DEKO

شركة ديكو مصر للإنشاءات الحديثة

GRC

Physical properties
Technical Data
Design Stresses

with compliance to

GRCA
GLASSFIBRE REINFORCED CONCRETE ASSOCIATION INTERNATIONAL

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عنوان مصنع بلبيس : مدخل غيتة - قرية السلام - بلبيس الشرقية .
عنوان مصنع ستايل : طريق بلبيس العاشر - من ميدان الطائرة - بجوار مخزن العلا للحديد والصلب

NOMENCLATURE

σ	*root mean square*
x'	*sample mean*
F_d	*ultimate design load*
F_k	*ultimate characteristic load*
γ_k	*ultimate partial factor of safety*
f_d	*ultimate design strength*
f_k	*ultimate characteristic strength*
$\gamma_{f'}$	*ultimate partial load factor*
γ_{tv}	*ultimate partial factor to account for variations in thickness of GRC*
γ_b	*ultimate partial factor to account for differences in bending between test coupons and full size sections*
γ_c	*ultimate partial factor to account for mode of collapse and consequences of failure*
F_{sk}	*serviceability characteristic load*
F_{sd}	*serviceability design load*
γ_m	*serviceability global factor of safety*
γ_{ss}	*shrinkage stress*
γ_{ts}	*thermal stress*

2

PHYSICAL PROPERTIES OF GRC

GRC is not a single material and its properties can be varied to suit the end use. The design process should recognise this and specify the grade of GRC based upon the required physical properties. The physical properties of GRC are dependent on the composition of the cementitious slurry, the fibre content and the method of manufacture and curing.

The GRCA classifies GRC into 3 grades of material based on the 28 day flexural strength.

These are Grade 18, Grade 10 and Grade 5 and there are significant differences between them as illustrated by the following load deflection curves.

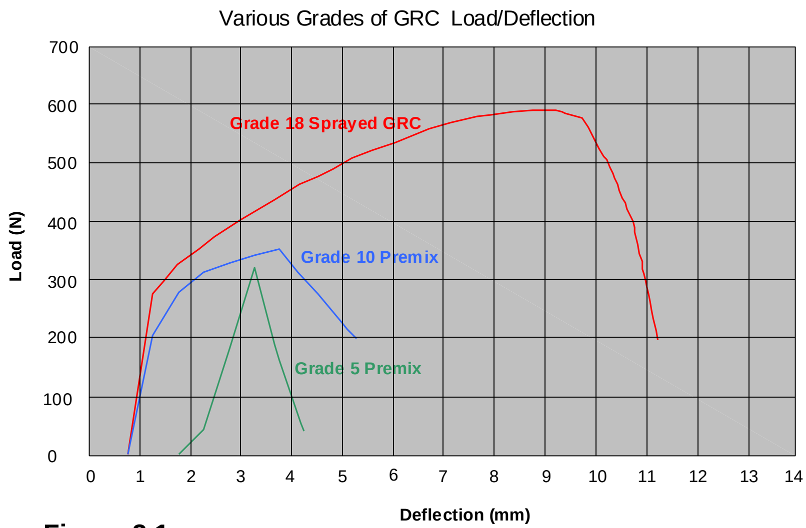

Figure 2.1

The importance of selecting the appropriate grade consistent with the application and the engineering design of the product cannot be over-emphasised.

2.1 Effects of Mix Composition and Fibre Content

The simplest mix design of GRC contains cement, sand, water, superplasticiser, and alkali resistant glass fibre.

Variations such as the use of pozzolanic cement replacements (PFA, Pulverised Fuel Ash) are common in a number of countries and acrylic polymer emulsions are widely used to allow “dry curing”. Pigments can used to impart colour as with traditional concrete.

In terms of effect on strength properties, the quantity and form of AR glassfibre used in the GRC is a significant factor, linked to the process by which it is introduced. Sprayed GRC is the strongest material and typically incorporates 4-5% of glassfibres, of length 25 - 40mm. GRC manufactured by the premix (vibration casting) method typically incorporates between 2% and 3.5% of glassfibres by weight, of usual length 12 - 13mm.

2.2 Flexural Strength.

General

Flexural strength is probably the most important physical property of GRC. It is the property that is most frequently tested and is the property on which most designs are based. Whereas concrete would be referred to in terms of its compressive strength e.g.

Values cannot be assumed and flexural testing should be a part of a quality assurance programme for all manufacturers.

C40/50, GRC is categorised by its flexural strength. Grade 18 would mean a characteristic flexural strength (Modulus of Rupture) of $18N/mm^2$ at 28 days.
The flexural strength depends on many factors, glass percentage, mix design, method of manufacture and curing all being important. Values cannot be assumed and flexural testing should be a part of a quality assurance programme for all manufacturers.

Test Method

The flexural strength of GRC is tested using a four point bending test. The test is described in
"GRCA Methods of Testing Glass Fibre Reinforced Cement Material" and the following standards:
BS EN 1170 PARTS 4 and 5
ASTM C947 MODIFIED

Table 2.1 - Test Values at 28 days

Type of GRC	LOP (N/mm^2)	MOR (N/mm^2)
Sprayed	5 - 10	18 - 30
Premix	5 - 10	5 - 14

2.3 Tensile Strength

General

Historically it has proved difficult to achieve reproducibility from tensile testing results on GRC samples and because of this the flexural test has assumed more importance. Tensile testing is not normally carried out as part of routine quality control.

Test Method

There is no standardised test method although there are published research papers on the subject.

Table 2.2 - Test Values

Type of GRC	BOP (N/mm^2)	UTS (N/mm^2)
Sprayed	4 - 6	8 - 12
Premix	3 - 5	3 - 6

2.4 Shear strengths

General

Testing for Shear strengths is not part of routine testing although for some products it can be a significant factor in design. This is particularly the case with the bearing of permanent formwork, in webs or ribs of single skin cladding and for fixings.

Test Method

No specific method for GRC

Table 2.3 - Test Values

Type of GRC	Punching Shear (N/mm^2)	In Plane Shear (N/mm^2)	Interlaminar Shear (N/mm^2)
Sprayed	25 - 35	7 - 12	2 - 4
Premix	4 - 6	4 - 6	4 - 6

2.5 Shrinkage and Creep

General

Shrinkage

All cement based materials are susceptible to dimensional changes as they are wetted and dried. After manufacture and cure, shrinkage from the original state occurs as drying takes place. Re-wetting results in expansion but not to the extent of restoring the original size: there is therefore an initial irreversible shrinkage, which will be followed in subsequent service conditions by a reversible dimensional movement dependent on the moisture content of the cement. For GRC the irreversible shrinkage is one quarter to one third of the total possible shrinkage: typical figures for a 1:1 sand:cement ratio GRC mix are 0.03% irreversible shrinkage and a total ultimate shrinkage of about 0.12%. The shrinkage and moisture movement behaviour are represented diagrammatically

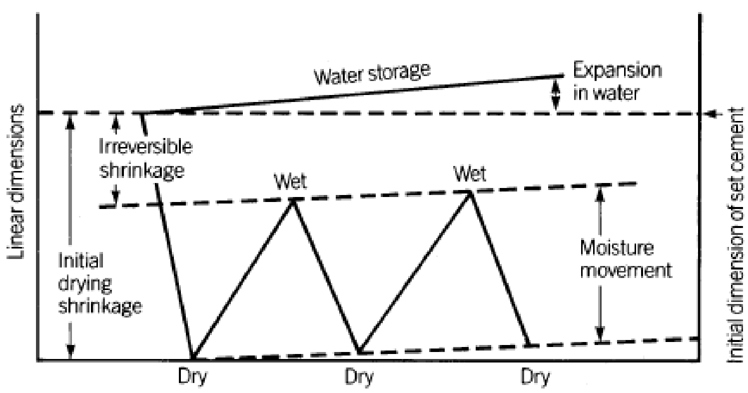

Figure 2.2a - Diagrammatic representation of moisture movements.

It should be noted that the amplitude of reversible movement quoted above is between fully-dried and fully-soaked conditions, as in the laboratory. In practice these extremes may not be experienced in normal weathering conditions although there will be some cyclic movement about a mean level which is effectively shrunk relative to initial manufactured dimensions.

The moisture content of the material is related to the relative humidity of the surroundings, so it is convenient to express the dimensional change in terms of relative humidity. Figure 2.2 (a) shows the reversible shrinkage obtained when neat cement GRC is completely dried from equilibrium with any value of relative humidity (based on published data).

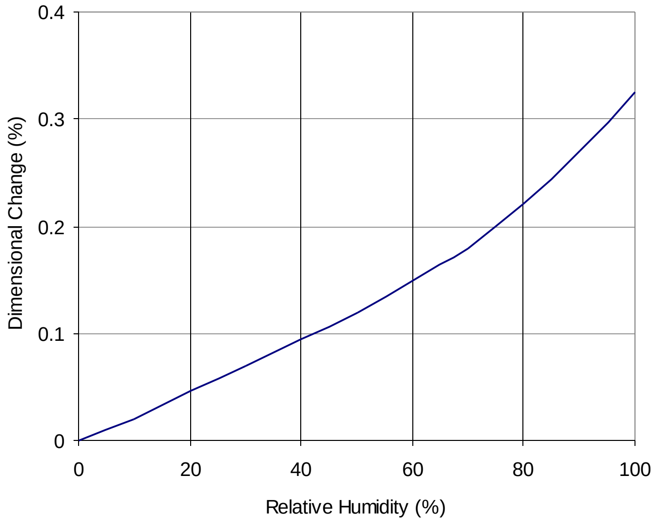

Figure 2.2(b)

Test Method

BS EN 1170 -7

Values

Total ultimate shrinkage up to 0.2% depending on mix design.

Design Values

An understanding of the magnitude of shrinkage and moisture movements is fundamental to the design process particularly with regard to the fixings. In general an allowance of 1 to 1.5 mm per metre of product dimension must be allowed for in terms of joint design and fixing movement.

2.6 Impact Resistance

General

GRC resists Impact loads very well and when damage does occur it is restricted to a localised area. The presence of the fibres in GRC restricts the propagation of cracks outside the zone of stressed material. This damage can often be repaired with no detriment to the GRC products.

The impact strength of GRC is high when many long fibres fail by being pulled out of the matrix, this process absorbing a great deal more energy than fibre breakage. The impact strength of GRC is lower when few fibres are pulled out of the GRC. If the fibres have a very short critical length the GRC may exhibit brittle characteristics under impact loads.

Test Method

Impact strength of GRC is normally measured using a modified Izod or Charpy test machine, on samples 25-50 mm wide and 6-12 mm thick. The values obtained in such a test are not readily used in any design calculation but are useful for the purpose of comparison with samples of GRC and other materials subjected to the same test. Such comparisons show the impact strength of GRC to be higher than that of many similar materials.

Of more significance is testing done on actual products to simulate real conditions that the product may have to face. These tests are product specific and often designed to cover one set of circumstances with the impact load being supplied by either a dropping or swinging weight.

Table 2.4 - Typical values obtained at 28 days

Type of GRC	Charpy Impact Strength ($N/mm/mm^2$)
Sprayed	15 - 25
Premix	7 - 12

Design Values

Calculations are difficult and so are rarely performed. As above, Impact Strength of GRC is good and is not normally a significant factor in design.

2.7 Density, Water Absorption and Permeability

General

The density of standard GRC materials is commonly around 2000 kg/m^3 which is below that of conventional dense concrete. GRC forms lightweight components by virtue of thin section, rather than by lightness of the material; although low-density versions of the material are possible.

The significance of density, however, goes beyond the simple concept of weight. Density is a good indicator of material quality, a high density meaning slightly greater fibre volume fraction but more significantly indicating well-compacted, well-made material of correct water:cement ratio.

Water absorption and apparent porosity figures are higher than those for typical concrete, which would normally exhibit a water absorption less than 10%. This is a direct result of the higher cement content in GRC. The permeability of GRC, is however significantly lower than that of concrete.

GRC is a waterproof material and is used for water retaining structures. GRC cladding panels withstand windblown rain under the severest of conditions.

Test Method

The Density, Water Absorption and Apparent Porosity are all determined in the same test which is carried out as part of routine Quality Control testing .
" GRCA Methods of Testing Glass Fibre Reinforced Cement Material" and the following Standards.
BS EN 1170 PART 6
BS6432
ASTM C948

The water vapour permeability can be tested according to BS 3177 although this is by no means a routing test.

Table 2.5 - Typical Values at 28 days

Type of GRC	Dry Bulk Density (Tonne/m^3)	Water Absorption (%)	Apparent Porosity (%)
Sprayed	1.8 - 2.1	8 - 13	16 - 25
Premix	1.8 - 2.0	8 - 13	16 - 25

2.8 Fire Resistance

General

GRC is a fire-safe material. Many GRC mix designs do not contain any organic materials other than very small amounts of superplasticiser and trace quantities of binder on the glass fibres. These formulations comply with the Non-Combustibility criteria for national and EU test standards. GRC that contains acrylic polymer for curing purposes also performs well, although not normally classified as Non-Combustible. When tested for Ignitability, Fire Propagation and Surface Spread of Flame it achieves the highest possible ratings and conforms to the requirements for Class O defined by the British Building Regulations. In all cases the smoke emission is very low and the emission of toxic fumes is minimal.

When GRC is used in a panel construction the Fire Resistance achieved depends on the whole of the construction. Single layers of GRC do not have guaranteed Integrity in the usual fire resistance tests unless the GRC mix design has been modified to allow the GRC to release moisture vapour easily during the initial part of the test procedure. Panels using GRC in conjunction with other materials have been designed and tested to give Fire Resistance of up to 4 hours.

2.9 Sound Insulation

GRC obeys the **Mass Law** for sound transmission loss through a partition.
Below about half the critical frequency, sound transmission loss is generally only related to the mass of a material or partition. Mass law helps quantify the sound transmission loss at these frequencies. At these frequencies, doubling the mass per unit area of a partition panel, or doubling the frequency for a given mass per unit area, increases the sound transmission loss by 6 decibels in the frequencies controlled by mass law.

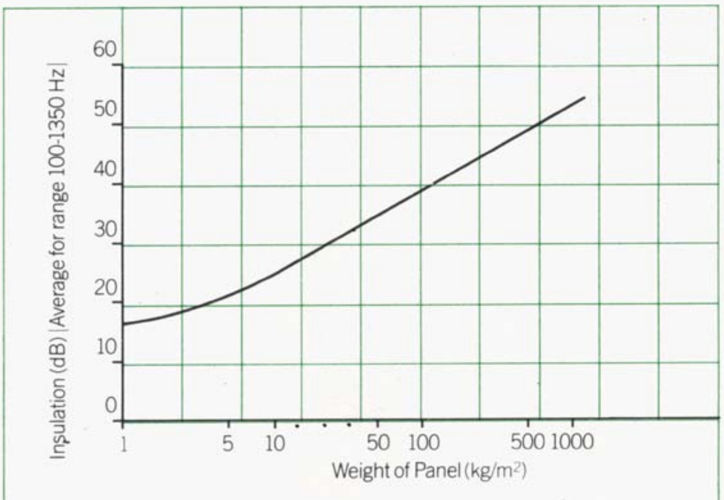

Figure 2.3

A significant reduction in sound transmission loss (i.e., a significant increase in the transmission of sound) through a partition occurs at the **critical frequency**. The critical frequency is the frequency at which the wavelength of sound in air equals the flexural bending wavelength in the partition or material. The critical frequency therefore depends on the fixing system used (Figure 2.3).

GRC is often used for Sound Barriers for roads and railways. The Mass Law does not work for these barriers and there is little benefit in increasing the surface mass above the minimum required for resistance to wind loading because of **diffraction**. This is the distortion of a wavefront caused by the presence of an obstacle (barrier) in the sound field. Above 12 kg/m^2 there is no useful improvement (Figure 2.4).

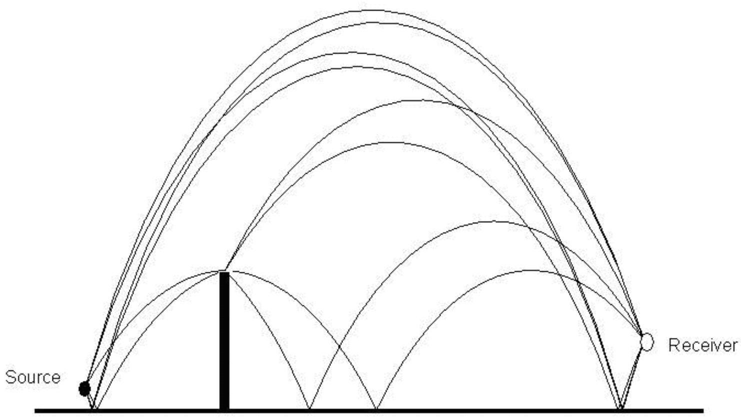

Figure 2.4

Since 20 kg/m^2 is the surface mass of 10mm GRC, any GRC panel designed to resist wind load will be heavy enough to give useful performance as a sound barrier material.

GRC sound barriers can either be:

Absorptive where an open grille at the front is backed up with sound absorbent material and a final layer of GRC (Figure 2.5).

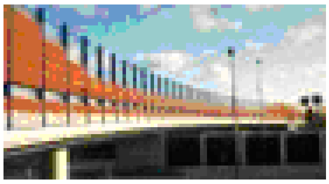

Figure 2.5

or

Dispersive where the surface of the GRC sound barrier panels is shaped such that the reflected sound interferes with itself and is therefore reduced in intensity (Figure 2.6).

Figure 2.6

2.10 Thermal Insulation

General

GRC with a typical density of 1900-2100 kg/m^3 has a thermal conductivity in the range of 0.5 to 1 W/mº C depending on moisture content. This means that GRC is not itself a good thermal insulation material. However, the design of either single skin or stud frame GRC cladding panels allows insulating materials to be incorporated without increasing the overall panel thickness.

When a particular 'U' value is required, the calculations of thermal resistance should be carried out by a specialist.

2.11 Resistance to Carbonation

General

Carbonation in GRC is not considered significant. GRC products do not normally contain mild steel reinforcement and so cover to the steel is not an issue.
GRC has been shown to carbonate at a very slow rate when compared to concrete and some studies have found no evidence of carbonation at all.
The low carbonation rate of GRC compared to normal concrete is due to the comparatively high cement content and low permeability of GRC.
The data shown below is taken from work carried out by the British Cement Association on the use of GRC as permanent formwork. In this application GRC has the benefit of protecting the reinforcing steelwork from corrosion by protecting the concrete from carbonation (Figure 2.7).

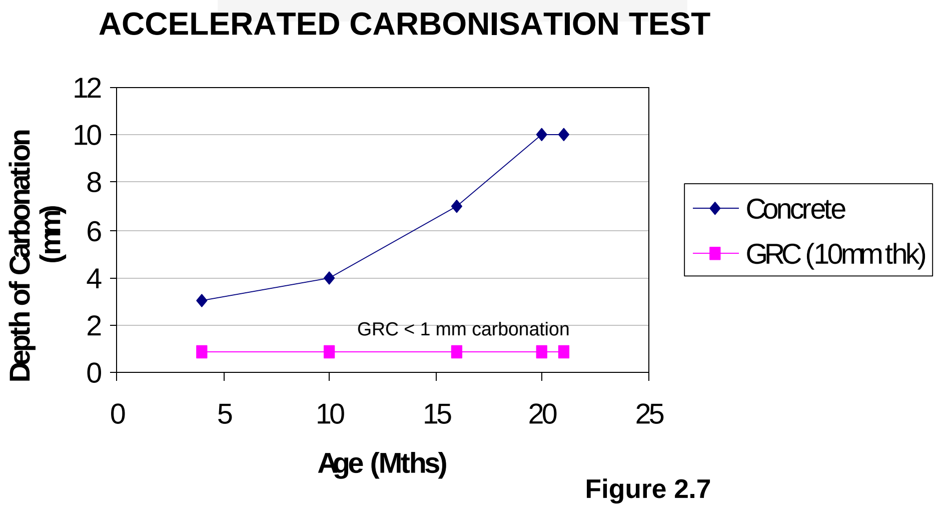

Figure 2.7

2.12 Thermal Expansion

GRC has a thermal expansion of 10-20x10^{-6}/^{o}C. The minimum values occur at high and low Relative Humidities. The maximum values occur around 50-80% RH. This should be considered along with moisture and shrinkage movements when designing GRC products.

Table 2.6 - Summary of Mechanical Properties at 28 days

Description	Hand Sprayed	Premix
Modulus of Rupture (MOR_{28}) in N/mm^2	18 - 30	5 - 14
Limit of Proportionality (LOP_{28}) in N/mm^2	5 - 10	5 - 10
Ultimate Tensile Strength (UTS_{28}) in N/mm^2	8 - 12	3 - 6
Bend Over Point (BOP_{28}) in N/mm^2	4 - 6	3 - 5
Interlaminar Shear in N/mm^2	2 - 4	N/A
In-Plane Shear in N/mm^2	7 - 12	4 - 6
Punching Shear in N/mm^2	25 - 35	4 - 6
Charpy Impact Strength in N/mm/mm^2	15 - 25	7 - 12
Dry Bulk Density in kg/m^3	18 - 21	18 - 20
Water Absorption (%)	8 - 13	8 - 13
Apparent Porosity (%)	16 - 25	16 - 25