CERAMIC TILES INCORPORATED IN THE MANUFACTURE OF GRC PANELS

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ABSTRACT

Some factors that may cause loss of performance in facade ceramic covering are stains and detachment of tiles. It was preferred to realize the ceramic tiles incorporation in the fabrication process of GRC panels to avoid these losses of performance. This paper intends to show the use of GRC panels covered with ceramic tiles on facade of three buildings situated in The Lutheran University of Brazil in Canoas. One of the facade project requirements of these buildings was the use of ceramic tiles covering, to match the architectural language of existing constructions. The GRC panel fabrication method with ceramic tile cladding begins with the steel mold cleaning and later fixing of lateral steel bars. The adhesive tapes are put on the steel molds. It facilitates the fixing of the ceramic tiles on the mold and helps to control the joint thickness between the tiles. One layer of adhesive mortar is applied upon ceramic tiles to provide one interface among GRC and ceramic tiles. The rest of the fabrication processes are similar to other types of GRC panels. The incorporated ceramic tiles on GRC panels allow transfer of the work from an outdoor environment to a controlled indoor environment. The facades built with this system are very similar in appearance to other buildings that use traditional masonry, because the joints between ceramic tiles were designed to produce the same image of theses traditional masonries. This technology provides an increase in facade productivity with ceramic tiles and better quality control for GRC panels.

1. INTRODUCTION

The last ten years has seen a development in prefabricated facades in Brazil and more recently, according to Barth et al (2003), in GRC panels for emblematic works like the facades of the Sé Cathedral towers in Sao Paulo. The building work presented for this project has some peculiarities in terms of the planned characteristics of the buildings and the different manufacturing methods. In the three buildings analysed the structures and the facades are prefabricated in order to reduce the execution time. The use of prefabricated panels for the facades has led to greater efficiency in manufacturing and assembly. The panels externally clad with ceramic tiles allow the continuity of the architectonic composition of the already existing buildings. Furthermore, these panels present greater dimensional uniformity, regularity in the layout of the ceramic tiles and the absence of stains. These characteristics are achieved by controlling the manufacturing procedures and this in turn, contributes to the improved quality of the work.

2. COMPOSITE GRC

The first composites were developed by nature. Santiago (1997) differentiates compounded material from composites. Compounded materials are formed by the combination of two or more materials and composites are characterised by two distinct phases: the matrix phase and the reinforcement phase that in general constitutes fibres, sheets, or particles. The matrix is the greatest constituent part of the composite according to Weeton (1988). Its functions are to mix into the reinforcement phase, providing stability and distributing the forces present.

Reinforcement allows increase resistance to composite tensile and bending strength. The facade panels analysed in this study are made with a reinforced cementitious matrix with fibreglass. The fibres frequently used are: glass, metal, carbon, polypropylene, cellulose with PVC and aramid, also known as Kevlar. According to Santiago, (1997), the glass fibres are used more in composites produced for the building construction industry due to its characteristics and lower cost. However, it should be noted that the glass fibres show deterioration in alkaline environments. Therefore, the fibres need to resist the alkali in cement. Majumdar and Laws (1991) demonstrate through accelerated aging tests that fabricated fibre with 16.8% added zircon oxide shows a controlled loss of resistance to the alkali. This loss can be compensated by a safety coefficient in the calculation of the pieces or through the use of a higher quantity of fibres in the composite.

The GRC components are usually in thinner layers, compared to the corresponding prefabricated concrete panels, according to how the matrix is reinforced with glass fibres that are resistant to the alkali in the cement. The concrete panels use steel armour that should be protected by a layer of covering in order to avoid rusting. The protection layer is measured according to the aggressiveness of the environment and the required durability. The components of GRC do not require this minimum covering as the fibres do not show deterioration through the corrosive process. The AR (Alkali resistant) glass fibres show resistance to the alkaline attack from the cementitious matrix which gives adherence to the fibre-matrix and a higher resistance to the friction and inflexion of the composite.

The two types of GRC manufacturing most widely used in Brazil are premix and spray-up. The premix application method is firstly characterised by a mixture of materials that make up the mortar paste. The AR glass fibre is added afterwards in the mixer. The water/cement relation should be less than 0.35. The quantity of added fibres in the premix method is about 3.5% of the weight of the cement.

In the spray-up method, the glass fibre and the cement paste are projected separately through a gun. The fibre and the matrix are only mixed in the spray gun with concentric nozzle when the glass fibre is sprayed out and the cement is sprayed around the perimeter. The percentage of added glass fibre is approximately 5% of the weight of the cement.

3. ADHERED CLADDING

The surface finishings with ceramic tiles can be incorporated into the panels through guides fitted at the bottom of the mould. Nevertheless, these and other materials, like granite, marble and ceramic panels adhered to the GRC can generate stresses in their interface zone with the composite because of the dimensional variation caused by the initial creep of GRC and due to variations in temperature and humidity. One alternative in order to allow these movements is to attach a non-adhesive layer between the GRC and the ceramics. Another possibility is to attach a layer of adhesive mortar which is capable of adhering itself enough to allow demoulding and to allow the movements caused by the initial GRC shrinkage, which is irreversible. During the curing period there is another significant water loss from the GRC which consequently leads to the reduction in size of the panels. Given this phenomenon, a layer of mortar is necessary with polymeric additives that provoke shrinkage and hardening and, furthermore, allow the different movements of the GRC sheets and the ceramic tiles.

4. CASE STUDIES

The three buildings were constructed in the Lutheran University of Brazil in 2002 and 2003. The sports centre, the Faculty of Odontology and the parking lot building demonstrate GRC with ceramic cladding shown in Figures 1, 2 and 3. In order to reduce building execution time and to improve construction work and quality control, metallic moulds were used in the manufacturing of panels. The panels for the sports centre were manufactured using the premix method as the manufacturer did not have the most up-to-date manufacturing machines at that time. Nevertheless, the panels for the Faculty of Odontology and the parking lot building were produced using the spray-up method due to the fact that it is a more productive alternative technology compared to the premix method.

Figure 1. Sports Centre

Figure 2. Faculty of Odontology

Figure 3. Car park

These panels have GRC layers of 12 and 15 mm that vary according to size and the reinforcement structure of the panels. The facades are formed by two types of construction. The sandwich panel is comprised of two GRC layers, a polystyrene nucleus and a shell panel with steel frame. The international term is *stud frame*. The sports centre's sandwich panels reach about 2 x 3.8 metres and the Faculty of Odontology *stud frame* panels are 3.40 X 4.95 m, which bring the surface area to a total of 16.80m². You can see the subsequent results of the *stud frame* panel in Figures 4 and 5 as well as a horizontal section corner of the Faculty of Odontology.

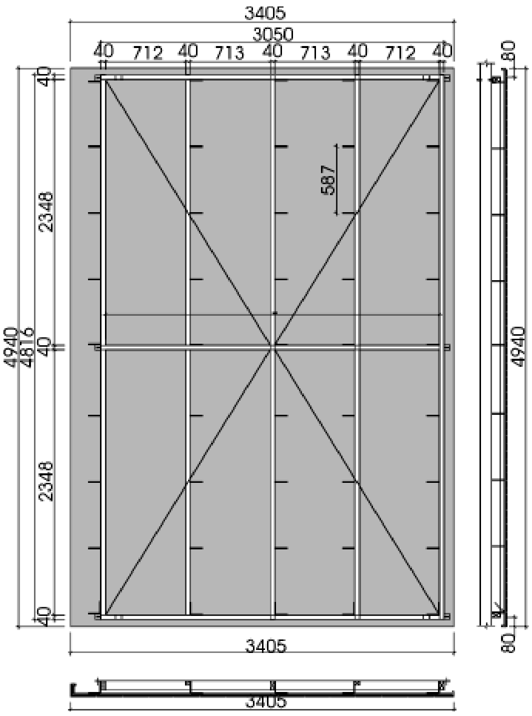

Figure 4. Rear view of the horizontal stud frame panel

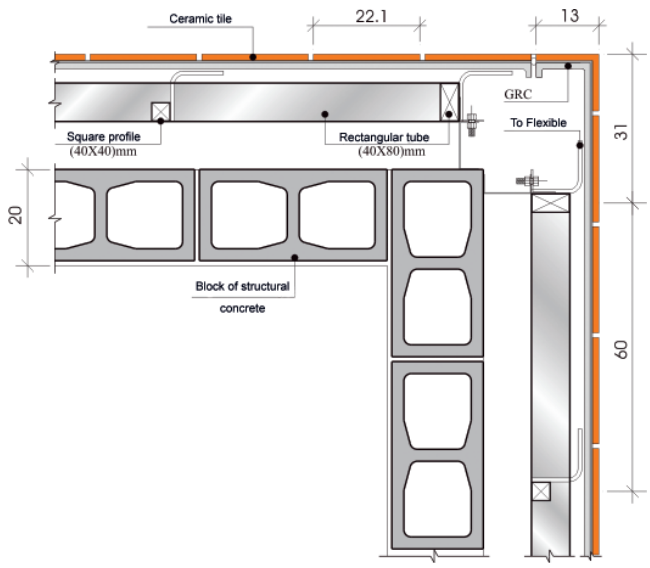

Figure 5. Horizontal section of the corner panels

5. MANUFACTURING OF SANDWICH PANELS WITH CERAMIC CLADDING

The GRC sandwich panels with ceramic tiles are produced using the premix method, in accordance with the following stages:

1 - Cleaning of the metallic moulds.

2 – Corner piece fixing where two fixed sides and two sides can be prepared with a fastening magnet.

3 – The preparation of the guides with the measurements of the ceramic tiles

4 – The application of the demoulding element in the adhesive strips and the outside panels of the moulds.

5 – Placement of the tiles at the bottom of the mould, as shown in Figure 6.

6 – Application of mortar type AC-III and the regularisation of the surface with an average thickness of 5mm above the underside of the tile as shown in Figure 7.

Figure 6. Positioning of the tiles in moulds

Figure 7. Application of adhesive mortar on top of these tiles.

7 – GRC preparation in accordance with the composition in Table 1;

Material	Quantity
cement	50 Kg
fine sand	50 Kg
AR fibre (premix / projection)	(2.5 / 3.5) Kg
Water	17.5 litres
Superplasticiser	0.3 litres

Table 1. Quantities of materials used for the premix method.

8 – Application of the first layer of GRC with a nominal thickness of 15mm with simultaneous compacting and fluted metal rollers.

9 – Placement and positioning verification of the expanded polystyrene pieces.

10 – Placement of the metal inserts as shown in Figure 8;

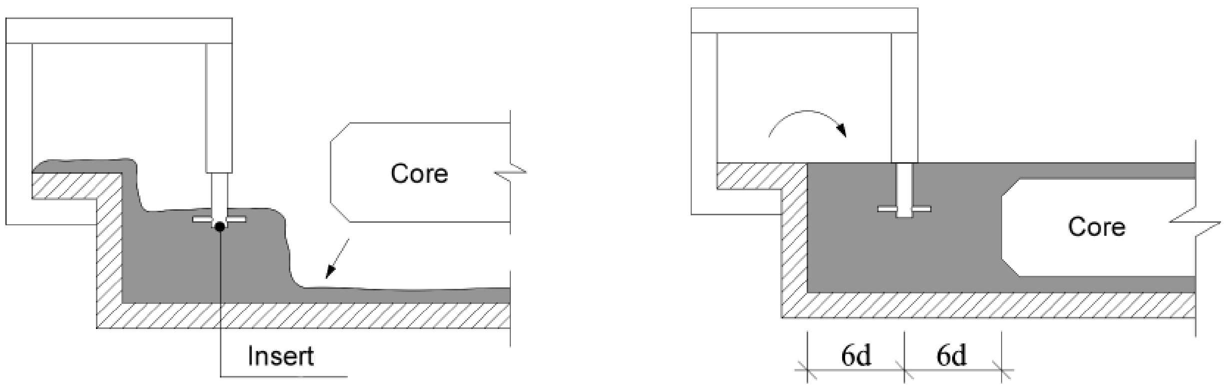

Figure 8. Placement of metal inserts with subsequent GRC application. (CEM-FIL, 1996).

11 – Vein filling according to the project.

12 – Application and compacting of the second GRC layer with a thickness of 15mm.

13 – Regularisation and finalisation of the panel with cement mortar and fine sand (1:1).

During the manufacturing of the sandwich panels through the spray-up method the previously described stages are similar. The composition of the material is identical. However there is some increase in the quantity of fibre in the composite. Because it is a layer spray process, the fibres are distributed in two directions. The mixture of fibres with the matrix occurs in the mould. For this reason, the fibre content used is higher. Contrary to the premix process, the application of GRC is carried out in layers of 3-4mm in thickness, as per the illustration in Figure 9. The polystyrene plate laying and anchorage stages are the same as the previous process.

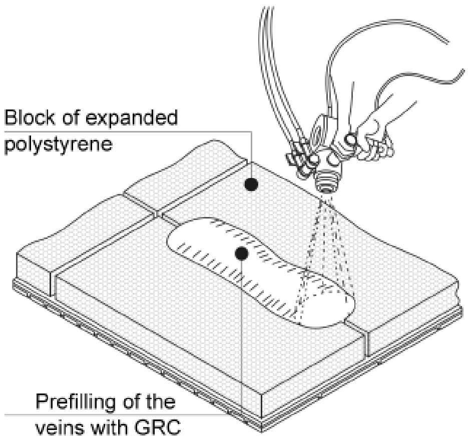

Figure 9. (photo) Spraying of the first GRC layer on adhesive mortar and on polystyrene.

6. MANUFACTURING OF STUD FRAME STYLE PANELS WITH CERAMIC TILES

The manufacturing of the stud frame panels involves most of the stages used in the previous methods. This type of panel has a steel structure and does not need reinforcement veins. The mixture proportion and spraying of it on the metallic mould follows the same manufacturing instructions as the sandwich style panels. After spraying and GRC shell compacting the metal framework is placed on it. This frame is made up of a panel/frame and by flexible shafts of small diameter in an "L" shape which are welded to the panel making a joint between the frame and the GRC shell as shown in Figure 10. The metal shafts allow the movement of the shell for the dimensional changes which are brought about by variations in temperature and humidity in the GRC. The framework should be placed on the GRC shell before it hardens.

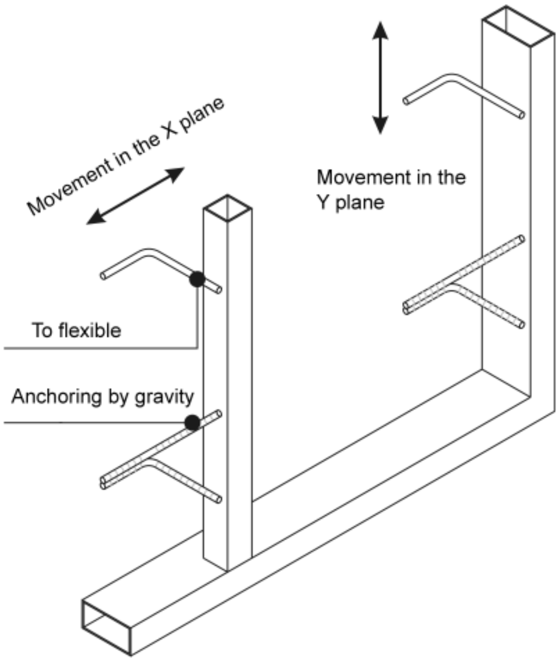

Figure 10. A view of a part of the metal frame showing the ground anchor on the lower part and the flexible shafts on the upper part.

The positioning of the frame should be done carefully in order to avoid the shafts making contact with the GRC shell. If for any reason this occurs, the affected area should be repaired immediately. On the contrary, the pressure exerted by the weight of the frame on the area between the shafts and the GRC can change the density of the composite and the water/cement relation of the matrix which leads to a variation in the tonality of the GRC surface. Direct contact with the shafts and the shell can lead to an excess in restriction for the former due to the variations in temperature and humidity incurred. The shell, in turn, responds quickly by becoming very thin.

The direction and size of the flexible anchors influence the greater or lesser restriction of the panel. Due to GRC retraction in the first hours, it is recommended that these anchors are positioned on the sides of the frame nearest the centre of the panel. The GRC shell will not return to having the same initial dimensions which is also the case in very humid environments.

In order to make the joint between GRC layer and the metal frame, a GRC buffer is laid with the same characteristics as the matrix sprayed on the panel, shown in Figure 11. This should be laid before the composite hardens so that the joint between the GRCs takes place while the material is still fresh.

Figure 11. Laying of GRC buffers on the shafts of the metallic frame.

The spray-up manufacturing method and metal frames allow the execution of panels with large dimensions as seen in Figure 12. These panels decrease the quantity of joints and make the assembly time quicker.

Figure 12. Assembly of prefabricated GRC panels with ceramic cladding.

7. FINAL CONSIDERATIONS

In the first construction work the premix manufacturing method was used. In the other works the GRC spray-up method was used which allowed greater productivity and ease of use. The incorporation of a larger volume of glass fibre in the cementitious matrix which is allowed with the spray-up method allows greater composite durability. Alkali attack from the cement is compensated by the excess fibres and therefore the loss of mechanical properties is slower. The metallic moulds used guarantee a higher rate of repetition; this in turn makes them more economical for the manufacturing of the components. The insertion of ceramic tiles directly into the panel manufacturing ensures speed in their execution thanks to the placement facility of these at the bottom of the moulds.

Nevertheless it has been observed that the panels with metal frames of large dimensions showed sagging due not only to the initial retraction, that was reduced through the use of mortar with polymeric additives, but also due to shrinkage over three years of its application. This problem could be minimized by limiting the dimensions of the panels or by using additives that can reduce the initial GRC shrinkage.

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