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The Absent Opportunities in Using Reinforced Concrete with Glass Fibre as an Environmentally Friendly Structural Material

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Abstract: The idea of using reinforced concrete with glass fiber (GRC) is usually associated with exterior cladding materials and decorative works. This material is made of cement as a basic component in addition to glass fibers with some other additives that increase bond strength and improve hardness while contributing to facilitate formation and adjusting the temperature, humidity and sound resistance. Many people may not realize the interconnection between these materials and green architecture, especially with the presence of cement in its components.

The aim of this paper is to study how to exploit the capabilities of this material and its specifications in green and sustainable designs. This has been done through a methodology that begins by studying the properties of these materials in terms of raw materials, production methods, installation options and recycling capacity. So that their effectiveness can be assessed as an alternative to external walls, cladding or barriers, especially in new cities that usually have distinctive designs and need to integrate with the external environment to improve their overall efficiency and achieve sustainable design and rise the living quality as general. The methodology ends by presenting an innovative GRC product which could be a starting point for many productive ideas in this field, and help for further exploitation of the capabilities of this material.

Keywords: GRC. , GRC technical specifications, MARMOX applications, GRC and Green Architecture, Innovations in GRC.

1 Introduction

The ancient Egyptians are considered the first to know glass and melt it. They did not use it as an additive material to concrete mixture, but instead they added straw to mud in order to repair the rifts caused by the shrinkage of bricks, (see Fig. 1). The same idea of GRC (Glass Fibres Reinforced Concrete). This idea came from the replacement of mud by cement and sand, and the straw by the glass fibres.



Fig. 1. The ancient Egyptians glass and bricks (Ancient Egyptian Science and Technology 2019).

There have been a lot of researches on the development of such material. It has become one of the prominent external claddings in particular, and of the concrete material in general. This research paper will tackle the technical and technological potentialities of such material, the fields that can be used in, and the possibility of adding it to the eco-friendly materials according to the principals of sustainable

architecture. Consequently, it will be at the top of the construction and finishing materials used in cities and new urban communities. Throughout this paper, some of the up-to-date and most prominent projects will be presented as models to display how they employed the potentials of such material and the additions that were processed to increase its efficiency I order to utilize it and increase its performance rates in the local and international markets.

2 The definition of GRC and the idea of fiber

GRC is a mixture of cement, soft sand and water added to anti-alkali fibers, then to be mixed in a way similar to the normal concrete, (see Fig.2). After that, it be casted in molds according to the types and shapes of the needed units (bricks). Its durability is higher than the common concrete, so it can be used in the basic concrete of ceilings, walls, internal boards, external claddings and in all decorations.

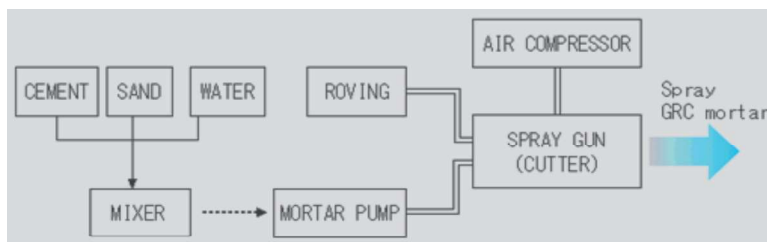


Fig.2. The Mixture of GRC.

The existence of the fibers in the concrete improves the functions of both if used separately. While fiber in the produced units constitutes the basic durability, the surrounding material is considered as a carrying surface of durability and a mold that shapes the units. It means that fibers act as reinforced metal, so that they have different types, length and density according to the type and solidity of the required unit. Such fibers can also be directed, allocated as of the number of its layers in the single unit (as previously shown (The International GRCA, 2018).

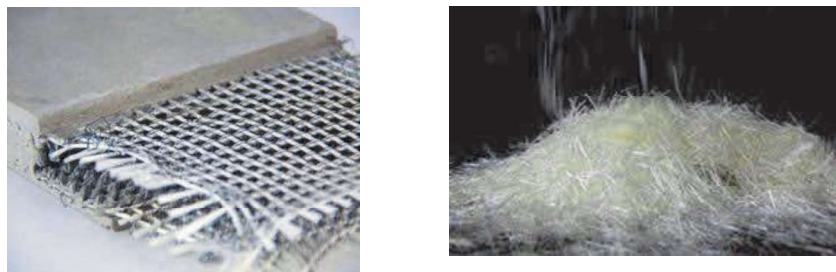


Fig.3. Mascot's alkali resistant glass fiber (Glass-Reinforced Concrete. 2019).

After casting this mixture in molds, its durability will be checked, including pulling, pressuring cutting, bending, in addition to the secondary durability such as heat, moisture, hanging etc, as previously shown (Corey, 2010).



Fig.4. Testing and Quality Assurance (GRC/GFRC Quality Control, Testing, and Special Equipment Reinforced Concrete. 2019).

3 The technical specifications :

GRC is one of the most plastic materials if compared to the pre-casted reinforced concrete. Both of them share the same concept of producing ready-made units out of site and installing them on site (as previously shown (Jeffrey M Girard 2010)).



Fig.5. NEW SLANT Korean capital (Letter from Seoul.2017).

GRC is less in weight by 80% if compared to the units of concrete that produced for the same purpose. Safety factors are to be considered when produced for huge structures and bases. GRC can be produced in units with a small thickness that starts from 12.6 mm. Furthermore, most of its units can be lifted and handled manually. On the other hand, the weight of the external units made of concrete (thickness 10 cm) is 240 Kgs/m² when compared to GRC that weighs 40-50 Kgs/m².

GRC is highly resistant to rust, corrosion, weather conditions including heat, moisture, especially in the coastal areas. It can also resist the reproduction of insects, the growth of bacteria, and the effects of rodents.

GRC has high solidity, anti-friction, and breakage durability that reaches 3 times double concrete as a result of the internal proportional distribution of fibers in the unit.

GRC's life cycle is not less than 4 times double reinforced concrete as a result of its high physical and chemical specifications, as previously shown (Peter J. M. Bartos. 2017).

GC is proved by researches to be efficient in the field of thermal and sound insulation than rock wool and foam, but less than the compact foam in thermal insulation. GRC has high aesthetic aspects that provide infinite collection of designs that match different architectural trends. It is easily-manufactured and molded, so it provides meticulously-detailed shapes. Its outer shape resembles the shape of stone, and it can be dyed, colored with various paints. Moreover, its soft surface saves the effort of surface adjustment and the cost of finishing. (see Fig.6).



Fig.6. GRC thermal and sound insulation (Sustainable Case Study, (2019).

GRC is classified as a non-flammable material as per the UK, European standards, however fiber is not, but it complies with the prerequisites of Category 5 defined by UK Building Regulations.

So, the GRC units are used in a lot of construction works:-

1 .In building facades as non-bearing cladding panels that bear only its weight, in addition to the side durability such as earthquakes and wind. In this case, it will be fixed by iron supports on the main wall. (see Fig.7). It can also be used as alternative walls with holes and details whether for the whole building or for the light extra floors in the existing buildings.



2. In the crust coverings such as domes and basements, and in the sliding and horizontal ceilings. (See Fig.8).

3. The external ornaments of buildings, columns claddings, roof tiles in addition to fences, sound-adapted ceilings.

4. The internal division boards in the sterilized rooms inside the pharmaceutical factories and precision industries.

5. In light buildings and caravans.

Fig.7. Installation units. (GRCA International . <https://grca.org.uk/grc-projects.php>)

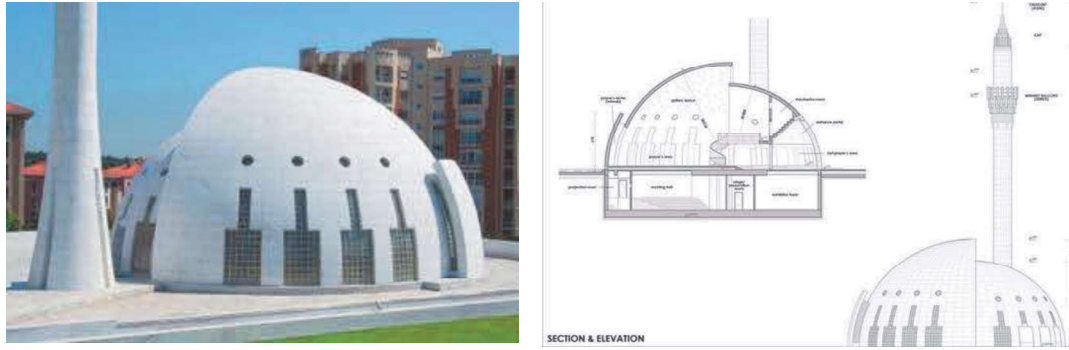


Fig.8. A GRC Dome. (GRCA International . <https://grca.org.uk/grc-projects.php>)

GRC is an eco-friendly green material (GRC and the sustainable architecture)

There have been architectural trends and calls for the sustainable green architecture that is environmentally-friendly. Such calls question the ability of GRC in achieving the requirements of such trends in spite of using cement as a major ingredient.

Sustainable architecture is connected to the objectives of health care for the users of free space. It's related, as well, to the conservation of the surrounding environment, cutting power consumption, and the operating costs of building during its virtual life cycle, and the maximization of its resources. Nowadays, the world is witnessing endless numbers of designing ideas, new and developed materials for sustainable construction. This fact leads to a strong competitive market among products(see fig.9).

GRC is a functional material that suits sustainability requirements of the new urban communities including:

1. Medical raw materials.
2. Alternatives to the Portland cement.
3. Power efficiency.
4. Recyclability.
5. Production methods.



Fig.9. Selected projects of GRC (GRCA International. <https://grca.org.uk/grc-projects.php>)

4 GRC and Energy Efficiency

If the special insulation capacities of GRC were properly used, the usage of GRC SIP (Structural Insulated Panels) or the cladding panels would be power saving. Measurements have proved that the wall

of two layers with 12 inch thick foam in between can raise the performance of the building's thermal insulation. The GRC SIP will pay for itself in no time as previously shown (R Moceikis et al 2017).

5 Recyclability:

The main ingredients of GRC are not regarded as pollutants. GRC material, whatever its shape, can be crushed and land filled. It uses less energy and takes less time to crush GRC than reinforced concrete since the former has no coarse aggregate and the time to recycle steel bars is saved. There have been researches on the effectiveness of recycling GRC to make new one (I.White,et al.,2011). (see Fig 10)



Fig.10. Recyclability of GRC. (GRC Recycling Ltd company,Dundee City, United Kingdom, <https://www.google.com/maps/>)

6 Production methods

There are traditional basic methods of producing the GRC whether by manual/mechanical spraying or cast premix. (see Fig 11) . The more quantities of the GRC material are produced and connected, the less casts are incurred.



Fig.11. The Specification of GRC. (Niki Cauberg, Tine Tysmans, 2012).

Some manufactures have developed GRC production methods according to the infinite architectural requirements. They have adopted a production system adequate for the number of the products and the required properties. They managed to produce three dimensional forms, empty forms.....for instance Rieder in Germany employs a special extrusion process to make cladding panels (fiber) for various projects including the soccer city stadium in south Africa for the 2010 fifa football world cup. Also, winsum in China uses the same technology in a number of projects. Hence, production technologies are defined according to the shape of the material and the capabilities of manufacturing.

7 Egyptian Experience In Producing GRC

In Egypt-based group comprising 16 companies known for their innovative and pioneering solutions and building products.

Over the last three decades, not only the companies have established a stronghold in the National market but also developed a multinational sales network, creating a global platform for the innovative Egyptian products.

7.1 Solutions

Admixtures for improving concrete and mortar properties, Release agents for formworks and concrete curing after pouring, waterproofing products

Sound and thermal insulation, Bonding agents and adhesive products

Construction repair and strengthen products, Floor leveling and strengthen products

Protective coating products, Epoxy compounds for special purposes

Joint sealant products, Paints, plasters and putties Solvents, cleaners and safety data sheets

MARMOX Board – Tile Backer Boards are made of XPS-foam with fiberglass reinforced cement coating.

The special XPS-benefit is that its thermal insulation properties are not affected whatsoever by wet. So the boards are resistant against water, moisture and humidity and they are non-capillary, light weight and easy to cut – ideal prerequisites for multi-purpose application, especially in wet room areas.

Marmox Board – Tile Backer Boards are recommended for use on walls, floors, and to build or insert wash tables, shelves, claddings, insulations under electric heating wires or partition walls. The options to use the boards are wide and creative (see Fig .12).It's surface is suitable for the application of tiles, mosaic, natural stone, plasters or putties. The boards allow a quick, easy, and creative construction without or reduced drying time.



Fig.12. The Solutions of marmox. (Marmox Board- http://marmoxboard.com/ZA/marmox_board_pro.html)

This board made from CFC- and HCFC-free extruded polystyrene foam (XPS). The surfaces are covered from both sides with an alkali-resistant glass fiber mesh embedded in polymerized cement mortar. The closed cell structure of XPS-foam is water-resistant with good insulation properties. A newly developed production technology ensures an excellent embedding of the reinforcing glass fiber mesh in the special cement mortar. The characteristic honey comb finishing is the outstanding feature of the very strong and professional marmox Board PRO. The mechanical properties of marmox, such as compressive strength, improved bonding strength and shear strength, are some of the best in the market..

7.2 MARMOX Board – Standard

Marmox Board PRO are characterized by their honey comb surface finishing. This new innovative finishing provides significant enhanced properties: The glass fiber mesh is fully embedded in special

cement mortar covering the mesh completely, in order to optimize the absorption of mechanical strengths. Due to that MARMOX Board PRO are characterized by excellent mechanical properties. Improved bonding strength of tile adhesive. Increased maximum shear force bond of MARMOX Board PRO. The working load of the MARMOX Board PRO reached more than 60 kg/m² in vertical position, if a polymer glue will be used. Other properties for different dimensions are shown below (table 1)

Table 1. The standard dimensions for marmox board. (Marmox Board- http://marmoxboard.com/ZA/marmox_board_pro.html)

Reference	Thickness (mm)	Width (mm)	Length (mm)	U-value (W/m ² K)	Weight (KG/m ²)
4MB125	4	600	1250	10	1.88
6MB125	6			7	1.95
10MB250	10			3.5	2.22
12.5MB250	12.5			2.7	4.60
20MB250	20		2500	1.5	4.96
30MB250	30			1	5.48
40MB250	40			0.7	6.00
50MB250	50			0.57	6.52

MARMOX Board - Angle are ideal to cover pipes or for decoration such as trays and shelves. Pre-fabricated pipe boxing saves considerable time at the job site (see Fig .13).

MARMOX Board - Jagged are flexible boards designed to bend to the required curve ready for mosaic tiling. The boards are created to make curved designs more achievable in a fast and price competitive way (see Fig .14).

MARMOX BOARD ULTRA are made of extruded polystyrene foam boards, covered on both sides with special polymeric cement mortar,(see Fig .15) reinforced with alkali resistance glass fiber mesh providing a very special surface texture which ensures a good adhesion to tile adhesive.

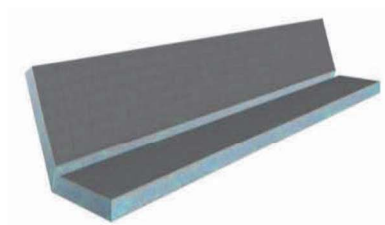


Fig.13. Marmox Board-Angle.



Fig.14. Marmox Board-Jagged

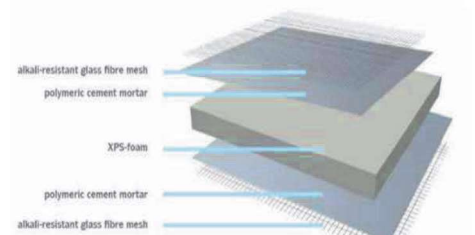


Fig.15. The marmox board ultra

(Marmox Board- http://marmoxboard.com/ZA/marmox_board_pro.html)

MARMOX Board PRO - VBR – breathable are made of a closed cell CFC and HCFC free polystyrene foam (XPS) as the core. The surfaces are coated with a cement based special mortar, reinforced with glass fiber mesh (see Fig .16) .

MARMOX Board PRO - CS1 -impact sound insulating the special feature of MARMOX Board PRO - CS1 is the elastic foam rubber layer that provides impact sound properties. (see Fig .17)

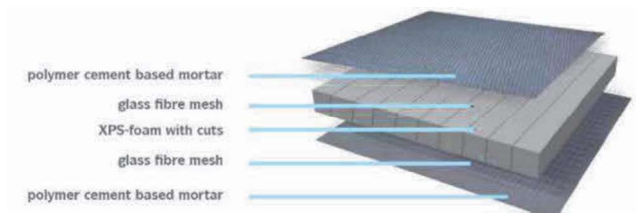


Fig.16. The marmox board-VBR.

(Marmox Board- http://marmoxboard.com/ZA/marmox_board_pro.html)

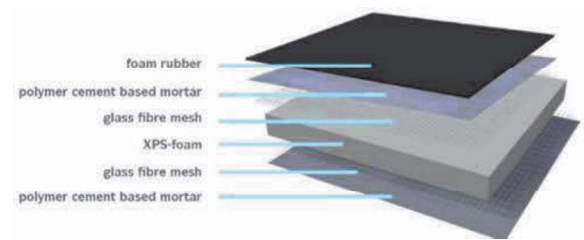


Fig.17. The marmox board –CS1.

MARMOX Rock Board is a high performance, reinforced insulation board made of mineral wool core, each side being faced with a waterproof cement polymer mortar reinforced with alkali-resistant fiberglass mesh. (see Fig .18) .

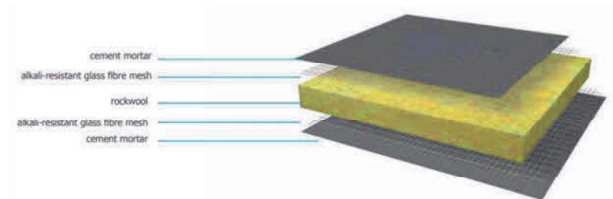


Fig.18. The Marmox rock board (Marmox Board- http://marmoxboard.com/ZA/marmox_board_pro.html)

7.3 Installation

Marmox Board PRO is suitable for installation on walls and floors. It very easy to install on floors provided that the underground is prepared to be flat, rigid and clean. A complete embedding of the boards without hollow spaces is required if the boards are used on floors. The boards should be installed in a staggered pattern. An additional mechanical fixing of the boards is possible with recommend use of 5 nails/screws per m². Marmox Board PRO is suitable for installation on metal and timber frame walls as well as on brick and concrete walls.(see Fig.19,20) It is preferable to install the long side of the board vertically in a staggered pattern. The fastening can be done using screws and/or glue, either applied complete or partial. All available thicknesses of Marmox Board PRO are suitable for wall application. Boards of 4 mm and 6 mm thickness need to be glued completely without hollows on a stable substrate.

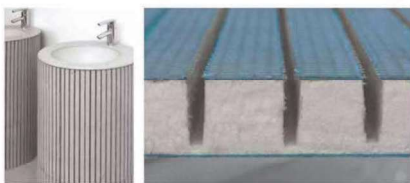


Fig.19. MARMOX Board PRO – Pipe Boxing.



Fig.20. The Installation on Timber Working

(Marmox Board- http://marmoxboard.com/ZA/marmox_board_pro.html)

MARMOX Board PRO – Insulation under electric underfloor heating system is designed for application under electric underfloor heating systems. The boards are heat insulating, compressive resistant, and ready for tiling. The boards are available in a wide range of different thicknesses from 6 mm - 100 mm, which affect the reaction time and the energy consumption accordingly (see Fig .21).



Fig.21. Marmox underfloor heating system. (Marmox Board- http://marmoxboard.com/ZA/marmox_board_pro.html)

Conclusion

GRC's lightweight nature is not only easy to install, it's also better for the environment than other materials like precast concrete that fulfill the same function. The results show that GRC has a lower environmental impact (around 40% less). The reduced environmental impact is due to the reduced cement usage per product and reduced transport costs.

Egypt has become a leader in the industry of GRC and committed to introduce manufacturing, storage and packing processes that reduce the impact on the environment. There are already many modern ideas and other could be develop to exploit the capabilities of this material, which is easy to form and use for engineering, architectural and decorative uses, Marmox is one of these applications worth pursuing.

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