glass Reinforced Concrete (GRC)</i>
AS 3582.1	<i>Supplementary cementitious materials for use with portland and blended cement - Fly ash.</i>
AS 1130	<i>Code of practice for use of fly ash in concrete.</i>
AS/NZS 1170.1	<i>Structural design actions - Permanent, imposed and other actions.</i>
AS/NZS 1170.2	<i>Structural design actions - Wind actions.</i>
AS 1170.4	<i>Minimum design loads on structures (known as the SAA Loading Code) - Earthquake loads.</i>
AS 1379	<i>Specification and supply of concrete.</i>
AS 3610	<i>Formwork for concrete.</i>
AS 1478.1	<i>Chemical admixtures for concrete, mortar and grout - Admixtures for concrete .</i>
BS 1014	<i>Pigments for Portland Cements and Portland Cement Products</i>
BS EN 1169	<i>Precast Concrete Products - General Rules for factory production control of glassfibre reinforced cement.</i>
BS EN 1170 Parts 1-8	<i>Precast Concrete Products - Test Methods for glass-fibre reinforced cement.</i>

2 MATERIALS

2.1 GENERAL

Materials used for making the GRC unit shall generally comply with relevant British and Australian Standards and Codes. Any reference to a British Standard shall mean that current at the time of going to tender.

Where materials are not fully covered by this specification or alternative materials are offered, the Contractor shall forward to the Construction Manager prior to commencing the work, details of those he proposes to use together with supporting evidence indicating that the finished product will be capable of meeting the performance requirements of this specification.

2.2 ALKALI-RESISTANT GLASSFIBRE

Glassfibre shall be an alkali-resistant, continuous filament fibre developed and formulated specifically to have high strength retention in Ordinary Portland Cement environments. The glass fibre shall have a minimum ZrO₂ content of 16% by weight, in accordance with internationally-recognised standards, and shall have a minimum strength retention (determined by Strand In Cement (SIC) testing) of 300 MPa (Test Method: GRCA SO 104/0184).

The producer shall provide certification from the glassfibre manufacturer to show that the glass fibre conforms to these requirements, has a history of successful use in similar matrices, and is manufactured under an internationally-recognised Quality Management system. Suitable alkali-resistant glassfibres are "Cem-FIL", manufactured by Saint-Gobain/Vetrotex and "NEG ARG Fibre" manufactured by Nippon Electric Glass.

2.3 CEMENT

The cement shall be Ordinary Portland Cement, supplied by a manufacturer of assessed capability to AS 3972-1997 and BS 12 or its derivatives, and should be supported by suitable certification. Cement shall be obtained from one source throughout manufacture.

Cement shall be correctly stored and kept dry to avoid deterioration.

2.4 SAND

Sands should be washed and dried to remove soluble matter, and to permit control of the water/cement ratio. Sand added to the mix shall not exceed 50% by weight of the total mix and sand/cement ratio shall not exceed 1:2. Sand shall be only high silica and conform to the following specification:

Silica content	> 967%
Water content	< 2%
Soluble salts	< 1%
Grain size	< 1.2 mm < 10% passing a 150 micron sieve

Sands other than silica sands may be used subject to approval of the architect and engineer, but the producer must be able to show proof of their suitability.

2.5 ADMIXTURES

The manufacturer shall ensure that any admixtures used do not have any harmful effects on the product, and are used in accordance with the manufacturers' recommendations. The use of superplasticisers may be encouraged to keep water content of the composite to a minimum without loss of suitable working characteristics, especially the ease of attaining full compaction.

Any admixtures used, shall comply with AS 1478.

2.6 PIGMENTS

Any pigments used shall conform to BS 1014. These shall be:

- Harmless to the GRC's set and strength.
- Stable at high temperature.
- UV-resistant and alkali-resistant.

The client should recognise that some colour variation may occur, and must agree an acceptable range of variation with the producer.

2.7 WATER

Water shall be free from deleterious matter that may interfere with the colour, setting, or strength of the concrete.

2.8 MIX DESIGN

The mix shall have been determined by the manufacturer, and written confirmation of the mix design shall be submitted so the proportions shall be chosen to achieve the quality-control requirements specified herein.

2.9 MOULD-RELEASE AGENT

The mould-release agent shall be selected by the manufacturer and approved by the architect or engineer. This should be compatible with the surface finish required for the product. Any residue shall be removed from the finished product so that this does not interfere with any joint sealants or applied finishes which may be used.

2.10 FORMWORK

The design, material and manufacture of the forms shall be consistent with the type and quality of the surface finish required from the panel, and with the tolerances specified. The forms shall be constructed such that the finished products conform to the profiles and dimensions indicated by the contract documents.

2.11 SUPPORT STEELWORK AND FIXINGS

The Manufacturer will be responsible for the design, manufacture and installation of all support framing, cleats and fixings inserted into and affixed to the GRC panels, or provided for the support of the GRC panels. Fixing zones are described on the drawings, together with primary structural concrete and steelwork provided by others for use by the contractor if required.

Fixings shall be concealed and cast into panels unless otherwise specified. They shall be of non-corrosive material and located at suitable spacings to ensure support of panels without creating undue stresses to the panels under thermal movements and/or moisture movement.

The recommendations of the *Recommended Practice - Design, Manufacture and Installation of GRC - NPCAA Publication, August 1999* (herein after called *NPCAA Recommended Practice*) shall be incorporated in the design of fixings.

Steel materials and workmanship shall comply with the relevant codes, and all steel will be free from rust, loose scale, pitting and other defects.

Fabricated steel components shall be true to line and free from twists, bends and open joints.

All ungalvanised materials shall be thoroughly cleaned prior to fabrication, by grit blasting to Class 2 in accordance with AS 1627 Part 4 and painted with Red Oxide Zinc Chromate in two coats to a minimum dry film thickness of 80 microns.

Fixing cleats to existing steelwork, where indicated on the GRC cladding shop drawings, shall be site-welded unless otherwise arranged with the construction manager.

Any damage to protective coatings on steelwork, supplied as part of this contract works, shall be repaired.

3 WORKMANSHIP

3.1 WEIGHING AND BATCHING

Dry ingredients shall be batched by weight using calibrated weighing equipment capable of an accuracy of $\pm 2\%$ of the stated batch weight. Liquids should be weighed, volume-batched or automatically dispensed. The producer must demonstrate that the method employed will give an accuracy of $\pm 2\%$.

3.2 MIXING

The cement slurry should be mixed in a high-speed shear mixer, or other high-speed mixer which can achieve a good and even dispersion of all slurry ingredients.

3.3 APPLICATION

Application shall be by spraying, using purpose-built equipment which allows the simultaneous deposition and uniform mixing of the glassfibre and cement matrix.

The glassfibre and cement slurry shall be metered to the spray head at rates to achieve the desired mix proportion and glass content. These shall be checked for each spray pump at least once per day and prior to commencing spray production after each stoppage. The test shall be conducted in accordance with the method described in BS EN 1170-3. Distribution of fibre in the mix shall be controlled by the operator in such a way as to be as uniform as possible.

Cleanliness of equipment and working areas shall be maintained at all times.

3.4 SHAPE AND FINISH

The panels are to be formed of GRC in moulds to achieve the profiles indicated by the architectural drawings.

The manufacturer shall provide a means for producing a replacement panel at any time during the building contract. Moulds shall be adequately cured to eliminate shrinkage and distortion and shall be properly braced.

The exposed face of the GRC panels surfaces shall be free of blowholes, cracks, undulation or similar imperfections.

3.5 MANUFACTURE

The panels shall be manufactured by a spray technique as detailed in the NPCAA Recommended Practice or as otherwise agreed between the manufacturer and architect/engineer to an approved method.

Spray applicators shall be experienced personnel whose proficiency meets industry standards.

If an architectural face mix is being used, this will first be sprayed into the mould. The thickness shall generally be the minimum possible to achieve the desired finish, which will normally make it at least 20% thicker than the largest

sand or aggregate being used and normally 4 mm minimum and 12 mm maximum thickness. An acrylic polymer should be used in the face mix to reduce any risk of this unreinforced layer cracking.

If no face mix is being used, a mist coat consisting of the basic mortar composition without fibre may, if necessary, be sprayed onto the moulds to prevent fibres from being visible on the finished surface of the product. The mist coat is intended to be just thick enough to cover mould details and surfaces so that fibres are not visible on the surface, but not so thick that crazing of this unreinforced layer may occur.

The normal target thickness of a mist coat for non-polymer GRC is 1 mm, though the use of acrylic polymer in the mix may allow the thickness to be increased up to a maximum of 3 mm. However, it should be noted that for design purposes the thickness of the mist coat should not be considered as contributing to the strength of the GRC panel.

Spray-up of GRC backing material shall proceed before any mist coat or face mix has set.

The method of spraying the main body of material shall achieve the greatest possible uniformity of thickness and fibre distribution.

Consolidation shall be by rolling and such other techniques as are necessary to achieve complete encapsulation of fibres and full compaction.

Control of thickness shall be achieved by using a pin-gauge or other acceptable method. Minimum thickness of panels is recommended as 8 mm (hand-spray) and 6 mm (auto-spray).

All hand-forming of intricate details, incorporation of formers of infill materials and over-spraying shall be carried out before the material has achieved its initial set so as to ensure complete bonding.

Inserts shall be properly embedded into thickened, homogeneous areas of GRC. Waste material such as over-spray is not acceptable to encapsulate inserts or for bonding pads.

Any rigid embedded items bonded to the GRC shall not create undesirable restraint to volume changes.

3.6 SHOP DRAWINGS

Prior to commencing manufacturing work, the manufacturer shall submit for approval detailed shop drawings showing the following information:

- layout (sectional plan and elevation) of complete wall panelling;
- full-size section of typical panel and support members;
- method of assembly and supports and fixings to the existing structure and provision to withstand imposed stresses;

- method of installation, caulking, flashing and provision for vertical and horizontal expansion;
- junction and trim to adjoining surfaces; and
- fittings and accessories,

The submission of shop drawings shall be supported by engineering design computations to show that cladding and supports comply with the design criteria specified.

3.7 TOLERANCES

The GRC elements shall be manufactured and installed to the tolerances stated in the NPCAA Recommended Practice (Section 10).

3.8 DEMOULDING AND CURING

Once the initial set has taken place, GRC elements should be covered with polythene for their protection and to prevent them from drying out fully. They must not be moved again until they are ready for demoulding.

The GRC elements must not be demoulded until they have gained sufficient strength to be removed from the mould and transported within the factory, without being over-stressed.

If the GRC elements are too large to be demoulded by hand, special demoulding sockets or loops should be embedded in the panel during manufacture, and demoulding should be assisted with a lifting frame. This procedure should be agreed with the engineer.

During demoulding, the panels shall be uniformly supported in a manner which avoids undue stresses in the panels.

If polymers are used in the mix to avoid wet curing, the panels should be stored under cover for a minimum of 7 days at a temperature of between 5°C and 35°C.

If polymers are not used in the mix, curing shall be continued after demoulding under conditions which shall provide free water on the surfaces of the panels at a temperature not exceeding 50°C for a period of not less than 7 days (including the initial cure in the mould).

3.9 IDENTIFICATION OF ELEMENTS

All panels shall be identified individually to indicate the panel type and date of manufacture.

At the time of preparation of shop drawings the manufacturer shall indicate his required order of delivery.

3.10 HANDLING, TRANSPORTATION AND INSTALLATION

The products shall be handled, transported and installed using methods which ensure that no damage or marking of architectural surfaces occurs and so that the panels are not subject to undue stress.

The safety and protection of GRC units shall be ensured throughout the whole of the contract works.

Site access and, if necessary, storage space shall be provided by the main contractor.

The main contractor shall also provide true, level and clean support surfaces and shall provide for the accurate placement and alignment of connection hardware on the structure.

3.11 TEST REQUIREMENTS

The specified glassfibre content shall be 5% by total wet weight of materials.

The GRC from which the panels are made shall have the following properties on completion of curing:

- Characteristic Modulus of Rupture (MOR) 18 MPa at 28 days.
- Characteristic Limit of Proportionality (LOP) 7 MPa at 28 days.

The value of MOR and LOP design stresses to be used should be determined by the design engineer for specific service requirements.

The minimum dry density shall exceed 1800 kg/m³.

3.12 TESTS

The following tests shall be carried out on coupons cut from the test boards in accordance with BS EN 1170 Parts 2, 4, and 5. If acrylic polymer is used in the mix, presoaking immediately prior to testing shall not be required for Modulus of Rupture or Limit of Proportionality.

- Glass Content – BS EN 1170 Part 2
- Modulus of Rupture – BS EN 1170 Part 5 (and simplified method in Part 4)
- Limit of Proportionality. – BS EN 1170 Part 5

Test boards shall be produced alongside each day's production (at least one per day for each production team). The recommended size of these sample boards is 600 x 600 mm. The test boards shall be produced with the same quality, thickness and curing as the actual panels.

Those test boards which are not required for testing should be kept for the duration of the contract, or for a period to be agreed between the manufacturer and engineer.

3.13 FREQUENCY OF TESTING

The frequency of testing shall be agreed between the architect, engineer and manufacturer.

The recommendation of BS EN 1169 is as follows:

- Glass content – tested in accordance with BS EN 1170 Part 2. Once per week for each spray team. (This is in addition to the calibration test referred to in section 3.3).
- Modulus of Rupture and Limit of Proportionality – tested in accordance with BS EN 1170 Part 5. Should be tested by the manufacturer or by a qualified laboratory as the mix design is being set-up and thereafter at least twice per year, or when the mix design is changed.
- A simplified bending strength test to determine the Modulus of Rupture (MOR) should be conducted by the manufacturer more frequently. The frequency of testing recommended by BS EN 1169 is for each 10 tonnes of GRC produced, or at least once per week.
- Water Absorption and Dry Density – tested in accordance with BS EN 1170 Part 6. As the mix design is being set-up, and then for each 10 tonnes of GRC produced, or at least once per week.

3.14 COMPLIANCE

Compliance with glass content and the characteristic strength for both LOP and MOR shall be assumed if the following conditions are met:

i) **Glass Content**

The glass content shall not vary from the specific amount by more than $\pm 20\%$.

ii) **Modulus of Rupture and Limit of Proportionality**

The characteristic MOR and LOP is defined as the value which 95 per cent of all the mean strengths of the individual test-boards shall exceed.

Compliance with the characteristic MOR and LOP requirements shall be assumed if no single test-board mean shall be less than 85 per cent of the characteristic MOR and LOP, and the average of 4 consecutive test board results shall exceed 21 MPa (MOR), and 8 MPa (LOP).

If any single test-board fails to meet any of the compliance requirements, the GRC at risk shall be that produced between the previous complying test board and the next complying test board.

Where failure to comply arises from consideration of consecutive groups of four test-boards, the GRC at risk shall be that represented by the first and fourth test-boards, together with all intervening material.

Note: If different values for MOR and LOP are required for specific service requirements, these should be determined by the design engineer for the specific service requirements. The selection of unnecessarily high strength requirements may result in cost penalties.

iii) **Dry Density**

The dry density of the GRC shall exceed 1800 kg/m³.

iv) **Non-Compliance**

In the event of non-compliance, the action to be taken should be agreed between the manufacturer and the client. Due regard should be paid to the technical consequences of the non-compliance and the economic consequences of adopting remedial measures or replacing the rejected products. Account should also be taken of the safety factors incorporated in the design and also the thickness of the GRC produced, compared with the design thickness.

Re-testing may be considered appropriate if it is considered that the storage conditions of the product may result in improved properties because of extended curing, or if the sampling, testing or calculation may have been at fault.

The material at risk may be reduced by the testing of additional test boards from the same, previous, or next manufacturing periods. Testing may also be performed on GRC samples cut from the actual GRC elements at risk.

3.15 WEATHERPROOFING

Responsibility for the weatherproofing of the whole installation of GRC panels rests with the GRC manufacturer.

The joint details shown on the drawings represent the appearance required and their minimum standard of weatherproofing acceptable.

Joints shall be weather-sealed with closed-cell polyethylene compressible backing rods and caulked with 2-part polysulphide sealant or other approved sealant in selected colours, installed completely in accordance with the sealant manufacturer's recommendations with regard to joint dimension, priming, substrates, mixing, curing, masking, cleaning and the like.

The GRC manufacturer shall submit details of the proposed sealant and the application recommendations for approval by the construction manager prior to commencement of the contract works.

Joints located and indicated on the drawings are those required for sealing the GRC cladding against adjacent materials and those required for architectural purposes for division of the panels into the design modules. Should the GRC manufacturer or contractor propose to subdivide the cladding into smaller panels for ease of casting, handling and erection, additional joints may be introduced in the design, provided the location proposed is discreet. The GRC manufacturer shall submit proposed locations and designs of additional panel joints with their tender submission.

4 OTHER ISSUES

4.1 RESPONSIBILITY

The GRC manufacture shall be solely responsible for the design and performance of the GRC panels and their supports. Information provided on the drawings or this specification shall not affect this responsibility.

4.2 GUARANTEES

The Manufacturer shall warrant the GRC panels installed, or to be installed, against any and every defect or failure which may occur during the period of practical completion for the works arising out of any fault of the GRC cladding system, workmanship, fabrication, fixing or quality of materials used.

4.3 DESIGN CRITERIA

Glassfibre-reinforced wall cladding shall comply with the following:

FINISH:

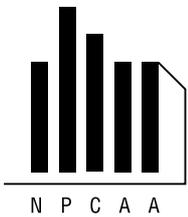
Class 1 to the formwork code, smooth face suitable for high paint finish.

DESIGN LOADS:

Cladding and framing shall be designed in accordance with AS1170.

DEFLECTIONS OF MAIN FRAME STEEL MEMBERS:

The attention of the contractor is drawn to the allowance made for differential deflections between the structure at level 2 and the ground. The anticipated allowance is 30 mm. The detailing of the GRC cladding should take this into account.



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