Methods of Testing Glassfibre Reinforced Concrete (GRC) Material.

The International Glassfibre Reinforced Concrete Association (GRCA)

October 2017

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GRCA METHODS OF TESTING GLASSFIBRE REINFORCED CONCRETE (GRC) MATERIAL

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FOREWORD

Glassfibre Reinforced Concrete (GRC) is an important building material which came into prominence in the early 1970`s.

The GRCA Methods of Testing Glassfibre Reinforced Concrete (GRC) Material define the procedures to be used when testing GRC as a material. The methods given here are those normally used in Quality Control situations and it is the intention of the GRCA to issue other standard test procedures covering different properties where necessary. Tests on the constituent material of GRC are not included in this standard. Also, certain products or applications using GRC may require different test on the finished products. These are outside the scope of this document.

In its preparation the GRCA Technical Group has kept in touch with organisations preparing GRC Standards in other countries in an attempt to ensure that the procedures given here do not differ markedly from those used outside the UK.

PART 1 DETERMINATION OF GLASS CONTENT OF UNCURED GLASSFIBRE REINFORCED CONCRETE (GRC) MATERIAL

1.1 Scope

This standard describes a method for the determination of the glass content (by weight) of GRC material in the uncured, green state.

1.2 Definitions

For the purpose of this GRCA Standard, the following definitions apply.

1.2.1 Green State
The stage in the manufacture of GRC when all physical processes which would after the composition of the material are complete, whilst permitting the fibre to be separated from the matrix by the action of running water.

This is usually up to 2 hours after manufacture under ambient conditions.

1.3 Apparatus

1.3.1 A laboratory balance capable of weighing 1000 grams in increments of 0.1 grams.

1.3.2 A laboratory oven equipped with forced air circulation and ventilation, capable of achieving a temperature of at least 300 ºC.

OR

A laboratory muffle furnace equipped with ventilation, capable of achieving a temperature of 500 ºC ± 20 ºC.

1.3.3 Mesh baskets (175 mm long x 100 mm wide x 25 mm deep) made from 3 mm stainless steel mesh.

1.4 Test Specimen

The test specimens shall be taken from the finished product or, where this is not practicable, from a test board prepared so that it represents the product in composition, manufacturing process and thickness.

The specimen shall be cut from the green state using a sharp knife or other means resulting in the test specimen having clean, cut edges.

1.4.1 Dimension of test specimens.
The specimen size shall be nominally 150 mm x 50 mm.

1.4.2 Number of test specimens.

Not less than 3 test specimens shall be taken from a product or test board to obtain a mean glass content for that product or test board. The specimens should be chosen so as to be as representative as possible of the total area of the product or test board.

1.5 Procedure

Perform the test immediately after cutting the specimen from the product or test board. Place a dry weighed mesh basket (M_1) and record the total mass (M_2). Hold the basket under a stream of running water and work the GRC with the fingers to break it up (care must be taken to ensure that no glass is lost).

When all the cement and other solid particles other than the glass fibres have been washed away, dry the basket and its contents to constant weight using either a laboratory oven at a temperature above 300ºC (approx. 1 hours) or a muffle furnace at a temperature not greater than 520ºC (approx. 5 minutes). On removing the basket and its contents from the oven furnace, allow it to cool to room temperature (preferably in a desiccator).

Check that the glass is clean and if necessary remove any residual sand by working the glass fibre by hand and shaking the tray.

Record the mass (M_3).

1.6 Calculation and Expression of Results

1.6.1 Glass Content (by weight)

The glass content (by weight) is calculated using the formula.

$$\text{Glass content (\%w/w)} = \frac{[(M_3 - M_1)}{(M_2 - M_1)]} \times 100$$

where M1 = Mass of basket (grams)
M2 = Mass of basket + specimen (grams)
M3 = Mass of basket + dry glass (grams)

1.7 Test Report

The test report shall include a reference to this standard and the following particulars, as necessary.

1.7.1 Product or test board identification mark, date of test and other pertinent data concerning the tested material.

1.7.2 The number of test specimens taken as a sample.

1.7.3 The arithmetic mean value of the glass content of all the results from the product or board tested and the range of results.

PART 2 DETERMINATION OF THE DRY AND WET BULK DENSITY, WATER ABSORPTION AND APPARENT POROSITY OF GLASSFIBRE REINFORCED CONCRETE (GRC) MATERIAL

2.1 Scope

This standard describes a single method for the determination of dry and wet bulk density, water absorption and apparent porosity of GRC material.

2.2 Apparatus

2.2.1 A laboratory balance capable of weighing 1000 grams in increments of 0.1 grams. The balance must be capable of weighing a test specimen suspended in water.

2.2.2 A suitable holder for suspending the test specimen in water.

2.2.3 A laboratory oven, equipped with forced air circulation, capable of achieving a temperature of 110 ºC ± 5 ºC.

2.2.4 A desiccator capable of holding several 100 mm x 100 mm test pieces.

2.3 Test Specimen

The test specimen shall be taken from the finished product or, where this is not practicable, from a test board prepared so that it represents the product in composition manufacturing process, curing or thickness.

2.3.1 Dimensions of test specimen. The specimen size shall be not less than 50 mm x 50 mm (nominal sizes) and preferably 100 mm x 100 mm.

The test specimens shall be cut out from the cured finished product or cured test board using a silicon carbide saw or other appropriate equipment.

2.3.2 Number of specimens. Not less than two test specimens shall be taken from a product or test board to obtain mean values for the product or the test board. The test specimens should not be taken from adjacent areas. The specimen should be free from visible cracks, fissures or broken edges.

2.4 Procedure

Immerse the specimen in fresh water until a constant weight is achieved. [This typically takes 7 days]. Determine the mass of the specimen suspended in water (M_1). Remove the specimen from the water, quickly remove the surface water with a paper towel and immediately weigh the specimen in air (M_2).

Heat the specimen in an oven at a temperature of 110 ºC ± 5 ºC to constant weight [this typically takes 7 days]. Remove the specimen from the oven, allow to cool in a desiccator to room temperature and weigh (M_3).

2.5 Calculation and Expression of Results

The properties are calculated using for the following formulae.

2.5.1 Dry Bulk Density

$$\text{Dry bulk density (kg / m}^3\text{)} = \frac{M_3}{M_2 - M_1} \times 1000$$

2.5.2 Wet Bulk Density

$$\text{Wet bulk density (kg / m}^3\text{)} = \frac{M_2}{M_2 - M_1} \times 1000$$

2.5.3 Water Absorption

$$\text{Water Absorption (\% by weight)} = \frac{M_2 - M_3}{M_3} \times 100$$

2.5.4 Apparent Porosity

$$\text{Apparent porosity (\% by volume)} = \frac{M_2 - M_3}{M_2 - M_1} \times 100$$

2.6 Test Report

The test report shall include a reference to this standard and the following particulars, as necessary.

2.6.1 Product or test board identification mark, date of test and other pertinent data concerning the tested material.

2.6.2 The number of test specimen taken as a sample.

2.6.3 The arithmetic mean value of the water/solid ratio of all the results from the product or board tested and the range of results.

PART 3 DETERMINATION OF FLEXURAL PROPERTIES OF GLASSFIBRE REINFORCED CONCRETE (GRC) MATERIAL

3.1 Scope

This standard describes a method for the determination of the limit of proportionality (LOP) and the modulus of rupture (MOR) of GRC material in the form of rectangular bars cut from sheets or moulded directly.

NOTE – This four point loading imposes pure bending forces over the middle third of the test specimen and is preferred to the three point loading test where the stress is concentrated at the centre.

This procedure relates to the use of a typical universal tensile test machine where the load deflection curve is recorded automatically.

3.2 Definitions

3.2.1 Limit of Proportionality [LOP]
The flexural stress developed when initial part of the load/deflection curve deviates from linearity. (See Fig. 1).

3.2.2 Modulus of Rupture [MOR]
The flexural stress developed when load reaches the maximum. (See Fig. 1).

3.3 Apparatus

3.3.1 Standard testing machine properly constructed and calibrated, which can be operated at a constant crosshead rate and in which the error for indicated loads does not exceed ± 1% and for indicated deflections not exceed 2%. The machine shall comply with the requirements of BS EN ISO 7500 2004.

3.3.2 A bending test jig (shown schematically in Fig. 2). The supports and loading rollers shall be at least as wide as the test specimen and be designed such that the forces applied to the specimen will be perpendicular to the surface of the specimen and applied without eccentricity. The radius of the loading rollers shall be at least 6 mm.

The distance between the supports, L, should be adjustable.

3.4 Test Specimen

The test specimens shall be taken from the finished product or where this is not practicable from a test board prepared so that it represents the product in composition manufacturing process curing and thickness.

The test specimens shall be cut from the cured finished product or cured test board using a silicon carbide saw or other appropriate equipment with water cooling. The specimens

shall be rectangular with parallel sides which are perpendicular with the mould or machine face of the specimen.

3.4.1 Dimensions of Test Specimens

The length of the specimen shall be not less than 25 mm and not more than 50 mm greater than the major span dimension given in the Table 1 for the thickness of the specimen.
[Typically, the thickness is 8-10 mm and no greater than 12.5 mm].

The width 'b' should be 50 mm ± 2 mm.

3.4.2 Anisotropic Materials

If the GRC is known to exhibit anisotropy in the plane of the sheet and the direction in which the greatest strength lies is known from the experience of the manufacturing procedure then test specimens (in accordance with Section 5) shall be taken whose length is parallel to that direction and test specimens (in accordance with Section 5) shall also be taken whose length is normal to that direction.

The direction of the greatest strength should be marked on the sheet before testing.

3.5 Number of Test Specimens

3.5.1 At least 4 test specimens should be used. Two of these should be tested with the mould or machine face of the specimen in contact with the major span rollers and two should be tested with the minor span rollers.

3.6 Procedure

3.6.1 Test Condition

The test specimens shall be either wet conditioned by soaking in water at room temperature for a period of between 4 and 24 hours and tested wet, or shall be dry conditioned at room temperature for a period of between 4 and 24 hours and tested dry.

If wet testing, perform the test within 5 minutes of removing the specimens from the soaking procedure. Removing the surface water with a towel is permitted.

3.6.2 Testing Procedure

3.6.2.1 Set the major and minor spans of the test jig to correspond with Table 1 (See Fig. 2 also). The loading rollers and supports should be aligned so that the axes of the cylindrical surface are parallel.

3.6.2.2 Place the test specimen symmetrically across the two parallel supports ensuring that the length of the test specimen is at the right angles to

each of these and that equal lengths of the specimens project outside of the rollers.

3.6.2.3 Adjust the testing machine so that the crosshead speed corresponds with Table 1.

3.6.2.4 Apply the load at constant crosshead speed to failure continuously recording the load/deflection curve. The load range should be chosen so that the LOP load occurs at not less than 30% of the full scale load range.

3.6.2.5 *Record the load (W_1), at which the load/deflection curve deviates from linearity (LOP load) and also the maximum load (W_2) obtained (MOR load). *Automatic on most current testing machines.

3.6.2.6 Separate the failed test piece and measure the specimen thickness at the failure zone in 3 places to the nearest 0.1 mm. Take the average. Measure the specimen width to the nearest 0.1 mm. These measurements should be taken at or near the failure location taking care not to choose places where the specimen may have expanded during the test.

3.7 Calculation and Expression of Results *

3.7.1 Limit of Proportionality

The limit of proportionality is calculated in MPa using the equation:

$LOP = W_1L / bd^2$

Where W_1 = LOP load, i.e. load at which the load/deflection curve deviates from linearity. (Newtons)

L = Major span (mm)

b = Width (mm)

d = Thickness (mm)

3.7.2 Modulus of Rupture

The modulus of rupture is calculated in MPa using the equation:

$MOR = W_2L / bd^2$

Where W_2 = MOR load (Newtons)

L = Major span (mm)

b = Width (mm)

d = Thickness (mm)

3.7.3 Directionality Ratio

Where anisotropic material is tested, the ratio of the mean value for both LOP and MOR from each direction shall be given as the Directionality Ratio.

** Purpose built testing equipment can be purchased with built in software which will automatically calculate the LOP and MOR PLUS Strain to LOP, Strain to MOR and Young's Modulus.*

3.8 Test Report

The test report shall include a reference to this standard. The report shall also refer to the following particulars, as necessary.

3.8.1 Product or test board identification mark, date of test, polymer or non polymer, tested wet or dry (see 3.6.1), and other pertinent data concerning the material.

3.8.2 The number of test specimens taken as a sample.

3.8.3 The direction from which the specimens were taken, if anisotropic material is tested.

3.8.4 The individual values of the LOP and MOR for each specimen tested.

3.8.5 The minimum and arithmetic mean value of the LOP and MOR with

(a) Mould face of the specimens in contact with the major span supports.

(b) Trowel face of the specimens in contact with the major span supports.

3.8.6 The minimum and overall arithmetic mean of LOP and MOR calculated from all the specimens tested.

Table 1: Major and minor span and crosshead speed for various specimen thicknesses.

Nominal Specimen Thickness (mm)	**Major Span (mm)**	**Minor Span (mm)**	**Crosshead Speed (mm/min)**
Up To 6.7	135	45.0	1.5 – 3.0
6.8 - 10.0	200	66.7	1.5 – 3.0
10.1 - 12.5	250	83.3	1.5 – 3.0
12.6 - 15.0	300	100.0	3.0 – 5.0
15.1 - 17.5	350	116.7	3.0 – 5.0
17.6 - 20.0	400	133.3	3.0 – 5.0

Fig 1 Typical Load Deflection Curve

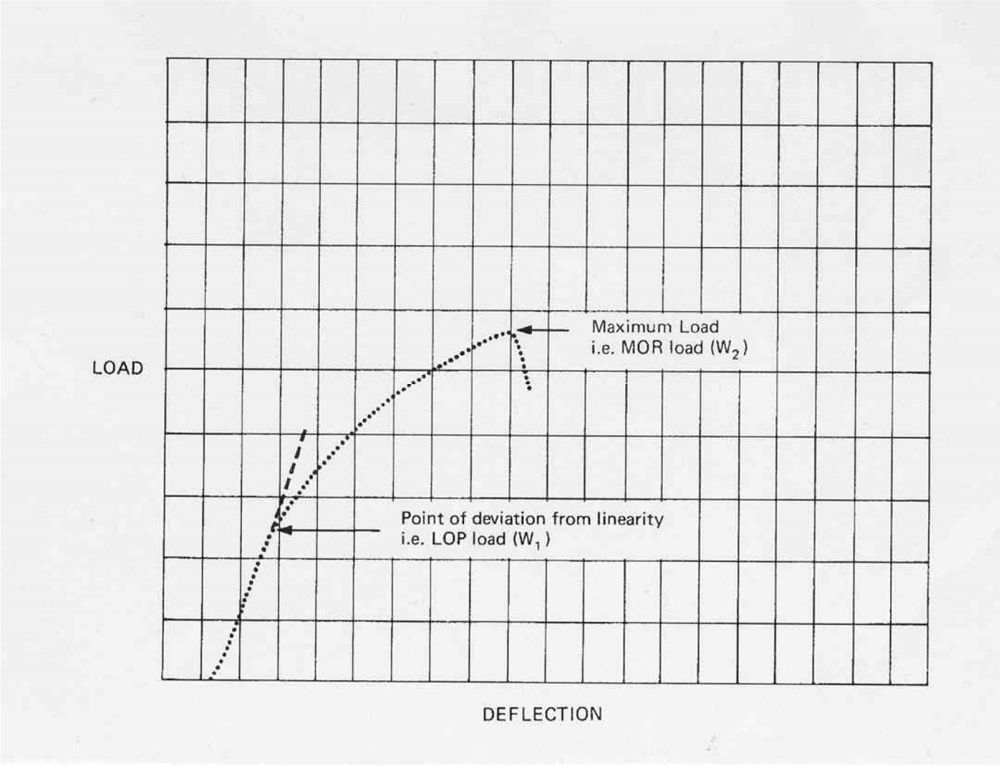
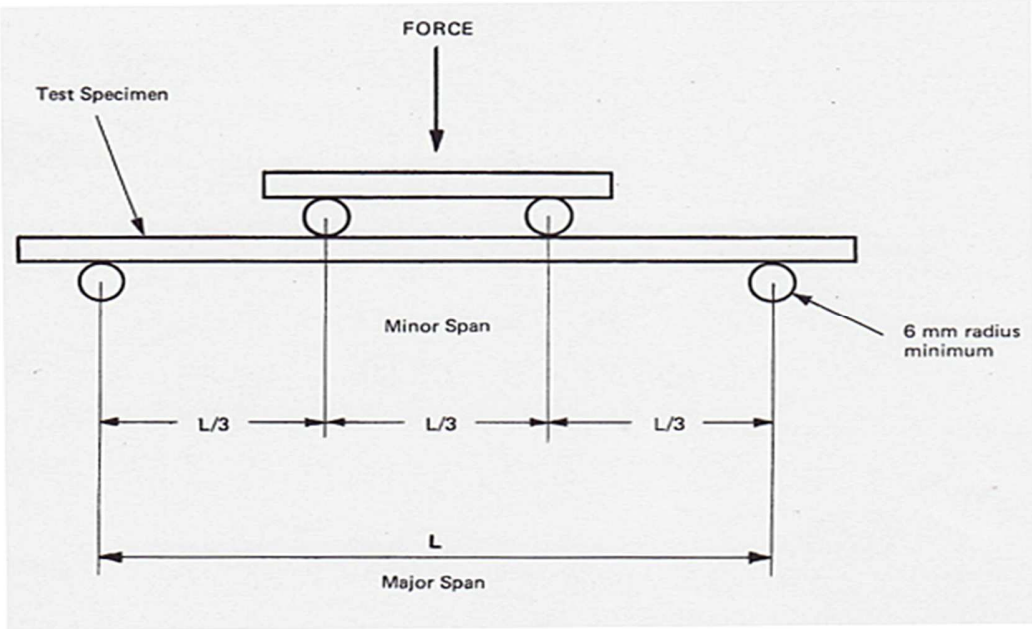


Fig 2 Diagram of Test Jig for loading GRC Diagram



PART 4 CALIBRATION OF GRC SPRAY EQUIPMENT

The strength of GRC composites depends upon the glass fibre content, which for all hand spray operations is generally about 5% by weight of finished product.

Before starting to spray, it is necessary to calibrate the slurry spray and glass depositor outputs using the Bag and Bucket Tests.

For a typical 12 kg/minute slurry output, the glass depositor output should be roughly 630 g/minute.

(In some specifications 5% is the minimum glass content allowed. In this case it is suggested to use a target glass content of 5.3%).

4.1 Bag Test

This is used to set the delivery of the correct amount of chopped fibre from the glass depositor.

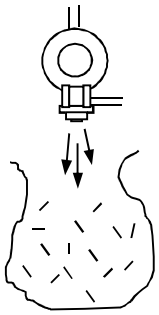
4.1.1 Apparatus

4.1.1.1 Laboratory balance capable of weighing 1000 grams in increments of 0.1 grams.

4.1.1.2 Plastic Bag, 600 mm x 1000 mm approximately.

4.1.2 Method

This should be carried out under actual running conditions.



4.1.2.1 Weigh empty bag (W grams).

4.1.2.2 Chop glass into bag for 15 seconds.

4.1.2.3 Weigh bag and fibre (G grams).

4.1.2.4 Glass output = (G – W) x 4 g/minute.

4.1.2.5 Adjust air pressure to glass depositor until required output is achieved, - note pressure setting.

4.2 Bucket Test

This is used to measure the output from the slurry spray.

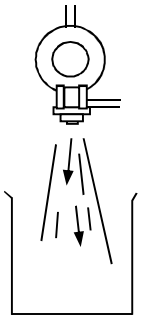
4.2.1 Apparatus

4.2.1.1 Laboratory balance capable of weighing 12kg in increments of 50 grams.

4.2.1.2 Plastic Bucket, minimum 10 litre capacity.

4.2.2 Method

This should be carried out under actual running conditions.



4.2.2.1 Weigh empty bucket (W grams).

4.2.2.2 Spray slurry into bucket for 30 seconds.

4.2.2.3 Weigh bucket and slurry (S grams).

4.2.2.4 Slurry output = (S – W) x 2 kg/minute.

4.2.2.5 Adjust pump output until required output is achieved,
- note pump setting.

(An alternative method for measuring the fibre content of fresh GRC and calibrating the equipment is contained in BS EN 1170 – 3 Measuring the fibre content of sprayed GRC)

Continued on Page 16

Table 2: Bag and Bucket Calibration Table (for 5% glass content)

Glass Output:	g / l5 secs	kg / min	Slurry Output:	kg / min	kg / 30 secs
	130.0	0.52		9.88	4.940
	132.5	0.53		10.07	5.035
	135.0	0.54		10.26	5.130
	137.5	0.55		10.45	5.225
	140.0	0.56		10.64	5.320
	142.5	0.57		10.83	5.415
	145.0	0.58		11.02	5.510
	147.5	0.59		11.21	5.605
	150.0	0.60		11.40	5.700
	152.5	0.61		11.59	5.795
	155.0	0.62		11.78	5.890
	158.0	**0.632**	**Typical Output for Concentric Guns**	**12.00**	**6.000**
	160.0	0.64		12.16	6.080
	162.5	0.65		12.35	6.175
	165.0	0.66		12.54	6.270
	167.5	0.67		12.73	6.365
	170.0	0.68		12.92	6.460
	172.5	0.69		13.11	6.555
	175.0	0.70		13.30	6.650
	177.5	0.71		13.49	6.745
	180.0	0.72		13.68	6.840
	182.5	0.73		13.87	6.935
	185.0	0.74		14.06	7.030
	187.5	0.75		14.25	7.125
	190.0	0.76		14.44	7.220
	192.5	0.77		14.63	7.315
	195.0	0.78		14.82	7.410
	197.5	0.79		15.01	7.505
	200.0	0.80		15.20	7.600
	202.5	0.81		15.39	7.695
	205.0	0.82		15.58	7.790
	207.5	0.83		15.77	7.885
	210.0	0.84		15.96	7.980
	212.5	0.85		16.15	8.075

Calculated Examples:

a) **Glass Output**

$$\frac{\text{Slurry Output (kg/min) x Glass Content (\%)}}{\text{100 - Glass Content \%}} \text{ kg/minute}$$

Example of Glass Output Calculation

If the Glass Content should be 5% and the Slurry Output is 12.6 kg/minute, the required Glass Output should be:

$$= \frac{12.6 \times 5}{95} = 0.663 \text{ kg/min} = 166 \text{ g / 15 seconds.}$$

b) **Slurry Output**

$$\frac{\text{Glass Output (kg/min) x \{100 -Glass Content (\%)\}}}{\text{Glass Content \%}} \text{ kg/minute}$$

Example of Slurry Output calculation

If the Glass Output is 0.7 kg/minute and the Glass Content should be 5%, the required Slurry Output should be:

$$= \frac{0.7 \times 95}{5} = 13.3 \text{ kg/minute.}$$

1. The chopped fibres from the Bag Test are scrap and are not suitable for premix.
2. The slurry can be returned to the pump hopper.
3. The Bag and Bucket Test should be carried out whenever there is a change in the mix, whether deliberate or accidental.

PROCEDURE

1. Set the glass depositor air pressure gauge to the required level.
2. Carry out the Bag Test for the glass fibre.
3. Read the required Slurry Output from the Table on the previous page.
4. Set Slurry Output using Bucket Test.

Note:

If the glass depositor output falls when using the same air pressure then the air motor or the filter to the air motor requires maintenance, or the oil bottle feeding the air motor has run dry.

PART 5 MEASURING FLOW OF SLURRY - SLUMP TEST

Note. This test is not always suitable for polymer mixes.

This is a useful check on the sprayability of a mix. It is quick and easy to perform.

5.1 Equipment

Open-ended Perspex Tube	Internal Ø 57 mm, External Ø 65 mm, Length 55 mm.
Perspex Target Plate	30 cm x 30 cm engraved with a series of concentric circles of diameters 65, 85, 108, 125, 145, 165, 185, 205 and 225 mm, numbered 0-8 respectively.

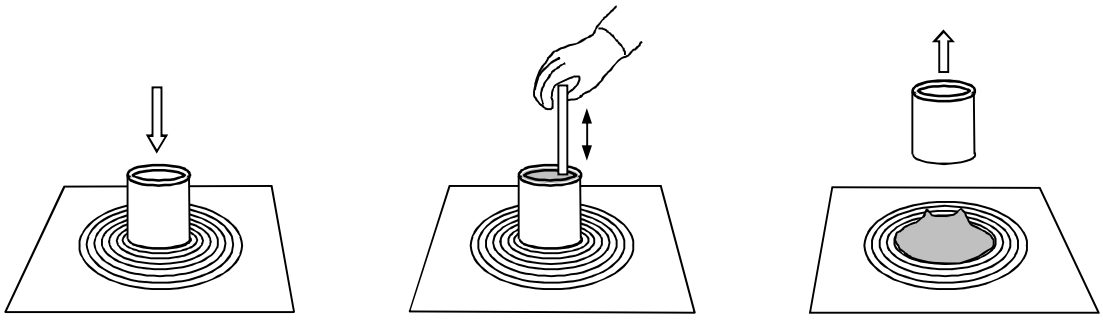
5.2 Method

The plastic tube is placed centrally onto the Plexiglas target plate and filled with slurry. If necessary, air bubbles are expelled by gently tamping the mix. The slurry top should be levelled with the edge of a spatula.

The tube is lifted vertically off the plate with a slow continuous motion allowing the slurry to flow over the concentric circles on the target plate. The slump is measured by the number of rings covered by the slurry. Standard formulations normally give 2-3 rings but it is for the manufacturer to achieve consistent results for the mix that they require.

The consistency of the mix can affect the spray characteristics and hence the pressures used in atomisation.

Maintaining a constant slump means that the sprayability of the mix will be constant. This will make spraying easier and should make compaction more efficient.



The consistency and quality of the mix can be affected by:

Cement age and type: Cold cement – low strengths
Warm cement – false sets

Sand grading:	Use the correct clean and dry grade

(Dirty or wet sand can affect workability and strength.
A high fines content increases water demand as does the presence of clay particles).

Water temperature:	Too cold – can retard the setting
	Too hot – can cause the mix to “flash” set
Superplasticisers:	Match the most suitable superplasticisers with the cement so as to obtain the best extended slump values.
Polymer:	Store in the conditions recommended by the supplier.
Mixing time:	By attaching an ammeter on the mixer the power required to mix the formulation can be monitored more closely and consistent viscosity mixes can be provided

Any change in consistency during spraying should immediately be reported to the management and checks made on the slurry output and quality.

N.B. If a ‘false set’ occurs in the mixer, stop mixing for 30 seconds and then re-mix for 30 seconds.

FURTHER READING

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

GRCA "Specifiers Guide to Glassfibre Reinforced Concrete"

GRCA "Assessment of GRC Test Results"

GRCA "Approved Manufacturer Scheme (AMS) Regulations"

Other GRCA Publications: See www.grca.org.uk for up to date list of publications.

The Concrete Bookshop
Tel: 07004 607777 (UK only) or +44 (0)1276 607140
Email: enquiries@concretebookshop.com
Web: www.concretebookshop.com

In addition, The International Glassfibre Reinforced Concrete Association (GRCA) holds a database of past GRCA Congress Proceedings and many other GRC related publications including some free downloads. Web: www.grca.org.uk.

NBS Specification H40 May 2002 *Glassfibre reinforced concrete cladding components.*

European Standards

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

BS EN 1170: 1998: *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

BS EN 14649: 2005 *Precast concrete products — Test method for strength retention of glass fibres in cement and concrete (SIC TEST).*

BS EN 15422: 2008 *Precast Concrete Products - Specification of glassfibres for reinforcement of mortars and concretes.*

BS EN 1169: 1999. *Precast concrete products – General rules for factory production control of glassfibre reinforced cement.*