1 ACHIEVING AESTHETICS AND DURABILITY IN GRC – SOME USEFUL TIPS

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SUMMARY: The market need for the aesthetic and durability aspects of GRC is quite obvious. The words 'aesthetics' and 'durability' are frequently associated with the GRC industry. GRC sellers and marketers are confronted by tough questions about the durability of GRC systems against other building technologies.

Durability of GRC is a critical point. The life cycle of GRC not only relies on good design and calculations, but also depends on the entire chain of activity following the design. We should also remember that GRC is a constructive system and it involves a variety of raw materials, process and method of fixing, i.e. erection and installation and final finishing including repairs that impact not only aesthetics but durability i.e. beauty and life cycle of the final product once installed.

This paper draws attention to the various steps to be taken towards improvement of aesthetics and durability of GRC. There are certain parameters of quality assurance, which contribute to enhancing the aesthetics of GRC while certain parameters ensure durability. The parameters responsible for better aesthetics are a good design, process control including materials and quality of moulds and component inspection, testing and repairs at plant and site as well as surface finishing at plant level.

The parameters responsible for achieving improved durability in GRC are type and quality of AR glass fiber, entire chain of activities including design and process of installation, erection and treatment of GRC at site including repairs and final finishing

Based on practical experience this paper reviews the developments concerning quality assurance at plant level and focuses on proper erection, installation and repair at site including final finishing to achieve better aesthetics and durability in GRC.
KEYWORDS: Admixture, aesthetics, aggregate, air cure, alkali-resistant fiber, anchors and inserts, durability, grading, life cycle, mix design, pigments, surface finishing, texture, water/cement (w/c) ratio, water cure.

INTRODUCTION

The words 'aesthetics' and 'durability' are frequently associated with the GRC industry. GRC sellers and marketers are confronted by tough questions about the durability of GRC systems against other building technologies.

But what is durability?

What does it mean?

Are we using the right word or concept?

The preference of many GRC experts is to refer to GRC service life or life cycle. But again the life cycle of GRC not only relies on good design and calculations but also depends on the entire chain of activity following the design.

Durability of GRC is a critical point. However, we should remember that GRC is a constructive system and that it involves a variety of raw materials, process and methods of fixing, i.e. erection and installation and final finishing that impact not only aesthetics but durability, i.e. the beauty and life cycle of the final product once installed.

There are certain parameters of quality assurance, which contribute to enhance the aesthetics of GRC while certain parameters ensure durability.

The parameters responsible for better aesthetics

- Good design
- Process control including materials, pigmentation and quality of moulds
- Component inspection, testing and repairs at plant and site as well as surface finishing at plant level

Again, ensuring proper design, using proper production and testing methods, curing the panels in the right environment, transporting and delivering the GRC components in the right way and installing on to the structure require talent, structure and great resources. After all, GRC is a technology. Norms, Standards and job specifications will help in making sure the aesthetics and life cycle of the GRC components based on serious design are respected.

THE PARAMETERS RESPONSIBLE FOR ACHIEVING DURABILITY ASPECTS

- Type and quality of alkali-resistant (AR) glass fiber
- Entire chain of activities including designing
- Process of installation, erection and surface treatment of GRC at site, joint filling including repairs and final finishing at site

Durability of GRC products means a longer life cycle for the building and therefore greater rate of return for the owner of such a building. So, specifiers and architects recall only the bad jobs or the accidents that happened on one contract or another. But in the end, what matters is respecting the norms, Standards and the specifications during the design process, the production process of the GRC units and of course the installation process. If things are done poorly, they will have to be fixed or replaced, whatever is being installed on the job site.

So, this paper draws attention to the various steps to be taken towards improvement of aesthetics and durability of GRC.

STEPS TO ACHIEVE BETTER AESTHETICS AND DURABILITY

1. Quality assurance at plant level, which includes:

- Material selection
- Mix design consideration
- Proportioning and mixing
- Process control
- Product control
- Component inspection and testing
- Repairs in the factory
- Surface finishes
- Curing techniques
- Quality of moulds

2. Proper erection, installation and repairs including final finishing at site, which include:

- Installation and erection at site
- Repairs at site
- Final finishing at site

1. QUALITY ASSURANCE AT PLANT LEVEL

Material selection

Cements

Type/storage
Use of old and set cement should be avoided as small granules of cement formed due to moisture or damp air may spoil the aesthetic appearance of GRC elements.

Color/shade
Color of the cement, especially white, plays a very important role in final color/shade and thus aesthetics of GRC. There should be no shade variation from lot to lot of cement received from suppliers.

Fineness
The fineness of cement also plays an important role in the final finish and texture of GRC elements.

Filler material

For better aesthetics of GRC, the sand should be washed and dried. Use of flaky and elongated sand aggregate should be avoided.

The value for loss on ignition should be accepted up to 3%, provided the material is hard, non-crushable, non-reactive and of similar shape and grading to that described below.

Grading

Sprayed GRC
The fine aggregate or sand shall be washed and dried to remove soluble matter and permit accurate control of the w/c ratio. The particle shape shall be rounded or irregular to BS1199 and BS1200 and shall have a smooth not honey-combed surface.

The grading shall allow for a 1.2mm max. particle size for sprayed GRC and 2.4mm for premix GRC. In both cases the fine fraction, i.e. passing 150mm, shall be less than 10%.

Premix GRC
The maximum particle size is not critical but the quantity of fines should be limited because of the effect on water demand and hence the water/cement ratio.

Fiber

AR glass fiber with high zirconia content, more than 18%, will provide true alkali resistance. The higher the zirconia content the better the alkali resistance. Cement is very alkaline and as such it will quickly corrode 'E' glass fiber.

Admixtures

To improve upon certain properties of GRC during production such as better workability, better cohesion, reduced bleeding and the properties of hardened GRC such as increase in strength and decrease in water permeability, the use of admixtures is recommended. These properties ultimately reflect on long-term behavior of GRC elements. The following precautions should also be taken:

- Add admixtures in small amounts to mixes
- Use correct dose as specified by supplier
- Don't use calcium chloride based admixtures

Pigments

For better aesthetics and durability of colored GRC it is essential that:

- GRC components should have consistency in color
- Color should not fade over a period of time
- Coloring pigments should not be attacked by sunlight or alkali

So, in view of this:

- Use of inorganic pigments (oxide colors) only is recommended as these are resistant to sunlight (UV) and alkali attack
- Don't use low-quality pigments
- Use pigments in small quantities – strong colors should be avoided
- Use of synthetic oxides is better in terms of their color fastness and intensity
- Dosages rates should be accurately monitored for no shade variation from batch to batch of GRC components
- For light and pastel shades, the color/shade or tone of cement, whether white or gray plays a very important role in achieving final color and consistency of color of GRC which provide aesthetic value

Facing materials

Where fine and coarse aggregates are used for exposed finishes on the face of GRC panels, they should be clean, hard, strong, durable and inert and free of material that may cause staining.

Anchors and inserts

Steel bars for anchors should conform to the appropriate requirements of AS3679.

Anchors incorporated in the GRC skin should be corrosion resistant; material should conform to the Standard specifications.

Wherever welding is required as part of the field assembly, the welded area should be cleaned and made good with a zinc-rich primer.

Mix design consideration
Mix design will depend upon strength requirements, density, the amount of detail needed, the form surface, fire rating and other physical properties.

However, the following factors should be considered in preparing mix design:

Water/cement ratio	approx. 0.30
Cement/sand ratio	1:1
Fiber content	3.5–5% depending upon the type of GRC component, method of manufacture, i.e. spray or vibration casting or both
Fiber type	AR with high zirconia: 15– to 19%
Fiber length	25–45mm
Acrylic copolymer content	5–7% by weight of polymer solid to cement
Admixtures (superplasticizer)	0.5– 1% (to maintain low w/c ratio)

Proportioning and mixing

Facing mix

- In proportioning the face mix, use similar cement contents for face and backing mix to ensure adequate compatibility.
- Large differences in physical properties, such as shrinkage and thermal coefficient of expansion of the face mix and GRC backing mix may cause cracking and/or delamination.
- Control of w/c ratio is an important aspect of design and influences both aesthetics and durability.

Backing mix

The spray process requires a mix that is sufficiently fluid for continuous pumping and spraying without blockages and that will allow proper compaction. Low water content mixes give high cured strength and simplify the spraying of near vertical mould surfaces.

Process control
During the production of GRC we have to keep a check of items such as:

- Raw material usage
- Thickness of product
- Final product weight
- Fiber output (from spray unit)
- Slurry output (from spray unit)
- Slump characteristics of slurry
- Glass contents of uncured GRC
- Water/solids ratio of uncured GRC

We have to understand the importance of w/c ratio, consistency and quality of mix.

Importance of w/c ratio

Excess water may assist workability initially but eventually will cause problems associated with bleeding, segregation, low mechanical properties and durability.

So, the w/c ratio should be kept as low as possible.

Any change in consistency during spraying will change not only physical properties but the aesthetics of GRC too.

Product control
The following tests should be conducted on cured GRC components:

- Dry and wet bulk density
- Water absorption
- Apparent porosity
- Limit of Proportionality (LOP)
- Modulus of Rupture (MOR)

Component inspection and testing
The final product should be inspected for:

- Surface flaws, i.e. pin holes, air voids etc
- Color uniformity
- Overall product dimensions
- Finish
- Surface cracks during drying and hardening process

Repairs in the factory
A certain amount of product repair is to be expected as a routine procedure. Repair work requires expert craftsmanship, if the end result is to be structurally sound, durable and pleasing in appearance. Repairs are acceptable provided the structural adequacy, serviceability and appearance of the product are not impaired. Excessive variation in color and texture of repairs from the surrounding surfaces may result in the panels not being approved until the variation is minimized. Major repairs should not be attempted until an engineering evaluation by the panel design engineer is made to determine whether the unit will be structurally sound.

Surface finishes
The surface finishes can be achieved by light exposure, deep exposure and medium exposure. The extent to which aggregates are exposed or revealed is largely determined by their size. What is revealed should be no greater than one-third the average diameter of the coarse aggregate particles and not more than one-half the diameter of the smallest-sized coarse aggregate.

In case of light exposure the sand color will greatly influence the overall panel color.

- To maintain standards of finish and exposure the reference sample should be available for matching.
- The samples should be protected during the course of the project to prevent any unwanted changes in appearance with time.
- The acid should be applied on a pre-wetted surface by brush to reduce acid penetration.
- Immediately after each washing, GRC units should be thoroughly rinsed with fresh, clean water to completely remove all traces of acid.
- If the coarse aggregate, fine aggregate and cement paste are similar in color, the depth of exposure and localized densities of material will not be as critical in maintaining color consistency. In contrast, if material colors are quite different, panels may appear blotchy for the same reasons.

Surface finishes by acid etching

Acid etching is most commonly used for light or medium exposure. In cases where aggregates are to be exposed to a considerable depth, only acid-resistive silicone aggregates such as quartz and granite should be used.

- Carbonate aggregate, i.e. limestones, dolomites and marbles will discolor or dissolve due to their high calcium content.
- Deep etch should be achieved by multiple treatments.
- Prior to acid etching, all exposed metal surfaces, particularly galvanized metal, should be protected with acid-resistant coating.

Mist coat

In case no facing mix is used and to prevent the appearance of fibers at the face level, a mist coat consisting of cement, sand, slurry and incorporating a polymer admixture should be applied to a thickness of about 0.5mm; thicker application may induce surface cracking.

Compaction

Time spent in rolling and trowelling reduces time spent in making good and a stronger product, which is responsible for long-term durability. So, compaction during processing is required to:

- Conform the GRC to mould shape and finish
- Remove entrapped air, thereby increasing GRC density and strength
- Coating each bundle of glass fiber in the matrix thereby giving stronger bonding

Curing of GRC

For full-strength development it is essential that GRC products are allowed to cure or hydrate for several weeks after casting.

There are two types of curing system and three curing durations to ensure full strength and long-term properties of GRC.

Types of curing

Moist curing

As GRC products are normally of comparatively thin section manufactured with lower w/c ratio than most conventional concretes and are prone to rapid hardening, to ensure complete hydration it is essential that products are kept moist immediately after manufacture. The best methods to achieve this are storage in a humidity chamber or fogroom or sealing with polythene sheets immediately after manufacture.

Curing periods can be divided into three parts:

A pre-demoulding cure

This is immediate covering of GRC products with polythene sheets to minimize air flow across the GRC surface, enabling the products to retain as much water as possible.

Post demoulding cure (main curing)

To achieve a substantial proportion of ultimate strength, the GRC products should be immersed in water for 7 days, in a humidity greater than 95% RH, and with a min. temperature of 15°C.

Post curing

This is a period during which GRC components are normalized to the ambient conditions prior to storage or use, particularly in extreme hot or cold conditions. The combination of direct sun and low humidity could cause problems with differential shrinkage even though the GRC strength is high at this stage in its life. This will affect aesthetics as well as reduce the durability of GRC.

Air curing

An alternative method of curing is to incorporate polymeric material into the GRC mix. The film of polymer formed allows moisture to be retained and hydration to continue.

Effect of curing upon design and durability

Quality and timely curing is essential in the development of strength of GRC and to control volume change and permeability. It is a critical aspect of manufacture which affects both aesthetics and long-term durability of GRC.

Role of moulds for better aesthetics of GRC

- The appearance of the finished panel surface is directly related to the choice of mould material and the quality of workmanship of the mould itself.
- All moulds should conform to the profiles, dimensions and to tolerances to the approved shop drawings.
- Moulds should be treated with a release agent that will permit release without damaging or staining the GRC and without affecting subsequent coating, painting or caulking operations.
- Moulds should be dimensionally stable to produce the required finish and tolerance.

2. TIPS FOR PROPER ERECTION, INSTALLATION, REPAIRS AND FINISHING OF GRC AT SITE TO ACHIEVE BETTER AESTHETICS AND DURABILITY OF GRC

Installation and erection at site
The erector should understand the function and performance of each connection detail to ensure that all GRC elements are installed in keeping with the design concept.

During panel installation, priority is given to aligning the exterior face of the panels for aesthetic reasons.

The design criteria for joint sealing should include:

- Amount of movement to be accommodated
- Architectural appearance
- Function of the building
- Exposure (orientation and climatic conditions)
- Economics

So, the following decisions must be made in response to the design criteria:

- Width and depth
- Type
- Member
- Architectural treatment
- Material selection

Ideally, joint locations should be determined during the design development phase; items affected by joint design are:

- Panel size and dimensional accuracy
- Weathering
- Tolerances
- Transition between adjacent materials
- Location of opening

The preferred material for joints is silicone which can accommodate up to 50% movement of their declared width.

The selection of plastic foams as core materials should depend upon operating conditions and the temperature stability of the foam. Polystyrene foam should work satisfactorily with sandwich panels of working temperature up to 80°C.

If an aggregate facing mix is used for one side of a GRC sandwich panel, it should be noted that the aggregate mix will probably exhibit different shrinkage and moisture movement properties. This may well result in bowing occurring soon after the panel is demoulded.

It should be remembered that the aggregate facing mix is not reinforced with fiber and therefore plays no part in the structural thickness of the panel. However, it will naturally increase the self-weight of panel and it may therefore be necessary to check the handling stresses.

Repairs at site
GRC panels may be superficially damaged (minor chipping or spalling) during transport or erection and job site repair will be necessary.

Workers experienced in such job site repair must perform this work. Repairs should be done only when conditions exist which assure that the repaired area will conform to the balance of the work with respect to appearance, strength and durability.

It is important that all repairs be performed in advance of the final cleaning and joint sealing operation. The repair work must be fully cured, clean and dry prior to caulking.

Final finishing at site

- Dry brushing, cleaning with water and mild acid, if necessary
- Application of silicon-based water-repellent coats and dust-preventive coats as per site situation and requirements
- To cover all metal fixtures, especially mild steel with rust-preventive coatings

FURTHER READING

GRC publications of National Precast Concrete Association, Australia.
Cem-FIL GRC Technical Data.
British Standards Institution. Methods for determining properties of glass fibre reinforced cement material. BSI, London BS6432: 1984.
GRCA 'Method of test for strength retention of glass fibre in cements and mortars'.