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ON AN UPWARD TRAJECTORY

Professional qualification/certification solutions for industry career development

QUALITY MATTERS

Considering supplementary quality and testing measures for GRC

CORROSION CONTROL

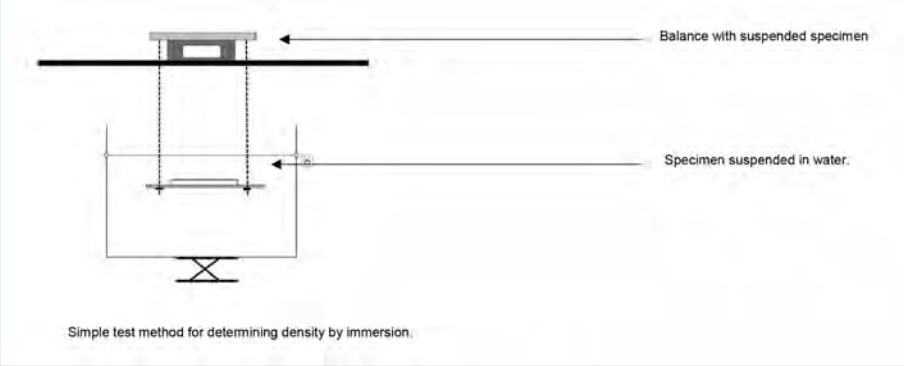
Analysing 15 years of hybrid anode performance data

QUALITY MATTERS

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 (as per Bartos[1]). Bob Faulding of The GRC Centre/PBS Synergies and GRCA considers what supplementary quality and testing measures may need to be considered by manufacturers, specifiers and purchasers when GRC is used in certain applications.

Although advances have been made with the introduction and development of the GRCA *Specification*[2] and BS EN 1169[3], these publications only cover minimum general requirements for both spray and premix production methods. As such, they cover basic manufacturing and are generally not comprehensive enough for large and high-rise construction projects using the spray process, which 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. While this covers some 180 pages, the GRCA and BS EN equivalents are 17 and ten, respectively.



Simple test method for determining density by immersion.

TOP:
Figure 1 – simple test method for determining density by immersion.

LEFT:
Figure 2 – testing pull-off capacity of anchor pads.

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

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.

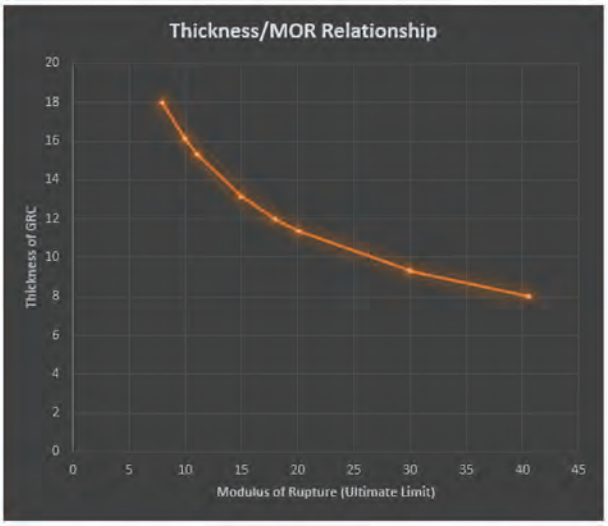
The role of trade associations must also be considered, in relation to quality and the confidence provided by external conformity assessments.

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*[5] and *Practical Design Guide*"[6].

In contrast, the PCI operates a plant certification scheme whereby

(Data courtesy of Power Sprays/Fibre Technologies International Ltd.)

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



TOP:
Figure 3 – graph showing thickness/MOR relationship. Please note, data are indicative and should be confirmed by engineering analysis of actual designed components.

ABOVE:
Figure 4 – sampling of full-sized panels for facing coat and flexural testing.

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 conduct third-party and independent conformity assessments, providing additional confidence on large projects.

FACING COAT COMPATIBILITY

One aspect of GRC product realisation that appears to be 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% has been known to cause cracking, bowing and delamination in composites.

Currently, there are no requirements to carry out 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[7] is a test requirement under BS EN 1169. 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.

INCREASED TESTING FREQUENCY

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 increased 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 and daily. In the case of GRCA manufacturing members, they should conduct the full bending test to determine both elastic (LOP) and ultimate (MOR) capacities at least twice per week.

On large projects, daily testing is strongly recommended. In this way, manufacturers will not only be more reactive to any problems but also be

LEFT:
Figure 5 – removal of facing coat to determine thickness and prepare specimen for flexural testing.

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. While 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.

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

EMBEDDED FIXINGS

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, when correctly fitted, this type of fixing would still have a relatively low resistance to the pull-out forces generated by negative wind pressure compared with 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 that needs careful quality control. Unlike traditional concretes that have good flow rates when poured into moulds, this is not the case with high-fibre-content sprayed GRC. As a result, the material must be hand-packed around the fixing rather than the natural flow 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 that 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.

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 Figure 3, page 8), while over-thickness will increase weight and may affect the capacity of support fixings causing post installation deflection.

The GRCA *Design Guide* does provide an indicative partial safety factor of 1.05 for GRC cladding panels (γ_{tv}), which is applied as part of the engineering calculation; however, as can be seen from Figure 3 (page 8), 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 decreases. This results in greater deflections occurring that 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 is 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 and 0.4m², from which coupons are cut and tested.

Given the handmade nature of GRC, 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 γ_b 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.

FINAL PRODUCT TESTING

Surprisingly for such a complex and hand-made 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 that the flexural strength required in the engineering analysis is achieved.

CONCLUDING REMARKS

The growth of GRC was restricted in the 1980s due to several in-service failures that were possibly considered 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 large and high-rise projects.

Specifiers and buyers also need to understand and play their part. GRC is not a material that can be either 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.

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 100 years.

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

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