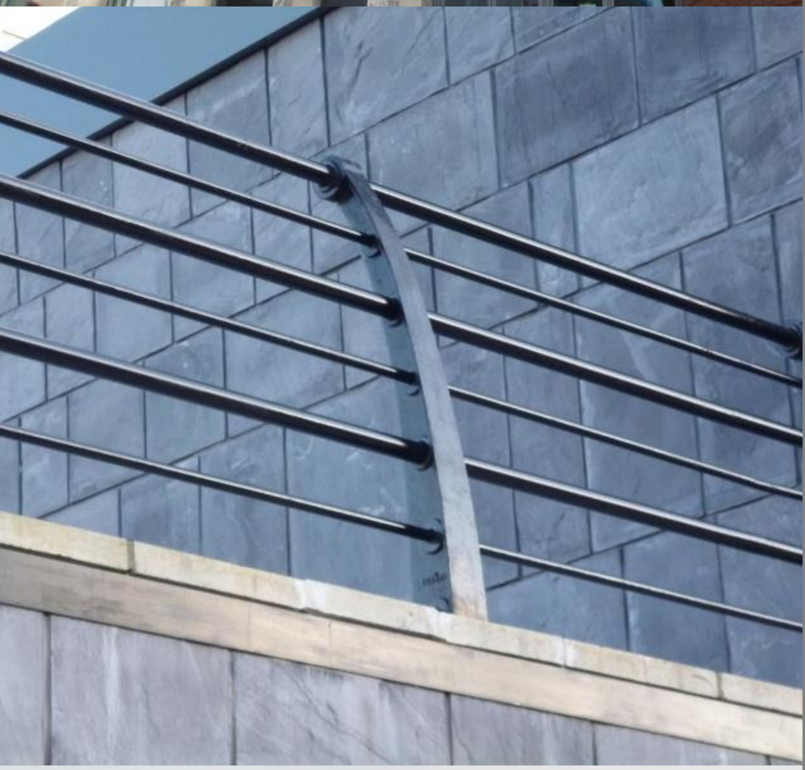
June 2012

GLASS REINFORCED CONCRETE DURABILITY & WEATHERING



passionate about grc

grcuk

INTRODUCTION

Glass Reinforced Concrete was first developed in the UK in the late 1960s. Although experiments to reinforced concrete with glass fibre strands had been conducted since the 1940s these had been in the main unsuccessful due to the alkaline nature of the cementitous matrix reducing the effectiveness of the fibres.

This problem was eventually overcome after collaboration between the British Research Establishment and Pilkington Glass resulted in the introduction of alkali resistant glass fibres which maximised the long term performance of the material.

Over the last 40 years more research has been done into the durability of the GRC than virtually any other facade cladding material. These well documented research and practical studies can give architects, engineers and contractors genuine confidence in the material when correctly designed and manufactured.

This publication is designed to give the reader an insight into the issues relating to both the mechanical and visual properties of the composite.

GRCUK is one of Europe's leading manufacturers of GRC products. We are committed to a programme of on-going research and development and operate the most comprehensive specialist GRC laboratory testing facilities in the UK. We do however remain equally committed to manufacturing using the techniques developed over the last 40 years given the proven durability of components made using these methods.

MATERIAL PROPERTIES

GRC is a cement rich concrete with a relatively low water/cement ratio reinforced with alkali resistant glass fibres blended throughout the matrix.

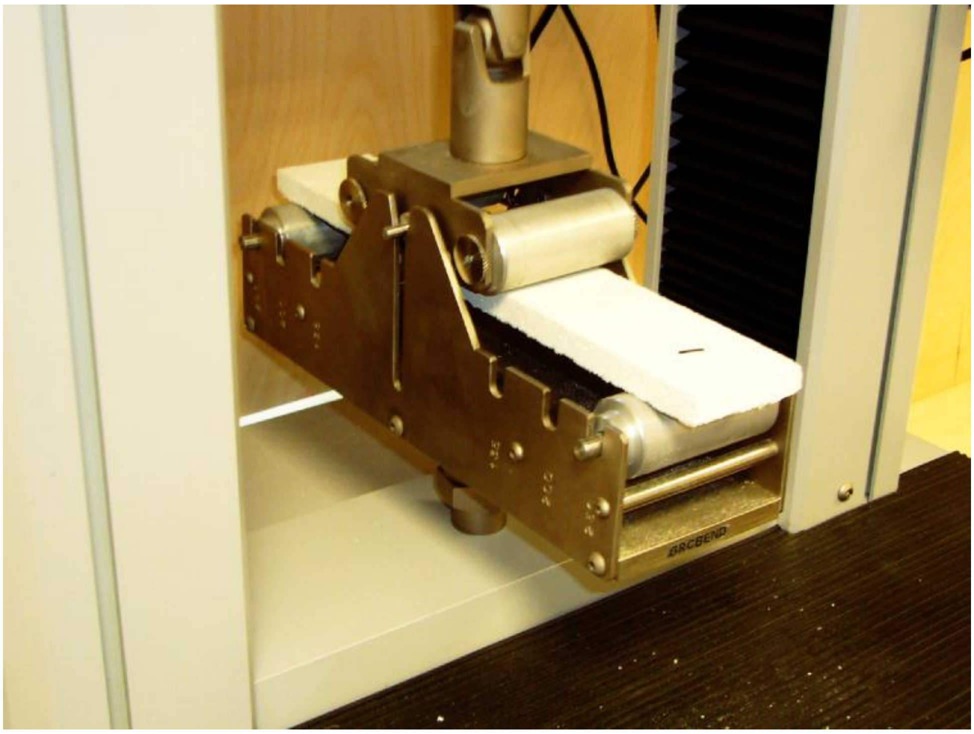
As GRC contains no steel reinforcement there need be no concerns regarding concrete cover. Equally because the reinforcement is spread throughout the matrix and not just in the tensile stress area, elastic and ultimate bending strengths are significantly increased. These properties allow items to be manufactured using thin skin profiles thus reducing component weight.

Although it has long been understood that there is some loss in ultimate bending strength or ductility over time equally elastic strength increases as hydration of the cement continues.

BS EN 1170 Part 5 is the primary test to establish the 7 and 28 day elastic and ultimate strengths of the material and is a direct development of the testing methodology established by Pilkington Glass and the British Research Establishment in their joint development of GRC.

In order to best predict loss in ultimate bending strength BS EN 1170 Part 8 (the cyclic weathering test) subjects the GRC to a further 50 cycles of heating, rapid cooling and total immersion in water. Further bending testing allows comparisons to the 28 day strength. The expected loss in ultimate bending strength is defined in BS EN 15191.

Established best practice however is to design all stresses below the elastic limit ensuring there is no decrease in the design properties. Retention of the ultimate bending strength does however assist in providing greater ductility so localised overloads do not cause the whole panel to fail



4 Point Bending Test (BS EN 1170: 5)
GRCUK Laboratories

It is because of these properties GRC is a favoured material in areas at risk from seismic activity. In these areas full scale testing has shown very high resistance to cracking.

APPEARANCE

Of equal importance to many is the ability of the material to retain it's supplied appearance.

GRC is a dense concrete and although it demonstrates similar water absorption to most other concretes the water permeability is significantly lower. For this reason GRC is extensively used to manufacture water channels and ducting.

The rate of carbonation is also significantly lower in GRC than other forms of pre-cast concrete with independent tests showing a 90% decrease over a given period. As a result of the above GRC will retain its supplied appearance longer than most other forms of pre cast concrete such as cast stone.

Permeability can be improved by the addition of polymer modification to the mix design. Acrylic polymers are designed to allow dry curing by locking the water incorporated into the mix design into the matrix. This assists in complete hydration of the cement thus increasing the material properties of the GRC. Polymers have also found to be beneficial in sealing the interface between the matrix and the fibres thus increasing ductility over a given period.

Polymers equally work in reducing absorption of water into the GRC again contributing to the retention of the supplied appearance longer. A further advantage of the use of the additive is to prevent migration of salts to the concrete surface. In this way efflorescence is minimised in polymer modified GRC. The addition of polymers also minimise any surface crazing

Long term analysis of installed GRC indicates that the application of surface sealants assist in the preservation of both physical and visual attributes of newly produced GRC. Such coatings, applied after the initial curing but before despatch, effectively seal the surface of the GRC reducing even further permeability.

Application of surface sealant to finished product—GRCUK production

30 CANNON STREET, LONDON

One of the first major projects to use GRC as a primary cladding material was the then headquarters of French bank Credit Lyonaisse. Constructed in 1974 the building utilised panels manufactured using Spray process GRC. Located in Cannon Street London the building sits in the shadow of St Paul's Cathedral

In 2002 with the cladding well beyond it's design life of 25 years, the panels were was fully inspected by Arup Materials Consulting to determine future maintenance of the now 28 year old GRC components. The original design calculations for the GRC had been carried out by Ove Arup in the 1970s. A full and complete examination was carried out which was presented as a paper at the 2003 international GRCA conference in Barcelona.

This involved removal of several sections of GRC which were subjected to the 4 point bending test as defined in BS 1170: 5. The results of these tests indicated an expected loss of ductility however this was not as low as expected with a drop of MOR of approximately 50%.

It was concluded that the loss in ultimate bending strength, which was not as high as BRE predictions, was due to the application of a water repellent solution the surface of the GRC. This prevented the GRC from being exposed to a constant wetting/drying cycle.

Good design considerations by Ove Arup had provided fixing solutions which allowed the free movement of the GRC ensuring the components were not subjected to “locked in” movement restriction caused by initial drying shrinkage and subsequent thermal expansion and contraction .

The conclusion of the report indicated that further loss of ductility was unlikely and that with continued application of a suitable water repellent the GRC would continue to perform. It should be noted that the GRC on this building has been cosmetically coated at some point over the last 37 years and therefore the conclusions of the Arup report are confined to the material properties of the composite as the underlying surface finish is no longer visible.

30 Cannon Street provides an excellent example of how correct design by the original engineers along with good manufacturing procedures determined by Pilkington Glass can result in long lasting and durable cladding facades.


30 CANNON ST
UNDERGROUND
SUBWAY

SHEPARD HALL, CITY COLLEGE, NEW YORK CITY

Shepard Hall was constructed on the City College campus in 1907. The original construction utilised both local walling stone with extensive use of terracotta features and dressings in a Gothic architectural design. By the early 1980s over one third of the original terracotta had already failed and another third was exhibiting severe distress. This resulted in large sections of the building including it's impressive main hall being closed due to falling sections of masonry. In addition over the past 70 years some of the terracotta had been replaced with brick and stucco render which itself was now failing.

The major failure of the original design had been a lack of understanding in relation to the differential movements of the facade elements. This has resulted in the terracotta literally being crushed apart. Renewal of these components would clearly involve a methodical and progressive approach particularly given there were over 72,000 incorporated into the original design.

New York architects The Stein Partnership (now Elemental Architecture) were commissioned to investigate how the terracotta could be replaced and with what. After extensive research it was concluded that a thin skin glass fibre reinforced concrete would offer the best solution. This would effectively act as a rain screen cladding to solid masonry beneath.

After research carried out in 1986 a formulation of E glass with a calcium alumina silica cement was used to manufacture components for the first stage of the works. Although this was in the main successful, manufacturing and continuity of supply were problematical. As such in 1990 the client commissioned further tests to find a more suitable material that, given the quantity of works involved could be manufactured by several producers.

More formulations of GRC were looked at and tested using the accepted accelerated aging testing methodology developed by Pilkington. The result was the choice of a GRC mix containing AR fibres, OPC, acrylic polymers and metakolin addition. Interestingly these tests also concluded that the GRC would perform best if a silane sealant was applied after manufacture. The use of such sealants would be endorsed some 12 years later in the Arup report on Cannon Street.

From the start of works to date over 66,000 sections of GRC have been installed with completion scheduled for 2013. 4 different manufacturers have supplied the various phases each manufacturing to exactly the same mix designs and manufacturing principles. Whilst the length of the renovation works has been far longer than originally planned (due to budgetary restraint) this has given the architects and client the opportunity to examine the weathering of the GRC over an extended period.

The conclusion is that the GRC has weathered exceptionally well. In some areas components have been installed in adjacent areas but 15 years apart with no discernable difference in appearance.

Shepard Hall is a powerful statement of how high quality GRC, manufactured to exacting and established methods really does stand the test of time. .

Polymer GRC Embellishments, Shepard Hall, New York. L-R 1995, 2002, 2011. All taken 2011.

We would like to acknowledge the following;

Article on 30 Cannon Street uses information contained within the 2003 paper presented at the IGRCA Congress by Chris Peaston and Bob Cather of Arup Materials Consulting

Article on Shepard Hall uses information contained within the 2011 paper presented at the IGRCA Congress by Carl Stein of Elemental Architecture, New York City

Glass Reinforced Concrete UK Ltd,
1-3 Redwood Court, Campbell Way, Dinnington,
Sheffield. S25 3NQ
T: +44 (0) 1909 566911 F: +44 (0) 1909 569399
info@grcuk.com
grcuk.com