



**Specification for the
Manufacture, Curing & Testing of
Glassfibre Reinforced Concrete (GRC)
Products.**

**The International
Glassfibre Reinforced Concrete
Association (GRCA)**

February 2021 (Rev.)

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- Companies who manufacture or develop GRC products,
- Plant or material suppliers to the industry,
- Professional partnerships or consultants,
- Other interested parties and associated industry trades.

All GRC manufacturing GRCA Full Members are annually assessed by an independent external assessor and must demonstrate that they have sufficient resources in plant, equipment and labour to consistently design and manufacture high quality GRC in accordance with the GRCA Full Member Regulations and this Specification.

Specification for the Manufacture, Curing & Testing of Glassfibre Reinforced Concrete (GRC) Products.

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SPECIFICATION FOR THE MANUFACTURE, CURING & TESTING OF GRC PRODUCTS

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FOREWORD

This Specification is designed to enable architects, structural engineers, GRC consultants and specifiers to specify GRC. It covers all aspects of GRC production from raw materials, through production, curing and storage to quality assurance and testing.

Grades of GRC covered are:

- General purpose cast premix GRC: Grades 8 and 8P
- Sprayed premix or high quality cast premix GRC: Grades 10 and 10P
- Normally sprayed GRC: Grades 18 and 18P

where 'P' refers to the use of an aqueous acrylic thermoplastic co-polymer dispersion in the GRC mix design.

Dependent on the application of the manufactured products other Grades may be appropriate as determined by the engineering analysis.

This Specification is intended as the foundation for specifications for GRC composites used to manufacture all types of products. The QC measures included are the minimum which the GRCA recommends. Further product specific quality control tests may be deemed necessary according to the type of product, the application and the consequence of failure. Where necessary, changes and additions should be agreed between the Purchaser, or their representative (e.g. architect, structural engineer, GRC consultant etc.), and the GRC Producer. In consultation with a Producer, the specifier should select the grade of GRC required. The specifier can then ensure that the product is manufactured and tested according to the specification.

The Specification is a material and manufacturing specification. A Structural Engineer should be consulted to ensure that the material grade selected is consistent with the structural engineering design of the product. This Specification supersedes all previous GRCA GRC Specifications.

This Specification should be used in conjunction with the GRCA "Methods of Testing Glassfibre Reinforced Concrete (GRC) Material".

1 INTRODUCTION

1.1 Scope

This specification covers the requirements for the manufacture, curing and testing of GRC products. It gives detailed requirements for grades of GRC manufactured by three different methods:

- 'Spray' Grades 18 and 18P
- 'Premix' Grades 10 and 10P
- 'Premix' Grades 8 and 8P

'P' refers to the use of an aqueous acrylic thermoplastic co-polymer dispersion in the GRC mix design.

This specification covers mixes with and without polymers. Selection of the applicable grade should be made by the Producer in consideration of the engineering design of the product. This choice should then be approved by the Purchaser.

1.2 References

Standards and other publications referred to in this specification are listed in "Further Reading".

1.3 Definitions

Aggregate/cement ratio

The ratio of the mass of total dry aggregate to the mass of dry cement in the GRC.

AMS

The GRCA "Approved Manufacturer Scheme" (AMS) is the old name for what is now the GRCA Full Member grade for GRC manufacturers.

Alkali resistant glassfibre

Alkali resistant glassfibres, or AR glassfibres, are glass fibres suitable for use in concrete which have a high alkali resistance (AR) as they have a minimum zirconium dioxide (ZrO₂) content of 16%. AR glassfibres for use in GRC shall conform to the requirements of EN 15422, EN 14649 category B, or other equivalent national standards.

See also GRCA technical document "techNOTE 11 AR Glassfibre for GRC".

'Bag and bucket' tests

Methods for the calibration of GRC spray equipment. See also GRCA "Methods of Testing GRC Material Part 4", or EN 1170-3.

Characteristic property

The value of a property above which 95% of the population of all possible measurements of that property of the specified GRC are expected to lie.

Concentric GRC Spray gun

A GRC spray gun whereby both the AR glassfibres and the cementitious slurry are emitted from one nozzle and sprayed onto the mould. The Concentric GRC Spray gun will have the capability to cut the glassfibre to a range of different lengths from approximately 6 mm to over 40 mm.

Dry curing

A method of curing which prevents early loss of moisture and allows curing to take place without keeping the GRC damp. Dry curing is carried out by adding an appropriate quantity of the polymer into the GRC mix. (See Tables 2 & Section 4.5.)

Extremes of dimensional variations

The maximum dimensional variations (residual hydraulic shrinkage and reversible expansion) of a GRC composition attributable to variations in the water content to which products exposed to the elements may be subjected. See also EN 1170-7.

Facing coat

An initial layer without fibres but containing decorative sands or aggregates and / or pigments.

Full Member

A GRC manufacturing Member of the GRCA who is annually assessed by an independent Full Member Assessor appointed by the GRCA and has been accepted into the GRCA Full Member grade.

Full Member Assessment

The annual assessment carried out by an Assessor relating to either an upgrade to the Full Member grade by a new GRC manufacturing Member, or the continued membership of the Full Member grade of GRCA membership by a Full Member.

Full Member Assessor

A person or company nominated by the GRCA to carry out a Full Member Assessment on a GRC manufacturing Member of the GRCA in accordance with the GRCA "Regulations, Membership, Procedure and Assessment".

Glassfibre content by weight (WF)

The ratio (expressed as a percentage) of the mass of AR glassfibre to the mass of GRC in the Uncured [wet mix] state.

Grade

The strength Grade of the GRC, based on the Characteristic MOR of the product.

GRC Consultant

A person who is experienced in certain aspects of GRC. A GRC Consultant would normally hold formal qualifications (e.g. degree, chartered, licensed, certified etc.) but not necessarily in the discipline of Structural Engineering.

GRCA

The International Glassfibre Reinforced Concrete Association.

Green state

See Uncured state.

High shear mixer

A mixer with a high shear action capable of the preparation of the fine sand/cement slurries required for the spray process.

Limit of proportionality (LOP)

Also known as elastic limit. The stress in a flexural bending test where the stress/strain plot deviates from a straight line.

“Methods of testing”

“Methods of testing”, or MOT, refers to the GRCA “Methods of Testing Glassfibre Reinforced Concrete (GRC) Material” document.

MFFT

Minimum film formation temperature, for acrylic thermoplastic co-polymer dispersions.

Mist coat

An initial cementitious sprayed coating without glassfibres.

Modulus of rupture (MOR)

The highest stress on a stress/strain plot during a flexural bending test.

Polymer

In respect to GRC production refers to an aqueous acrylic thermoplastic co-polymer dispersion.

See also GRCA technical document “techNOTE 12 Polymers for GRC”.

Polymer-modified GRC

GRC which has been modified by the addition of an aqueous acrylic thermoplastic co-polymer dispersion for “dry curing” and property enhancement.

Premix GRC

A method of manufacture in which the pre-cut AR glassfibres and the cementitious slurry are blended during mixing.

Premix GRC mixer

A two stage mixer which has the capability to mix the base cement/sand slurry at a high speed with a high shear mixing action and then to blend in the cut AR glassfibres with a slower, low shear mixing action.

Producer

The person or authority entering into a contract to manufacture a GRC product.

Purchaser

The person or authority entering into a contract to buy a GRC product.

Simultaneous sprayed GRC

A method of manufacture in which a GRC product is produced by simultaneously spraying the cementitious slurry and the AR glassfibre, which is chopped from a roving via a cutter mechanism inside a Concentric GRC Spray gun to the length required. Both cementitious slurry and the chopped AR glass fibres are emitted from the same nozzle.

Slump test

A test for checking the consistency of the cementitious slurry. See also GRCA “Methods of Testing GRC Material Part 5”, and EN 1170-1.

Specification

“Specification” refers to this GRCA “Specification for the Manufacture, Curing & Testing of GRC Products” document.

Sprayed GRC

A method of manufacture in which a GRC product is produced by spraying the cementitious slurry and the AR glassfibre mix with a GRC Spray gun.

Structural Engineer

The person or authority responsible for the structural design of the GRC component. A Structural Engineer must hold formal qualifications, e.g. degree, chartered, licensed,

certified etc. in the discipline of Structural Engineering, and hold Professional Indemnity insurance cover.

Supplier

In respect to this Specification refers to the person or authority entering into a contract to supply goods and/or raw materials to the Producer.

Test board

A sheet of GRC manufactured during production for the purpose of assessing the quality of the GRC products being made. The test board shall be made in the same way and at the same time as the GRC products so that it is representative of the quality of the GRC incorporated in the products.

Test board mean

The arithmetic mean value for a property calculated from all the individual test coupon results from one test board. For statistical analysis, this mean is regarded as one result.

Test coupons

A number of specimens taken from a single test board for the purpose of determining a property.

Top/bottom ratio

The ratio of the MOR results of samples tested with the mould face in tension to those with the trowelled face in tension.

Uncured state

The stage in the manufacture of GRC when all physical processes that could alter the composition of the material are complete but the fibre can still be separated from the matrix by the action of running water.

'Wash out' test

A method for the determination of glass fibre content of Uncured GRC. See also GRCA "Methods of Testing GRC Material Part 1", or EN 1170-2.

Water/cement ratio

The ratio of the mass of total water to the mass of dry cement in the GRC in the Uncured state. When pozzolanic fillers are used they can be considered as cementitious and the water/cement ratio can be expressed as a water/total binder ratio; examples of such pozzolanic fillers are fly ash, silica fume and metakaolin.

2 CONSTITUENT MATERIALS

2.1 Alkali resistant glassfibres

Glassfibres shall be an alkali resistant continuous filament glass fibre developed and formulated to have high strength retention in hydraulic cement environments. The Producer shall provide certification from the Supplier to show that the AR glass fibres conform to the requirements of EN 15422, EN 14649 category B, or other equivalent national standards (e.g. ASTM C1666).

2.2 Cement

Cement shall be supplied by a manufacturer of assessed capability, made to recognised standards such as EN 197 or other equivalent national standards and supported by suitable certification. Cement shall be correctly stored and kept dry to avoid deterioration.

2.3 Fine aggregates

Fine aggregate or sand shall be washed to remove soluble matter and dried to permit accurate control of the water/cement ratio. Sands with moisture content may be used provided the moisture content is known and the mix design is altered accordingly.

Fine aggregates shall comply with any applicable national standards. In all cases the fine fraction, i.e. sand passing a 150 micron sieve, shall be less than 10% of the total weight of sand.

The particle shape shall be round or irregular and shall have a smooth surface without honeycombing.

Silica sands are widely used and have proven to be acceptable in the manufacture of GRC. Sands other than silica sands may be used but the Producer shall provide evidence of their suitability. Soft building sands shall not be used.

2.4 Water

Water shall be clean and free from deleterious matter, see EN 1008, Mixing water for concrete.

2.5 Admixtures

Admixtures are permitted and their use is encouraged as they can enhance the properties of GRC. They shall always be used strictly in accordance with the Suppliers' recommendations and the Producer shall ensure that their use has no adverse effect on the product.

Admixtures shall comply with the requirements of EN 934 or other equivalent national standards.

Calcium chloride-based admixtures shall not be used if the GRC component contains steel reinforcement, fixing sockets or other cast-in devices.

2.6 Acrylic Thermoplastic Co-Polymer Dispersions

Acrylic thermoplastic co-polymer dispersions are permitted and shall be used in accordance with the manufacturers' instructions and shall conform to the material characteristics in Table 1.

Polymers with properties outside the above specification may be used provided adequate data based on research can be produced to support manufacturers' claims.

See also GRCA technical document "techNOTE 12 Polymers for GRC".

Table 1: Polymer curing aid – Material Characteristics.

| | |
|---|---|
| Compound type | Aqueous thermoplastic co-polymer dispersion |
| Polymer type | Acrylic based |
| Solids | 45-55% |
| pH | 4-10 |
| Appearance | Milky white creamy, free from lumps |
| Minimum film-formation temperature (MFFT) | 7 °C |
| Ultraviolet resistance | Good |
| Alkali resistance | Good |

2.7 Pigments

Powder pigments or dispersions may be used to produce coloured GRC. The pigments shall conform to any applicable national standards.

The Purchaser should recognise that colour variation may occur and must agree an acceptable range of variation with the Producer.

2.8 Other component materials

Other component materials (e.g. silica fume, metakaolin, fly ash, reinforcing fillers, admixtures, meshes), may be added to modify the properties of the mix. They shall conform to any applicable national standards and must be used in accordance with the Suppliers' instruction. The Producer shall demonstrate that their use will not adversely affect the properties of the GRC.

2.9 Storage of raw materials

All raw materials shall be stored in a manner which protects against deterioration and contamination.

The rotation of stocks shall be ensured so that the oldest stock is always used first.

3 COMPOSITION OF GRC

3.1 Mix design

It is the responsibility of the Producer to agree a suitable mix design for the product. The mix design must be such that the mechanical properties of the GRC in Section 8 of this Specification are achieved and that these requirements are consistent with the engineering design of the product.

The mix designs in Table 2a, 2b and 2c are intended as a guide, indicating typical figures.

Mix designs falling outside these guidelines may be acceptable but shall be fully scrutinised and tested before use.

Table 2a: Guide mix designs — Grade 8

| Premix Grade | Grade 8 | Grade 8P |
|--|------------------------|-------------|
| Description | General purpose premix | |
| Aggregate/cement ratio | 0.5 -1.50 | 0.5 -1.50 |
| Water/cement ratio | 0.30 - 0.40 | 0.30 - 0.40 |
| AR Glassfibre content (% by weight of total mix) | 2.0 - 3.0% | 2.0 - 3.0% |
| Polymer solids content (% by weight of cement) | Nil | 4-7% |
| Extreme dimensional variations mm/m | 0.6 – 1.2 | 0.6 – 1.2 |
| Water Absorption | 5 – 11% | 5 – 11% |
| Minimum bulk dry density kg/m ³ | 1800 | 1800 |
| Minimum bulk wet density kg/m ³ | 2000 | 2000 |

Table 2b: Guide mix designs — Grade 10

| Premix Grade | Grade 10 | Grade 10P |
|--|--|-------------|
| Description | Sprayed premix or High quality cast premix | |
| Aggregate/cement ratio | 0.5 -1.50 | 0.5 -1.50 |
| Water/cement ratio | 0.30 - 0.38 | 0.30 - 0.38 |
| AR Glassfibre content (% by weight of total mix) | 2.0 - 3.5% | 2.0 - 3.5% |
| Polymer solids content (% by weight of cement) | Nil | 4-7% |
| Extreme dimensional variations mm/m | 0.6 – 1.2 | 0.6 – 1.2 |
| Water Absorption | 5 – 11% | 5 – 11% |
| Minimum bulk dry density kg/m ³ | 1800 | 1800 |
| Minimum bulk wet density kg/m ³ | 2000 | 2000 |

Table 2c: Guide mix designs — Grade 18

| Spray Grade | Grade 18 | Grade 18P |
|--|--------------------|-------------|
| Description | Direct sprayed GRC | |
| Aggregate/cement ratio | 0.5 -1.5 | 0.5 -1.5 |
| Water/cement ratio | 0.30 - 0.38 | 0.30 - 0.38 |
| AR Glassfibre content (% by weight of total mix) | 4.0 - 5.5% | 4.0 - 5.5% |
| Polymer solids content (% by weight of cement) | Nil | 4-7% |
| Extreme dimensional variations mm/m | 0.6 – 1.2 | 0.6 – 1.2 |
| Water Absorption | 5 – 11% | 5 – 11% |
| Minimum bulk dry density kg/m ³ | 1800 | 1800 |
| Minimum bulk wet density kg/m ³ | 2000 | 2000 |

4 MANUFACTURE

Only GRC products manufactured by the Premix and Sprayed GRC production methods are covered by this specification. Cementitious composite materials which contain nets, scrims and other forms of textile reinforcement manufactured from Alkali Resistant glassfibre or other types of fibre (e.g. carbon, polypropylene etc.) are not covered.

4.1 Manufacture by Simultaneous spray

4.1.1 Weighing/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 shall be weighed, volume batched or automatically dispensed. The Producer shall demonstrate that the method employed will give an accuracy of $\pm 2\%$.

4.1.2 Mixing

The cementitious slurry shall be mixed in a high speed, high shear type mixer or equivalent designed for the purpose of preparing mixes for GRC manufacture. Standard concrete mixers or cement/sand mortar mixers as used on construction sites and elsewhere are not suitable. The Producer must demonstrate that the mixing system used is suitable for producing batches of "lump-free" slurry with good consistency.

4.1.3 Simultaneous Spraying

Simultaneous spraying shall be carried out using specialist equipment that allows the simultaneous deposition of known quantities of cementitious slurry and chopped AR glassfibre.

The spray equipment shall be calibrated to measure the deposition rates of the AR glassfibre and cementitious slurry and ensure that the specified glassfibre percentage is achieved. The calibration shall be carried out for each spray machine at the beginning of each shift, after any alteration of the equipment controls, and after any unsatisfactory 'Wash out' test results (see also Section 7.1). Calibration shall be carried out using the 'bag and bucket' tests in accordance with GRCA "Methods of Testing GRC Material Part 4", or EN 1170-3, or equivalent national standards.

A mist coat without fibre may be sprayed; this coat shall be as thin as practicable (~ 1 mm) and shall be followed immediately by the first GRC spray.

When a facing coat is used this may be sprayed or poured. This coat may be allowed to stiffen but the first GRC coat must be applied before initial set takes place. Typical thickness is 3-5 mm depending on subsequent treatment e.g. grit blasting or acid etching.

The GRC materials shall be sprayed and built up in thin layers of 3-4 mm until the required thickness is achieved. The sprayed GRC shall be compacted using a flexible hand roller before spraying the next layer. After the final layer has been sprayed the thickness of the GRC shall be checked using a template or depth gauge and compared to the design thickness.

Unless specifically stated in the agreed product manufacturing specification, the design thickness shall be considered as a minimum and no part of the component shall be below this thickness.

Over-thickness will be permitted and is to be expected particularly at corners or areas with a deep profile. It will not be permitted if:

1. Any flat areas exceed the design thickness by 4 mm.
2. The weight of the component exceeds the maximum design weight as specified by the Structural Engineer.

After checking the thickness, any areas of under-thickness shall be re-sprayed and areas of over-thickness removed and the material discarded. The specified finish to the 'back' of the unit shall be applied using a float or roller.

4.2 Manufacture by Premix

4.2.1 Weighing/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 shall be weighed, volume batched or automatically dispensed. The GRC manufacturer shall demonstrate that the method employed will give an accuracy of $\pm 2\%$.

4.2.2 Mixing

The GRC shall be mixed in a two-stage or other suitable mixer. The Producer shall demonstrate that the equipment is suitable for manufacturing premix GRC.

First the cementitious slurry shall be mixed at high speed in an intensive shear mixer or other approved mixer.

The slurry is then transferred to a second mixer

or the mixing action of the shear mixer adapted so that the AR glassfibre is blended uniformly into the slurry. The AR glassfibre may be added manually or automatically as chopped fibres or automatically as AR glassfibre roving using a fibre chopper.

4.2.3 Cast Premix

The premixed GRC material shall be pumped or carried in a holding vessel to the filling station. The material shall then be poured or pumped into the mould ensuring that the method of filling expels the air from the product and planes of weakness are avoided. Compaction may be by internal or external vibration or by the use of a 'self-compacting' mix. The Producer must ensure that the method chosen is consistent with the required surface finish and mechanical properties.

4.2.4 Sprayed Premix

The premixed GRC material may also be sprayed onto or into moulds using specialist sprayed premix equipment. A facing coat or a mist coat may be sprayed first. The GRC material shall be sprayed in layers 3-4 mm and compacted using a flexible hand roller before spraying the next layer. The thickness shall be checked as in 4.1.3

4.3 Storage before demoulding

Filled moulds shall be stored at temperatures between 5° C and 40° C. 'P' grades shall be stored at a temperature higher than the MFFT but below 40° C.

Moulds shall be stored on a level surface and supported in such a manner that they will not bow or twist.

Once the initial set has taken place the mould shall be covered with a sheet of polythene and shall not be moved until demoulding.

4.4 Demoulding [including lifting and fixing]

The GRC component shall not be demoulded until it has gained sufficient strength to be removed from the mould and transported without being over-stressed. The time required will be temperature dependent.

Demoulding shall be carried out in such a manner that no damage occurs to the component. Unique demoulding, lifting and fixings sockets must be suitably embedded in the component.

All embedded items shall be of a suitable material [preferably austenitic stainless steel or non-ferrous] and encapsulated in a block of GRC; size and procedures to be used should be agreed with the Structural Engineer before starting production.

4.5 Curing

4.5.1 Moist curing (for non-polymer grades)

GRC components should be cured at controlled temperature and humidity. Ideally this should be for seven days at 20 °C and 95% RH. This is not always practical and alternative curing regimes are satisfactory providing the Producer demonstrates that the procedure:

1. Enables the component to achieve the physical properties given in Section 8.
2. Ensures that excess shrinkage caused by a too rapid drying of the product does not occur.
3. The curing method is acceptable to the Purchaser and the Structural Engineer.

4.5.2 Curing of polymer grades

Components produced using polymer grades of GRC shall be loosely covered overnight and shall be dry cured after demoulding. Moist curing can be detrimental. Temperature above 35 °C or below 5 °C should be avoided for the first two days after manufacture.

Products shall not be exposed to drying winds or excessive heat for a minimum of two days after production.

4.6 Storage, handling and transport

GRC components shall be stored, handled and transported in such a way that:

1. No part of the component is overstressed.
2. Bowing or twisting is not induced in the component.
3. No damage is caused to any part of the component, particularly edges and corners.
4. No permanent staining or discoloration is caused either by the storage conditions or the stacking/protection material.

For large components, the method of handling, storage, loading and transporting should be agreed with the Structural Engineer.

4.7 Manufacturing tolerances

Architectural GRC components shall be manufactured to the tolerances set out in GRCA technical document “techNOTE 13 GRC Tolerances”.

Tolerances for other types of GRC products (e.g. permanent formwork, drainage channels, roof tiles etc.) should be determined by the manufacturer and/or, where necessary, agreed with the customer.

5 QUALITY CONTROL AND ASSURANCE

5.1 Quality management system

The Producer shall demonstrate that a quality assurance system is operated. This shall comply with the GRCA Full Member Regulations, ISO 9001, or equivalent national standards.

6 SAMPLING

6.1 Sampling and Test Boards

Tests may be carried out on coupons cut from the GRC components themselves but this is not normally practical. It is acceptable to produce a Test Board for testing. This shall be manufactured, demoulded and cured in the same manner as the component it represents. Its quality should be the same as the component, as far as possible.

Test Boards shall be large enough for sufficient coupons to be cut to meet the testing requirements; 500 x 800 mm is recommended so that with spray processes, any directional effects can be identified.

6.2 Frequency

The frequency of production of Test Boards shall be not less than 1 board per day per mixer/pump, for both spray and premix processes. Spray process Test Boards not tested shall be kept for a minimum of one year for any future testing requirements.

7 TESTING

The following tests shall be carried out and the required properties shall be as shown in Tables 3 and 4, and, unless alternative requirements are agreed, shall be as shown in Tables 2a, 2b, & 2c.

7.1 AR glassfibre content

With Simultaneous sprayed processes, the AR glassfibre content shall be determined at the frequency set out in 4.1.3. Testing shall be carried out in accordance with either the GRCA "Methods of Testing GRC Material Part 4", or EN 1170-3, or alternatively "Methods of Testing GRC Material Part 1" or EN 1170-2. Testing to equivalent national standards is permitted in countries where appropriate.

7.2 Limit of proportionality [LOP] and modulus of rupture [MOR]

The LOP and MOR shall be determined at 7

and/or 14 and/or 28 days in accordance with either the "GRCA Methods of Testing Glassfibre Reinforced Concrete (GRC) Material Part 3" or EN 1170-5 or equivalent national standards. 7 and 14 day results shall only be acceptable if they already exceed design requirements.

Additional information such as % Strain to LOP, % Strain to MOR and Young's Modulus provided by modern test equipment shall be recorded for information only.

The minimum LOP and MOR testing frequency shall be:

Spray: Twice per week per spray station or every 10 tonnes of GRC produced, whichever is the greater.

Premix: Once per week per mixer or every 10 tonnes of GRC produced, whichever is the greater.

These frequencies are an absolute minimum and individual manufacturers may elect to test more frequently, as they feel appropriate.

Table 3: Characteristic Values

| GRADE | 8 or 8P | 10 or 10P | 18 or 18P |
|---------------------|----------------|------------------|------------------|
| Characteristic LOP* | 5 | 6 | 7 |
| Characteristic MOR* | 8 | 10 | 18 |

*A minimum of 40 Test Board Mean shall be analysed in the calculation of the Characteristic Values.

7.3 Bulk density, water absorption and apparent porosity

These properties shall be determined in accordance with either the "GRCA Methods of Testing Glassfibre Reinforced Concrete (GRC) Material Part 2" or EN 1170-6 or equivalent national standards. All of these tests shall be carried out a minimum of once per month.

7.4 Other tests

An extremes of dimensional variations test, to EN 1170-7, or suitable alternative, shall be carried out when setting up a new mix design. Other tests of GRC may be carried out as required by the Purchaser, including, full-scale load tests of products and components, fire tests, performance testing of cast-in fixings etc. These tests shall be supervised by the Structural Engineer or GRC Consultant.

8 COMPLIANCE

8.1 General

The constituent materials shall comply with the requirements of Section 2 and the composition of the GRC shall comply with Section 3. The GRC shall be produced and cured in accordance with Section 4. It shall be sampled at a frequency complying with Section 6 and tested in accordance with Section 7. It shall meet the requirements of Section 8.

8.2 Minimum values for compliance

Table 4 indicates minimum LOP and MOR values using in-process inspection results as a guideline for initial compliance only. To conform to this Specification, the manufacturer shall also be able to demonstrate via their testing regime and documentation that analysis shows Characteristic Values as shown in Table 3. This analysis shall form part of their Quality Assurance procedures to be allowable.

If other properties, e.g. density or porosity, are considered to be critical for an application, compliance values and testing frequency shall be agreed between the Purchaser and the Producer.

9 NON COMPLIANCE

9.1 Failure to comply

- a. 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.
- b. Where testing is not carried out on a daily basis retained sample boards (see 6.2) may be tested to determine the extent of the non-compliant product.

9.2 Action in the event of non-compliance

The action to be taken over GRC products that do not comply with this specification shall be determined with due regard to the technical consequences of adopting remedial measures or replacing the rejected products.

In estimating the quality of the sub-standard GRC and in determining the action to be taken, the following should be established, wherever possible.

The validity of the testing shall be confirmed by

checking that the sampling, testing and calculations have been carried out in accordance with this Specification.

- a. That the raw materials and mix proportions used in the GRC under investigation comply with this Specification and/or with those agreed between the Purchaser and the Producer.
- b. That the curing regime adopted before testing complies with the requirements in this Specification. Re-testing of test boards may be appropriate when it is considered that the storage conditions of the product might result in improved properties because of extended curing.
- c. The effect of any reduction in GRC properties on the strength and durability of the product.
Three points should be considered:
 - i. The safety factors adopted in the design.
 - ii. The thickness of GRC produced compared to the design thickness.
 - iii. LOP/MOR strengths required by engineering calculations

Table 4: Minimum strengths

| GRADE | 8 or 8P | 10 or 10P | 18 or 18P |
|--|----------------|------------------|------------------|
| LOP MPa | | | |
| Mean of 4 consecutive test board means | 7.25 | 8.00 | 8.00 |
| Minimum for individual test board mean | 5.75 | 6.00 | 6.00 |
| MOR MPa | | | |
| Mean of 4 consecutive test board means | 9.50 | 12.00 | 21.00 |
| Minimum for individual test board mean | 7.50 | 8.50 | 15.00 |

FURTHER READING

GRCA Specification: “*Specifiers Guide to Glassfibre Reinforced Concrete (GRC)*”.

GRCA MOT: “*Methods of Testing Glassfibre Reinforced Concrete (GRC) Material*”.

GRCA Design Guide: “*Practical Design Guide for Glassfibre Reinforced Concrete (GRC)*”.

GRCA Fixing Guide: “*Practical Fixing Guide for Glassfibre Reinforced Concrete (GRC)*”.

GRCA Full Member Grade: “*Regulations, Membership Procedure and Assessment*”.

GRCA techNOTEs: A series of technical notes are available on most aspects of GRC.

GRCA Congress Proceedings: The International Glassfibre Reinforced Concrete Association (GRCA) holds a database of past GRCA Congress Proceedings, and many other GRC related publications, which are generally available to download free at www.grca.online.

GRCA Publications: See www.grca.online for up to date list of GRCA Publications.

The Concrete Bookshop

Web: www.concretebookshop.com

NBS Specification H40: *Glassfibre reinforced concrete cladding components.*

European Standards (NB: British versions of European Standards will be prefaced BS EN)

EN 197: Parts 1 & 2: *Cement.*

EN 480: Various Parts: *Admixtures for concrete, mortar and grout. Test methods.*

EN 934: Various Parts: *Admixtures for concrete, mortar and grout. Requirements.*

EN 1008: *Mixing water for concrete.*

EN 1169: 1999: *Precast concrete products — General rules for factory production control of glass-fibre reinforced cement products.*

EN 1170: Parts 1-8 *Precast concrete products: Test methods for glass-fibre reinforced cement.*

Part 1: *Measuring the plasticity of the mortar— 'Slump test' method.*

Part 2: *Measuring the fibre content in fresh GRC, Wash out test'.*

Part 3: *Measuring the fibre content of sprayed GRC.*

Part 4: *Measuring bending strength — 'Simplified bending test' method.*

Part 5: *Measuring bending strength — 'Complete bending test' method.*

Part 6: *Determination of the absorption of water by immersion and determination the dry density*

Part 7: *Measurement of extremes of dimensional variations due to moisture content.*

Part 8: *Cyclic weathering type test*

EN 13139: *Aggregates for mortar. NB: 2013 version is currently withdrawn.*

EN 14649: *Precast concrete products — Test method for strength retention of glass fibres in cement and concrete (SIC TEST).*

EN 15191: *Precast concrete products. Classification of glassfibre reinforced concrete performance.*

EN 15422: *Precast Concrete Products - Specification of glassfibres for reinforcement of mortars and concretes.*

USA

Prestressed Concrete Institute (PCI)

Tel: +1 312 786 0300

Web: www.pci.org

MNL-128: *Recommended Practice for Glass Fiber Reinforced Concrete Panels.*

MNL-130: *Manual for Quality Control for Plants and Production of Glass Fiber Reinforced Concrete Products.*

PCI-128: *Specification For Glass-Fiber-Reinforced Concrete Panels.*

American Concrete Institute (ACI)

Tel: +1 248 848 3800

Web: www.concrete.org

549.3: *Report on Glass Fiber-Reinforced Concrete Premix.*

549.5: *Report on Spray-up and Continuous Strand Glass Fiber Reinforced Concrete (GFRC).*

ASTM

C948: *Standard Test Method for Dry and Wet Bulk Density, Water Absorption, and Apparent Porosity of Thin Sections of Glass-Fiber Reinforced Concrete.*

C1228: *Standard Practice for Preparing Coupons for Flexural and Washout Tests on Glass Fiber Reinforced Concrete.*

C1229: *Standard Test Method for Determination of Glass Fiber Content in Glass Fiber Reinforced Concrete (GFRC) (Wash-Out Test)*

C1230: *Standard Test Method for Performing Tension Tests on Glass-Fiber Reinforced Concrete (GFRC) Bonding Pads.*

C1560: *Standard Test Method for Hot Water Accelerated Aging of Glass-Fiber Reinforced Cement-Based Composites.*

C1666: *Standard Specification for Alkali Resistant (AR) Glass Fiber for GFRC and Fiber-Reinforced Concrete and Cement.*

AUSTRALIA

National Precast Concrete Association Australia (NPCAA)

Tel: +61 08 8294 0833

Web: www.npcaa.com.au

Recommended Practice – Design, Manufacture and Installation of Glass Reinforced Concrete (GRC).

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