Quality Matters

Bob Faulding
The GRC Centre/PBS Synergies, United Kingdom

Abstract

GRC is a complex material which shares more in common with advanced composites such as those used in the aerospace industry than it does other types of precast concrete.

Ever since the material was introduced in the 1970s the need for a strict approach to the quality controls needed across all phases of the final product realisation process has been apparent to all professionals involved in the sector.

This paper is an update of that published by the GRCA in 2017 as Technote 13. It has been updated to reflect industry developments and the continuing growth in the use of GRC cladding especially in high consequence of risk applications such as high-rise construction.

Covering all aspects of the quality and compliance approach needed in design, manufacture and installation the paper will be of interest to anyone involved in the use of GRC cladding products.

Introduction

The importance of a strict approach to quality control and conformity assessment testing has been an integral part of GRC manufacturing since the introduction of the composite 50 years ago. Established processes and procedures must be strictly followed given GRC is recognised as the most complex material widely used in current construction practice. [1]

Although advances have been made with the introduction and development of the GRCA Specification [2] and BS EN 1169 [3] these standards only cover minimum general requirements for both spray and premix production methods. As such they cover basic manufacturing standards and are generally not comprehensive enough for large and high-rise construction projects using the spray process. This is the method recommended for elements with a large surface area such as cladding elements.

The American PCI MNL-130-09 [4] has been developed, primarily for this market and is far more robust. Whilst this covers some180 pages the GRCA and BS EN equivalents are 17 and 10, respectively.

In simple terms, both the GRCA Specification and BS EN 1169 cover every application that manufactured GRC products are produced for. These range from small cills and heads used in housebuilding to GRC cladding used on high-rise construction projects.

This paper considers what supplementary quality and testing measures may need to be considered by manufacturers, specifiers, and purchasers when GRC is used in such applications.

Facing Coat Compatibility

One aspect of GRC product realisation that appears misunderstood by some manufacturers and many specifiers and purchasers is the importance of assessing the compatibility of facing coats with the structural GRC.

Facing coats are a layer of non-reinforced concrete which typically contain decorative aggregates not included within the GRC matrix. The mix is applied using purpose made facing coat guns into the moulds prior to application of the GRC. After curing, further treatment exposes these aggregates to provide a textured surface resembling natural stone.

Problems with facing coats, in the form of micro crazing and cracking are, unfortunately common in the industry and may be caused by differential movement between the architectural finish and the structural GRC.

Compatibility between the two layers should always be confirmed by a process of development testing prior to any actual production commencing. Differential movement as little as 0.04% [5] has been known to cause cracking, bowing and delamination in composites.

Currently there are no requirements to carry of compatibility testing within the current GRCA Specification as this is not a compliance document for finished products. Consequently, any use of this standard as a specification will not require any such pre-production evaluation.

BS EN 1170-7:1998 [6] is a test requirement under BS EN 1169:1999 however it is not clear in the introduction that the test can be used to determine differential movement. Suitable additional clarification text is proposed to be added under the current review of the standard by CEN.

This aspect of GRC is extensively covered under PCI MNL 130-09 Division 5-40

On large projects specifiers may feel that further validation testing on facing coat material should be conducted prior to use. Recommended tests are:

- Compressive strength of facing coat mixes
- Reaction to freeze-thaw cyclic weathering.
- Combustion
- Flame Spread

Manufacturing Process Control

Given the complexity of the material and the handmade nature of GRC, strict quality control measures are essential. Ideally quality should be under the control of a responsible party (Quality Manager) who is not directly connected to production outputs or reports directly to production management. Of course, in any commercial operation, particularly one working to maintain contractual programmes and/or tight budgets, this can be difficult.

The role of trade associations must also be considered in relation to quality and the confidence provided by external conformity assessments.

It is a common misconception that any manufacturer displaying the GRCA logo, or “Full Member” accreditation automatically produces high quality GRC. It is wrong for specifiers or purchasers to draw

this conclusion. The annual GRC assessment is purely a desktop review by a non-industry related conformity assessment body. It is not in any way a guarantee of either design or manufacturing quality, and the GRCA recommends that specifiers and purchasers "must satisfy themselves that the Full Member has sufficient resources in plant, equipment and labour to consistently design and manufacture high quality GRC in accordance with the requirements of the GRCA Specification, Methods of Testing and Practical Design Guide" [7]

In contrast the PCI operates a plant certification scheme whereby manufacturers are subjected to two unannounced factory production control inspections per annum, each conducted by experienced industry professionals.

In the UK, Europe, Middle and Far East specifiers and users may wish to consider using experienced GRC consultants to provide third party and independent conformity assessments providing additional confidence on large projects.

Additional Testing Considerations

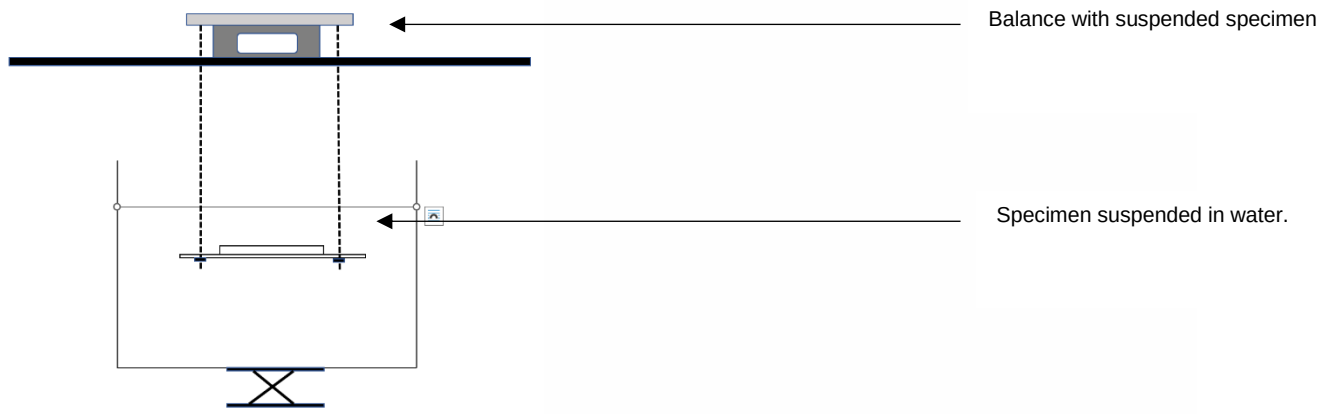
The critical testing requirements for any GRC are covered by the methods developed and evolved over the past 50 years. However, those involved with projects may feel that increasing testing frequencies are required above those already detailed in the various standards.

The bending or flexural test is the most important test conducted on GRC materials. Dependent on which standard is being followed testing can be between once per annum to daily. In the case of GRCA manufacturing members, these should conduct the full bending test to determine both elastic (LOP) and ultimate (MOR) capacities at least twice per week.

On large projects testing daily is strongly recommended. In this way manufacturers will not only be more reactive to any problems but also be capable of providing more reliable data to the design engineers. Daily testing can also reduce costs by providing opportunities for consistency in manufacture thus reducing material waste.

Regular third-party testing should also be considered to validate this critical aspect of product realisation.

Increased testing frequency can also be applied to the density test. Whilst many companies feel this test does not provide any pass/fail criteria it is extremely useful in measuring quality through consistency to raw material properties, spraying techniques, compaction efficiency etc. The equipment needed to conduct the test is low cost and minimal time is required.



Simple test method for determining density by immersion.

The uses and applications of GRC products has moved on since existing standards were drafted and further testing should be considered.

The biggest omission in most current standards is generally the testing of embedded fixings into GRC elements. These are typically either post-production fitted inserts or inserts cast into "bonding pads." In the case of the former it is likely any problems would relate to the competency of installation. However, this type of fixing when correctly fitted would still have a relatively low resistance to the pull-out forces generated by negative wind pressure compared to cast in fixings. Consequently, these are reliant on large numbers of fixings per element.

It is unlikely cast-in fixings will fail in normal use provided they have been correctly encased within the GRC matrix. This is a skilled operation and consequently one which needs careful quality control. Unlike traditional concretes which have good flow rates when poured into moulds, this is not the case with high fibre content spayed GRC. As a result, the material must be hand-packed around the fixing rather than the natural low of the mix providing the encapsulation.

The final consideration must be the bond between the insert pad and the actual GRC. Assuming the insert is correctly fitted then it will be generally the detachment of the pad from the GRC which will occur rather than the actual insert or area around it. The possibility of such delamination between the pad and GRC is of course increased if the initial sprayed GRC has been allowed to begin its initial set before the second stage pad is applied.

Although currently there are no published test methods, many manufacturers and consultants have developed their own in-house versions for proof testing embedded fixings.

Testing pull-off capacity of anchor pads.

Final Product Testing

Surprisingly for such a complex and handmade material, final product testing is not a requirement of any current standards. All testing is conducted on specially prepared boards with finished quality control checks limited to dimensional and visual inspections only. As such there is no guarantee that what is despatched to site is representative of test results.

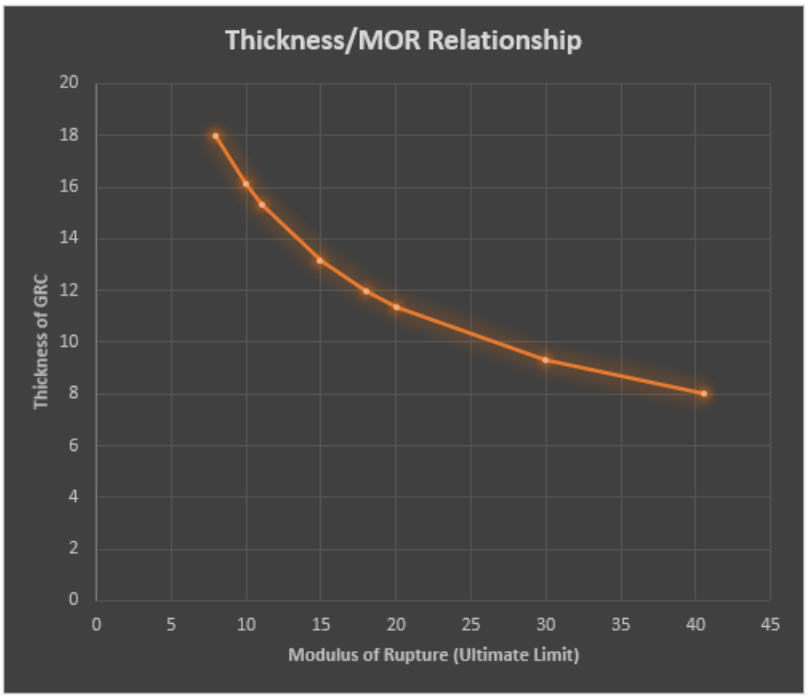
By assessing a random population of finished products, manufacturers and purchasers can be confident that design input values have been achieved.

Such testing can be useful in verifying the thickness of both the GRC and the facing layer along with confirming the flexural strength required in the engineering analysis is achieved.

Face and GRC Thickness

The flexural strength of GRC elements is directly related to the material thickness of the finished product. It is therefore imperative that the spray application thickness is monitored throughout the manufacturing operations to ensure design values are achieved. Under thickness of the structural GRC will result in higher flexural strength being required (see chart below) whilst over thickness will increase weight and may affect the capacity of support fixings causing post installation deflection.

Ultimate Flexural Stregth (MOR)	Minimum Thickness Required
8	18.00
10	16.10
11	15.35
15	13.15
18	12.00
20	11.38
30	9.29
40.5	8.00



Graph showing MOR/thickness relationship. Data courtesy of Power Sprays/Fibre Technologies International Ltd. Please note data is indicative and should be confirmed by an engineering analysis of actual designed components.

The GRCA Design Guide does provide an indicative partial safety factor of 1.05 for GRC cladding panels (ɣtv) which is applied as part of the engineering calculation however as can be seen from above, this may not be sufficient.

Another consequence of such a non-compliance in manufacturing is that with a decrease in the designed structural thickness the panel rigidity also reduces. This results in greater deflections occurring which can cause excessive stresses in the non-ductile facing coat. The result is excessive micro crazing and cracking across the architectural finish. This effect is even more exaggerated in over thick facing coats which are often a consequence of thinner structural GRC due to overall, rather than individual layer measurements being taken.

Any in-service display of excessive micro crazing or hairline cracking should always be thoroughly investigated to ensure the matter is only cosmetic and does not have wider structural implications.

Flexural strength

The characteristic flexural strength provided by the manufacturer for engineering input are based on tests conducted on specially prepared sample boards. Across all published test methods (BS EN,

GRCA, ASTM) a flat sample board is produced between 0.3-0.4m² from which coupons are cut and tested.

Given the hand-made nature of GRC, products in particular products manufactured using the spray process, it is highly unlikely that a panel typically ten times the surface area and often of a complex geometric shape would display the same uniformity of spraying and compaction as this flat, small sheet.

Good design should make a suitable allowance for this and the ɣb value provided as a guide in the GRCA Design Guide is again 1.05. On large projects this should be adjusted to reflect actual differential values between sample boards and finished manufactured goods. Again, these values are only obtained by final product testing.

Sampling of full-sized panels for facing coat and flexural testing

Removal of facing coat to determine thickness and prepare specimen for flexural testing.

Summary

Correctly designed and manufactured GRC is a unique material capable of being used to produce elements of complex shape and being characterised by light weight, high levels of sustainability, and good resistance to fire and spread of flame. It is a material that requires little or no maintenance and has a design life over one hundred years.

The growth of GRC was restricted in the 1980s due to several in-service failures which were indicative of the material. However, these failures were a direct consequence of either a lack of understanding of the strict quality controls required or simple cost cutting to reduce tender prices. The industry must make efforts to ensure history is not repeated !

Although associations such as the GRCA have made great steps in advancing quality and testing standards these still require developing and expanding given the accelerated use of the composite especially as a cladding material on high rise projects.

Specifiers and buyers also need to understand and play their part. GRC is not a material that can either be sold or bought on price. Purchasers should look to manufacturers who can demonstrate an uncompromising attitude to both quality and testing, which unfortunately attracts a higher selling price than those who do not.

In summary it is essential that all stakeholders fully appreciate that with GRC quality really does matter.

References

[1] GRC Principals, Production, Properties and Applications. Peter M Bartos 2017

[2] Specification for the Manufacture, Curing and Testing of GRC products. GRCA 2021

[3] BS EN 1169: Precast concrete products. General rules for factory production control of glass-fibre reinforced cement. CEN 1999

[4] PCI MNL-130-09 Manual for QUALITY CONTROL for plants and production of Glass-fiber reinforced concrete products. Precast/Prestressed Concrete Institute Second Edition 2009

[5] BS EN 1170-7 Precast concrete products. Test method for glass fibre reinforced cement. Part 7 Measurement of extremes of dimensional variation due to moisture content. CEN 1998

[6] GRCA. Practical design guide for Glass fibre Reinforced Concrete. Version 1.1 2018