GRC In Action

Today's GRC for Architects and Engineers

Glassfibre Reinforced Concrete (GRC) is a material that is making a significant contribution to the economics, technology and aesthetics of the construction industry worldwide

GRC Contents

This publication has been prepared by the International Glassfibre Reinforced Concrete Association. Its aim is to give architects, engineers, and other construction professionals an insight into the wide range of applications of GRC currently being executed throughout the world.

* GRC is also known as GFRC is some countries

GRC Introduction

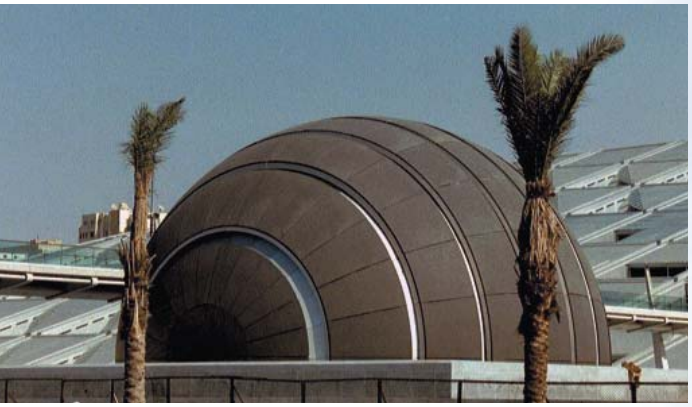
Glassfibre Reinforced Concrete (GRC*) is one of the most versatile building materials available to architects and engineers.

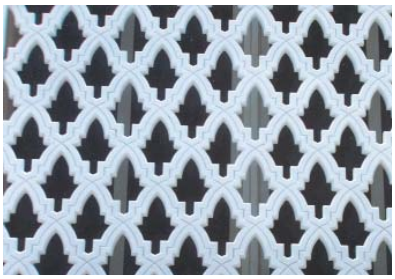
Developed in the twentieth century, GRC has been making a significant contribution to the economics, technology, and aesthetics of modern construction worldwide for over 30 years.

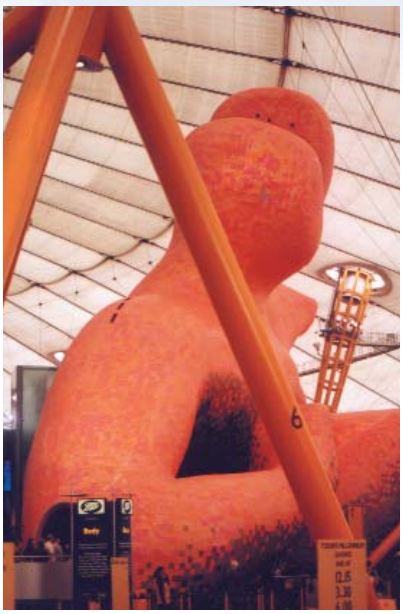
GRC is not a single material but a family of high-performance cement-based composites reinforced with special alkali resistant glass fibres, which can be engineered to suit a wide range of applications.

GRC products can be formed into sections as thin as 6 mm ($^1/_4$ inch) so their weight is much less than traditional precast concrete products.

The design and manufacture of GRC products is covered by international standards, which have been developed in Europe, America, Asia and Australasia. GRC is manufactured in over 100 countries.







GRC in Architecture

GRC presents architects and engineers with a material from which the most ambitious designs can be created. It can be moulded to form modern futuristic designs or to replicate traditional historic features. GRC can be painted, faced with fine aggregates, coloured or simply left with a natural white or grey, smooth or textured finish.

Key features

GRC *products are lightweight, easy to handle and fast to erect*

GRC *products reduce loadings on buildings leading to significant savings in superstructure and foundations*

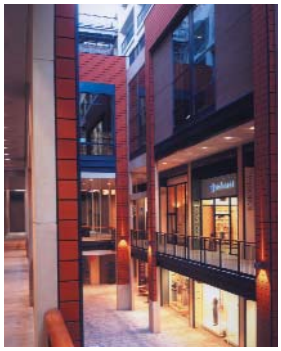
GRC *is excellent for reproduction and renovation*

GRC *is environmentally friendly*

GRC provides the designer with a complete technology that few other materials can match for versatility.

GRC Cladding

GRC is one of the most popular materials used for creative prefabricated architectural cladding. GRC's ability to be moulded into thin, lightweight panels with a wide variety of shapes, forms and surface finishes has been appreciated by a growing audience of architects and engineers worldwide.



Key features

GRC *is easily moulded to reproduce shapes, details and textures*

GRC*'s high strength allows design of thin, lightweight cladding elements*

GRC *can be coloured with pigments, paints and natural stone facings*

GRC *cladding can replace non-structural precast concrete where weight and/or shape may be problematic*

GRC cladding panels are generally manufactured by the 'Hand Spray' technique. As the name implies, the material is sprayed into a mould using special machinery. The method can produce high-performance materials from which panels with extremely thin, lightweight sections are achievable.

GRC Features and Mouldings

GRC products are formed by a variety of manufacturing techniques. One of the most versatile is to cast the composite in moulds manufactured from rubber, timber or Glassfibre Reinforced Plastic (GRP/FRP). This is known as Premix GRC. As the high-performance alkali resistant glass fibres are evenly distributed in the mix, the material is reinforced throughout, enabling products with the finest of details to be created.

GRC is used to produce beautiful architectural mouldings and features. Whilst often cast with thicknesses in excess of 25 mm these products remain easy to handle and erect, and permit the architect or engineer an unrivalled freedom for creative design.

Key features

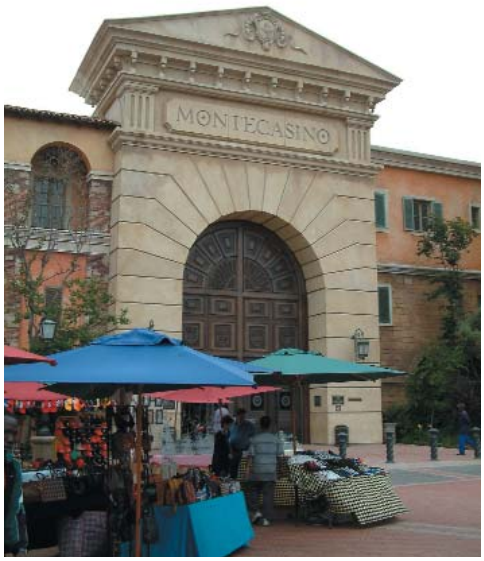
GRC *can be cast into fine details*

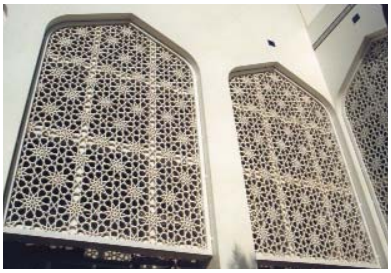
GRC *offers designers unrivalled flexibility*

GRC *mouldings and features are easy to handle and erect*

GRC *does not suffer from corrosion*

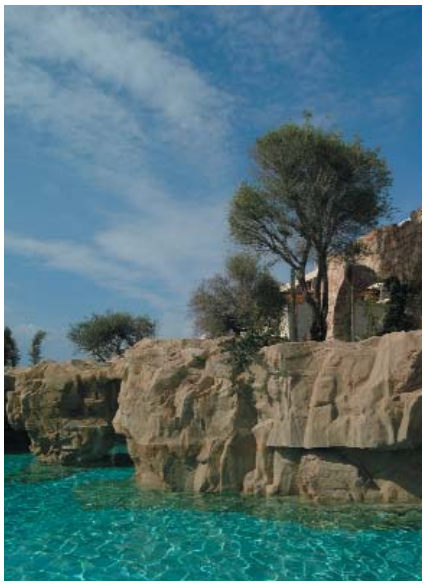
GRC does not suffer from corrosion of the reinforcement. Unlike traditional concrete, GRC does not require a minimum of concrete cover to the reinforcement.

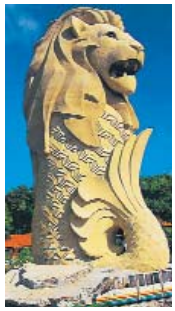




GRC Landscaping

In building projects, leisure facilities, urban renewals and municipal schemes ever-increasing attention is being focused on the built environment. GRC is playing a major role.



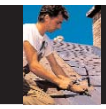


Key features

- **GRC** *is environmentally friendly*
- **GRC** *is durable against extreme weather conditions*
- **GRC** *products are lightweight and easy to handle*
- **GRC** *offers a wide variety of shapes and surface finishes*

Seating, planters, receptacles, kiosks, bollards, signs, statues and fountains, to name but a few, all benefit from being made in GRC with its ability to tailor shape, form and surface finish and to be aesthetically compatible with the chosen environment.

GRC also provides theme park and zoological architects with a medium through which they can turn dreams into reality. Many of the world's largest theme parks and zoos use GRC to create rockscapes, replica buildings, simulated environments for animals, and much more.



GRC in Building

In recent years, a shortage of skilled workers combined with the need to produce lighter weight building components has led to significant advancements in the use of prefabricated GRC elements. Builders worldwide are appreciating the increase in speed of construction that GRC provides.

Furthermore, engineers are discovering that small additions of alkali resistant glass fibres can benefit the quality of traditional concrete elements, whether precast or cast in-situ. Research has shown that high-modulus alkali resistant glass fibres can help to control cracking and improve durability.

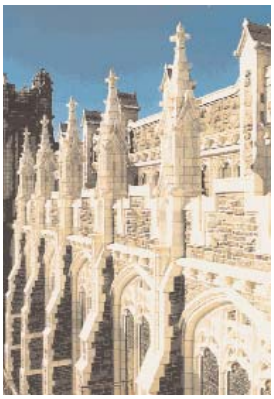
Key features

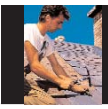
GRC *is easy to mould*

GRC *is fast to fix*

GRC *is durable*

GRC *is crack resistant*



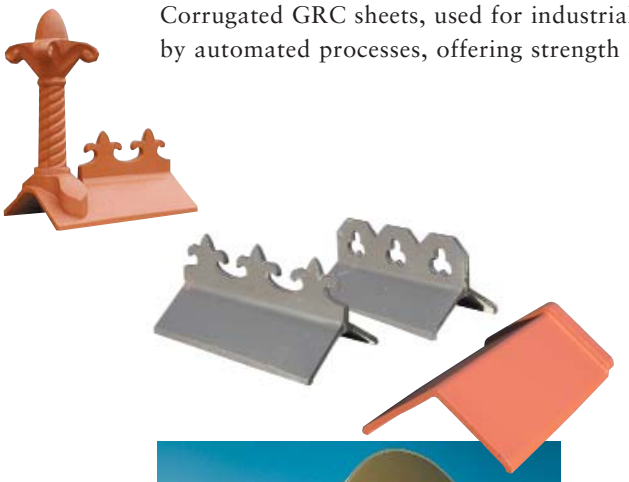


GRC *Roofing*

GRC is an ideal material to use on a variety of roofing structures. It is lightweight but tough, easy to fix and unaffected by environmental conditions. It can imitate traditional roofing materials such as slate, natural stone or clay products but unlike these materials it is neither heavy nor brittle.

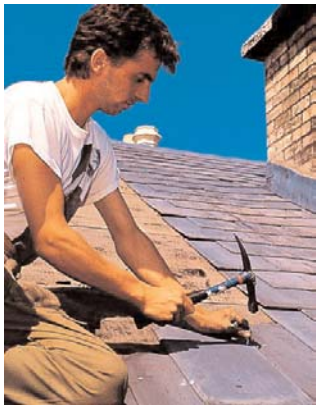
GRC can be moulded into complex shapes for roofing accessories such as finials, ridges and chimneys. It is non-combustible with a high impact strength and can be used on all types of roof.

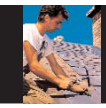
Corrugated GRC sheets, used for industrial and agricultural roofing, are manufactured by automated processes, offering strength and impact performance benefits.



Key features

- **GRC** *is impact resistant*
- **GRC** *can reproduce colour and finish*
- **GRC** *products are lightweight*
- **GRC** *has excellent durability*





GRC Walls and Windows

Key features

GRC *is easily moulded*

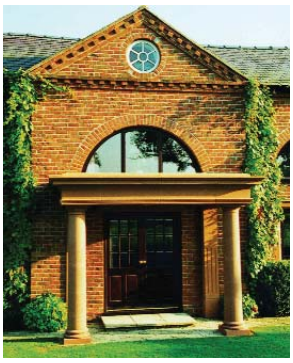
GRC *products are quick to install*

GRC *is durable and crack resistant*

GRC *offers a wide range of surface finishes*

GRC's versatility enables it to be used in different ways in the construction and decoration of building walls. In its simplest form, GRC renders reinforced with alkali resistant glass fibres can be used on a variety of substrates to provide a durable and decorative finish. They may be applied over external insulation as part of a system to upgrade the thermal characteristics of the wall, directly onto blockwork or masonry, or onto metal lath. In all cases the glassfibre reinforcement gives a long-lasting and crack-free performance.

Moulded GRC components such as window sills, window surrounds, cornices, doorportals and columns can add decoration to residential and commercial buildings while also meeting functional needs. Standard prefabricated panels incorporating a choice of surface finish including exposed aggregate, natural stone and brick effect are possible.



GRC is an ideal material for use in renovation.

Thin lightweight panels are easy to fix and minimise the weight imposed on the existing structure. In many cases the opportunity is taken not only to improve the aesthetics of the building but also to improve the thermal and acoustic properties.

GRC's ability to be moulded and finished with natural materials means that traditional architectural forms can be maintained when required.

Key features

- **GRC** *preserves historic features*
- **GRC** *improves aesthetics*
- **GRC** *reduces the load on existing structures*
- **GRC** *enables thermal and acoustic properties to be upgraded*

GRC Foundations and Floors

GRC can provide practical solutions in the construction of foundations and floors. As permanent formwork under suspended, in-situ concrete floors it can give economic benefits together with excellent appearance. In balcony slab construction, GRC can provide a pre-finished moulded edge while simplifying construction. On ground floor concrete slabs, insulated GRC edge formwork can help in minimising heat loss from the building in cold climates. Similarly, in wall construction insulated GRC base course and sill units can be incorporated, which contribute to the overall wall insulation performance.

On the construction site, forms of glassfibre-modified concrete can be used in floor screeding, both in relatively thick concrete screeds and in thin self-levelling overlays.

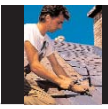
Key features

GRC *permanent formwork protects concrete*

GRC *floor screeds and overlays offer improved crack resistance over traditional finishes*

GRC *insulated products improve thermal performance*

GRC *improves concrete durability*



GRC Modular Building

The qualities of GRC are shown to great advantage in the area of modular building. GRC panels are light and easily transported but also resistant to damage. Small units such as modular bathrooms or telecommunications equipment housings can be shipped in one piece and rapidly lifted into position. The strength of GRC is sufficient so that, even in thin skin construction, small modular buildings can be designed without heavy structural frames.

GRC walls can incorporate thermal insulation if required, while the absence of steel reinforcement can be a benefit in electrical or telecommunications applications.

Aesthetically, the full range of natural and applied finishes, and freedom of design, which characterise GRC permit solutions to satisfy any architectural requirement.

Key features

- **GRC** *enables rapid construction*
- **GRC** *products are lightweight and portable*
- **GRC** *provides a turn-key solution*
- **GRC** *products can improve thermal performance*

GRC in Engineering

Compared to traditional concrete, GRC offers the engineer an unrivalled range of material properties. GRC is not a single material. Its properties can be engineered to suit each application. For example, for products such as permanent formwork, high short-term strength is required. While for utility and drainage products light weight combined with durability give GRC a considerable advantage.

Key features

- **GRC** *is durable*
- **GRC** *is lightweight*
- **GRC** *is easy to handle and transport*
- **GRC** *is fast to install*

Examples of engineering applications can be found worldwide.

GRC Permanent Formwork

More than 2 million square metres of GRC permanent formwork have been used over the years. The most popular application is in bridge construction. Small (1-2 m span) GRC panels are fitted between precast concrete beams before steel reinforcement and concrete are placed. GRC permanent formwork panels are not only fast to install, they also provide extra corrosion protection to the steel reinforcement. GRC carbonates very slowly and has low permeability providing a barrier to the ingress of de-icing salts.

GRC permanent formwork has also proved to be an efficient solution to the world's ageing sewers. In the UK, France, Holland and elsewhere thousands of kilometres of brick-built sewers have been lined with GRC permanent formwork and grouted in place. Not only does this safeguard the structural integrity of the sewer but also the smooth surface of the GRC enhances the hydraulic performance.

In building construction, GRC permanent formwork has been used in innovative ways to produce complex forms and shapes.

Key features

GRC *is easy to mould*

GRC *is fast to install*

GRC *provides protection to the steel reinforcement in the concrete*

GRC *ensures a consistent finish*

GRC *decorative finishes can be created in factory conditions before installation*

GRC Utilities

Opportunities to take advantages of GRC's inherent durability in the utility industries abound. GRC provides protection against both man-made and natural environmental hazards.

In the railway industries, GRC ducts run alongside the lines to protect both electrical and communication cables. Railway engineers internationally appreciate the advantages of lightweight, high-strength units that can be installed many times faster than the traditional concrete equivalents.

GRC not only offers functional solutions in such applications; it also provides designers with the opportunity to enhance the environment. Many producers offer a wide range of finishes from natural texture to imitation stone.

Key features

- **GRC** *is durable*
- **GRC** *provides a high level of protection*
- **GRC** *products are lightweight*
- **GRC** *is environmentally friendly*

GRC Acoustics

GRC has found favour with acoustics engineers worldwide as a primary choice for both internal and external acoustic barriers and screens.

GRC's high density, smooth surface finish and ability to be easily moulded have been used to advantage in concert halls and other auditoria.

In road and railway construction, GRC noise barriers, which can either disperse or absorb sound, have provided nearby residents with a better environment.

GRC not only offers functional solutions in such applications, it also gives designers the opportunity to create interesting features that enhance the aesthetics.

Key features

GRC *improves the environment*

GRC *disperses or absorbs sound*

GRC *is ideal for elevated structures*

GRC *enhances the aesthetics*

GRC Bridges and Tunnels

Lightweight, durable GRC elements are frequently used in the world of bridges and tunnels. GRC parapet panels are used to provide aesthetically pleasing architectural features without burdening the structure with excessive weight.

GRC tunnel lining panels are normally noted for their contribution to the architecture of the structure. GRC panels can be manufactured with thin sections, which means that the encroachment into the open space of the tunnel is minimised.

Key features

- **GRC** *products are lightweight*
- **GRC** *is fire resistant*
- **GRC** *products are fast to fix*
- **GRC** *is functional and aesthetic*

GRC Water and Drainage

GRC's high strength enables products with thin sections to be manufactured. These products are considerably lighter in weight than their counterparts made from normal concretes. Advantages, in addition to the inherent durability of GRC, are that the products are easy to handle and fast to install. Furthermore, GRC units can be manufactured with dense smooth surfaces that minimise resistance to water flow.

Product weight is a critical health and safety issue in many countries. Limits on the weights that individual workers can carry often mean that the heavier traditional concrete alternatives are not acceptable. GRC products can be designed to be as little as one-fifth of the weight of a comparable precast concrete product. A 100-kg concrete product requires mechanical lifting; a 20-kg GRC product is a one-man lift.

Key features

GRC *is easy to handle and transport*

GRC *is strong and durable*

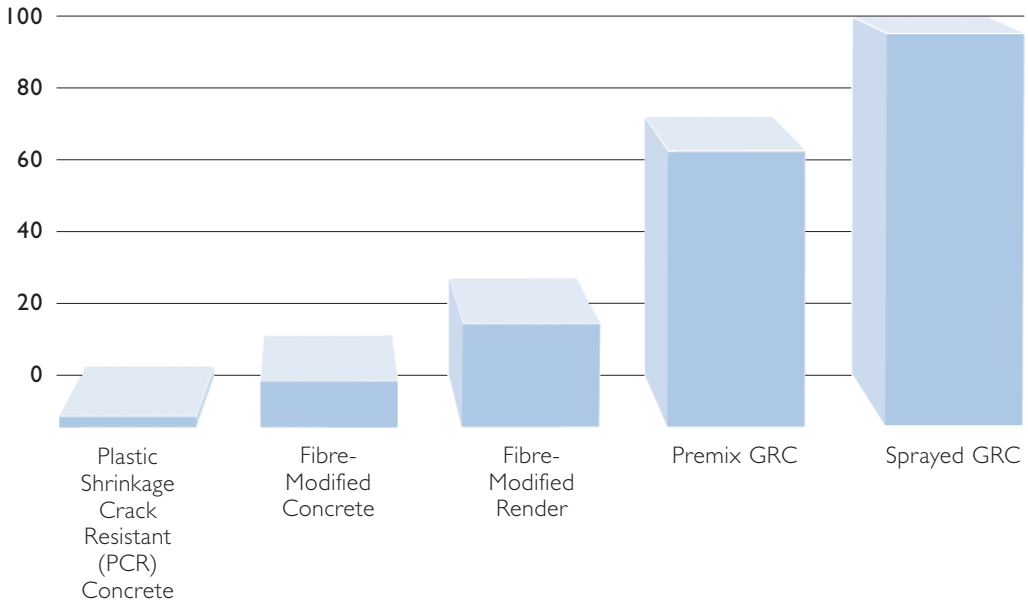
GRC *is fast to install*

GRC *has low resistance to water flow*

GRC Technical Appendix

GRC is a family of materials that can be defined by the addition rate of alkali resistant glass fibre. At one end of the spectrum low dosages of dispersible fibres are used to control plastic shrinkage cracks in normal concretes (PCR). At the other end, integral fibres are used at high dosage levels to reinforce cement-rich mortars (GRC).

Fibre contents for different GRC product types (kg of fibre per m^3 of concrete)



Most GRC products are manufactured by one of two processes – Vibration Casting and Spraying.

The vibration cast form is normally referred to as "Premix GRC". Premix GRC is produced in a two stage process. A mixture of cement, sand, water and chemical admixtures is first prepared in a high speed mixer. Fibres are added in the second stage with a slower speed. The Premix GRC is then poured into moulds and compacted by vibration.

Sprayed GRC is sometimes called "Hand Spray GRC" or "Machine Spray GRC" depending on the method of manufacture. A mixture of cement, sand, water and chemical admixtures is prepared in a high shear slurry mixer. This is then placed in a machine that conveys the slurry to a special spray gun where the fibres are added at the nozzle as the GRC material is sprayed onto a mould.

A third production process called "Spray Premix" is also often used for the manufacture of smaller elements and the application of renders.

The strength of Sprayed GRC is generally higher than Premix GRC.

The table below shows typical values for Sprayed GRC and Premix GRC manufactured with 5% and 3% (by weight of mix) alkali resistant glass fibre.

Property	Hand or Machine Spray GRC	Vibration Cast Premix GRC
Glassfibre Content by Weight of Mix	**5%**	**3%**
Bending:		
Ultimate Strength (Modulus of Rupture – MOR) MPa	20–30	10–14
Elastic Limit (Limit of Proportionality – LOP) MPa	7–11	5–8
Tension:		
Ultimate Strength (Ultimate Tensile Strength – UTS) MPa	8–11	4–7
Elastic Limit (Bend Over Point – BOP) MPa	5–7	4–6
Shear:		
Interlaminar Shear Strength MPa	3–5	N.A.
In-plane Shear Strength MPa	8–11	4–7
Compressive Strength MPa	50–80	40–60
Impact Strength kJ/m^2	10–25	10–15
Elastic Modulus GPa	10–20	10–20
Strain to Failure %	0.6–1.2	0.1–0.2
Dry Density Tonne/m^3	1.9–2.1	1.8–2.0

Hand Spray GRC

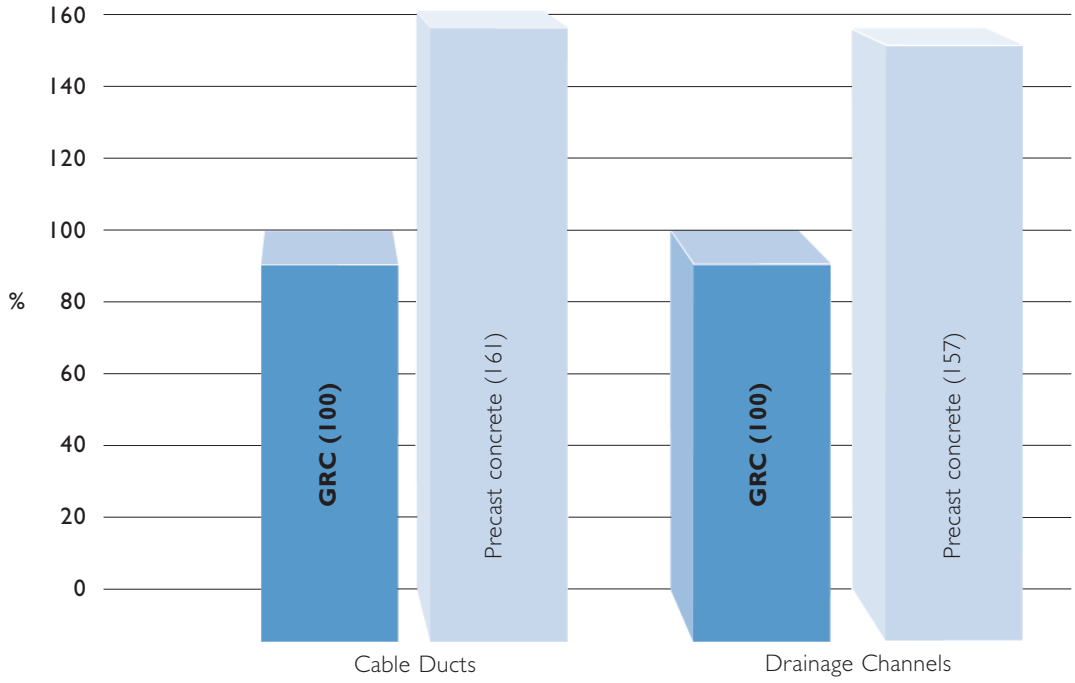
Spraying Premix GRC render

Vibration Cast Premix GRC

GRC and the Environment

The main constituents of GRC are based on the naturally occurring earth oxides that are used in the manufacture of cement and glass fibres. These are not generally regarded as pollutants. Wash water from the manufacturing process contains cement and this is alkaline. It is normal for factories to have settlement tanks so that solids do not enter the drainage system.

Eco-95 Weighted average environmental impact



The reduced weight of GRC compared to steel reinforced concrete products does provide environmental benefits. An assessment carried out as part of a UK government DETR/Concrete Industry Alliance 'Partners in Technology' project compared two precast concrete and GRC products that fulfil the same function. The results show that GRC has a lower environmental impact.

The main reasons for the reduced environmental impact of GRC compared to traditional precast concrete are:

- ***Reduced cement usage per product***
- ***Reduced transport costs***

Sources of Information, Specifications and Recommendations

Standards

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

EN 1170: 1998: *Parts 1–7 Precast concrete products: Test methods for glass-fibre reinforced cement.*

Other Publications

The International GRCA also issues its own Specifications and Guidelines, including:

Specification for the Manufacture, Curing and Testing of GRC Products, 2000.

Current publication lists are available from The Concrete Bookshop
Telephone: +44 (0) 1344 725704
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Website: www.concretebookshop.com

In addition, the International GRCA holds a database of all past GRCA Congress Proceedings and many other GRC related publications and books.
Information can be obtained from the GRCA Advisory Service, Email: info@grca.co.uk

Prestressed Concrete Institute (PCI) USA
Telephone: +1 312 786 0300
Website: www.pci.org

Recommended Practice for Glass Fiber Reinforced Concrete Panels - Fourth Edition, 2001.

Manual for Quality Control for Plants and Production of Glass Fiber Reinforced Concrete Products, 1991.

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The International GRCA has relationships with other associations connected with the GRC industry. Further information together with a full list of members can be found on the International GRCA website: www.grca.co.uk

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