Quality Matters

Glassfibre Reinforced Concrete (GRC/GFRC) is acknowledged as a modern and complex composite which has more in common with high tech materials than traditional precast concrete. As such both specifier and users should exercise a high level of due diligence when selecting the GRC supplier for their project.

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This is the nineth in a series of technical notes covering aspects of glassfibre reinforced concrete (GRC) technology.

Correctly designed, manufactured and installed GRC products will have a service life well in excess of 80 years. However there is a potential for product failure if the best practices established after nearly 50 years of research and development are not completely followed by everyone involved in the delivery of both performance and architectural expectation.

GRC was first developed in the late 1960s with initial production undertaken by manufacturers licensed by the material developer Pilkington Glass. Unfortunately the strict manufacturing processes were not always adhered to resulting in several failures which restricted the growth in the market for several decades. With the surge in popularity of GRC and inexperienced manufacturers and suppliers participating in the supply chain, there have been increasing instances of incorrectly manufactured products appearing with resultant remedial or replacement issues for both building owners and contractors.

When selecting a manufacturer, a user or specifier should select to use those producers who have been independently assessed as having the necessary skill, equipment and management processes to produce high quality GRC. Within the GRCA these will be those organizations who are designated as "Full Members" in the appropriate members listing. These companies have been assessed by a competent and independent third party appointed by the Association and have been found to have capability to manufacture high quality GRC products at the time of inspection. Although such inspections are based on a single annual visit the accompanying accreditation may provide some reassurance. Companies who are ISO 9001 certified with suitable scope are not further inspected by Association representatives. It should be noted that membership of the GRCA does not require "Full Member" inspection and "Member" designation is applied to any suitable applicant including unassessed manufacturers. Although in recent years the GRCA has increased the membership requirements, specifiers and users must satisfy themselves of a manufacturer's suitability.

Figure 1

30 Cannon Street, London - An example of the excellence of GRC

The starting point for any GRC project is a robust specification which will ensure the supplier or manufacturer is fully aware of the specifier or clients requirements. These specification must be project specific given the many variations in production, testing and compliance standards that exist. The failure to produce exacting and detailed requirements applicable to the manufacturing process is a high contributing factor to potential in service failures.

All products manufactured from GRC, excluding some purely decorative items such as garden ornaments or small architectural dressings should be correctly designed to be able to resist all imposed loads. The failure mechanism of the composite and its characteristic attributes must be clearly understood by the design engineer. As such clarification should be sought as to the competency

and experience of any party carrying out the design of GRC products and associated fixing systems. The GRCA recommends that all design is carried out in accordance with the Associations published design recommendations as detailed in the GRCA Design Guide.

Once a suitable design has been produced rigorous processes should be implemented to ensure standard and specification compliance. No GRC project should be undertaken without a comprehensive inspection and testing plan (ITP) being produced and all stakeholders committing to its implementation. The specification and ITP documentation are the key inputs in any successful GRC delivery outcome.

At the manufacturing stage the ITP must be followed with all required inspection and testing being carried out and recorded. The manufacturer should always follow established best practice which is detailed in the many publications available. Especially important are verification of fibre content, manufactured thickness, flexural strength at both elastic and ultimate failure level. Full traceability is also an essential component of good quality GRC manufacture.

Once the GRC product has been correctly designed and manufactured correct installation becomes critical. The composite has far higher reversible and irreversible movement than other forms of precast concrete. This is a consequence of the high cement content which characterises GRC. A competent design engineer will have provided exacting fixing details which will allow for such movement with the use of oversized or elongated fixing points, friction reducing plastic spacers, elastomeric high performance sealants etc. It is absolutely essential the installers understand the need these details are exactly followed. For this reason the choice of installer must always be restricted to those with experience in successfully installing GRC products.

If all the correct processes are employed GRC is a highly robust material which will perform beyond expectation. An example of this is 30 Cannon Street, London (Figure 1) which features in many GRC publications. The unique GRC facade cladding on the building has already performed for over 40 years and a recent in-depth examination has shown that the components should last at least another 40 years. The building continues to provide credible performance evidence of the durability of correctly manufactured GRC.

Where there is failure of GRC products in use this generally takes the form of either structural cracking caused by a variety of reasons or delamination of any applied mist or face coat. Structural cracking should not be confused with surface crazing (refer to techNOTE 10 - Appearance). It occurs when the structural GRC fails through either imposed loads exceeding the capacity of the product or restricted movement causes the unit to literally tear itself apart. Structural cracking can ultimately lead to sections of the GRC element becoming detached and is generally caused by either, low flexural strength, products being manufactured too thin, or incorrectly designed/ installed fixing systems. Delamination of the face coat can occur where correct manufacturing process have not been observed creating a weakness at the interface between the applied aesthetic finish and the actual structural GRC.

Very few building products offer the versatility in both appearance and performance than can be obtained with high quality GRC products. This unique composite is one of the ultimate expressions of both function and form available in the modern construction environment and is successfully used by some of the world's leading architects and contractors. However correct selection of suppliers and manufacturers is absolutely paramount in ensuring successfully executed products which will stand the test of time.

Case Studies

The following details case studies of where correct procedures have not been followed with resultant product failure and expensive remedial or replacement works. They are not representative of the industry however the GRCA feels that buyer awareness of potential issues is paramount in maintaining the integrity of this exciting composite.

Case Study One

GRC architectural dressings and claddings were specified for use on a large retail/office development constructed in 2007. Within two years of completion the GRC was suffering from excessive weathering and cracking across all elevations. Various consulting bodies were employed to determine the cause of the failures with the consensus being various contributory factors were causing continuing and progressive failure.

These factors included, elements being manufacture too thin, flexural strengths not attaining design requirements, incorrect installation and the use of non-corrosion resistant fixings. As a result the GRC was unable to resist the various forces and loads imposed on it and duly failed in service.

The result of all the above was a building which was covered in scaffolding and netting for some five years while investigative and legal processes were progressing. Ultimately all the GRC units were removed and replaced with high quality GRC in 2014 at substantial cost to the building owner.

Figure 2

example of incorrect thickness of face coat and GRC structural backing

Case Study Two

This project is a high profile office development located in a major European city constructed in 2017. Even before completion the client noted excessive cracking to vertical GRC fins fitted to the external façade by the specialist sub-contractor.

Investigation showed that the fins had been manufactured using a mix design which fell outside the recommendations of the GRCA Specification. As a result the main contractor commissioned a series of flexural bending tests to be carried out on samples taken from finished products. These tests showed the fins flexural strength differed considerably between test coupons.

It was ultimately concluded that the method of production differed considerably from the method of producing the required weekly test samples. As a result actual material strength in the finished product was lower than those used in the design calculations.

At the time of this publication it is likely all the fins will require replacement resulting in a significant practical completion of the building.

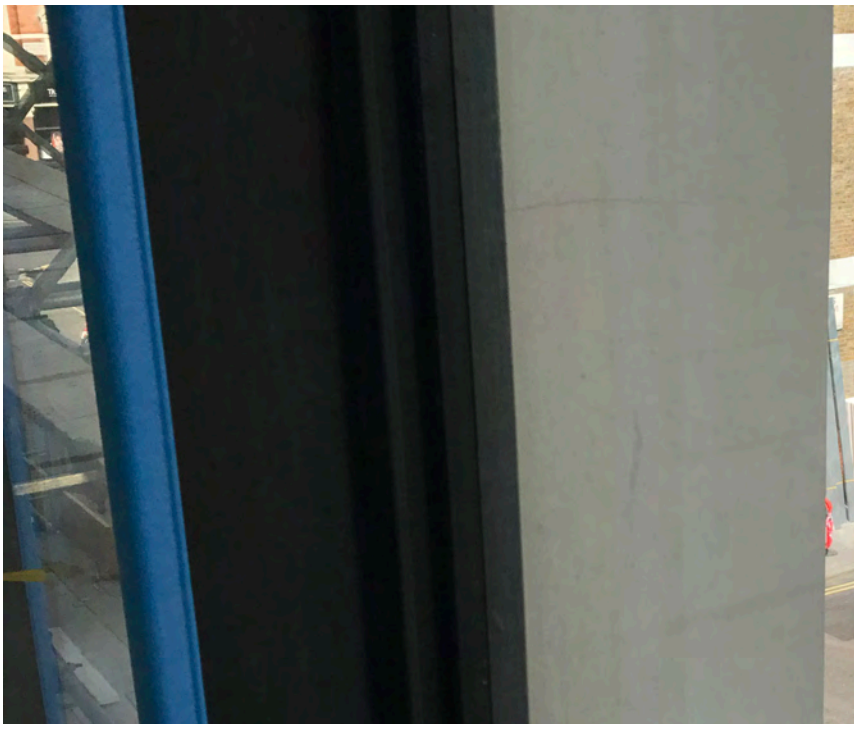

Figure 3

Example of cracked fins

Case Study Three

A unique and inspirational design at a European University Campus built in 2015 featured extensive use of complex geometry GRC cladding panels. Within 12 months of completion cracking began to appear across some 25% of the GRC units.

Specialist investigation revealed good manufacturing practices had been completely ignored by the manufacturer. The thickness of the GRC was found to be up to 10mm below that required in the design calculations. Manufacture had used split mould casting techniques which were not competently executed resulting structural delamination. In addition it was found that bright zinc plated cast in threaded anchors had been cast into the units to act as primary fixing points. These had already began to significantly corrode.

Ultimately all the GRC is likely to be removed with monthly safety inspections being carried out until this can be practically completed.

Figure 4

Example of incorrect thickness resulting in failure

Case Study Four

This is high value residential development centrally located in a major European City. Completed in 2008 the development which rises to 40 storey's features GRC cladding at all levels.

Within the main contractors defects liability period cracks and delamination of the face coat began to appear. Specialist reports and testing were commissioned which concluded that not only was the GRC not of sufficient structural strength at the ultimate failure load but the face/ mist coat had been allowed to dry out prior to application of the backing GRC structural coat.

The only course of action open was removal and replacement of all GRC panels to ensure the public's safety. The cost, inconvenience and reputational damage are of course considerable.

Figure 5

Example of face coat delamination

Case Study Five

Prior to installation of several thousand square meters of GRC cladding the facade sub-contractor, becoming concerned, appointed a specialist GRC consultants to visit the manufacturer and ensure correct manufacturing methods were being employed. This inspection revealed significant failings in the manufacturing process control.

Subsequent full sized product testing revealed significant failures and the GRC panels being rejected as not specification compliant. Replacement panels were manufactured with suitable corrective actions including a robust ITP, and regular supervision by external quality control specialist consultants.

Figure 6

Example of badly compacted GRC

Concluding remarks

It must be recognized that GRC is a highly advanced cement based composite which requires significant levels of process, input and controls to enable the manufacture of high quality products. Paradoxically only relatively inexpensive equipment is required to produce GRC, which can lead to a proliferation of manufacturers without the required skills and controls to produce high quality GRC.

When using GRC on any project specifiers and users must satisfy themselves that all required manufacturing and testing procedures are in place, along with robust and correctly observed documented Inspection & Testing Plans.