

2 GRC and Sustainable Building Design

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Sustainable building design demonstrates commitment to energy efficiency, environmental stewardship and conservation. A sustainable building is constructed of materials that minimize life-cycle environmental impacts. Environmentally preferable materials have a reduced effect on human health and the environment.

Over the years, fiber glass has been rigorously studied by government and independent research organizations. GRC (glass fiber reinforced cement) composite material has been widely used to construct buildings. GRC is one new cement-based material in which short length glass fibers are dispersed, leading to an increase of the tension and impact strength of the material.

Because fiber glass is made with available resources and recycled content, it can be locally or regionally produced. That fact is extremely important when looking at fuel consumption and its environmental impact.

In this paper, the relation between glass fiber reinforced concrete and sustainable building design is investigated and it presents suggestions about the better its usage in construction industry.

Keywords: GRC, Sustainable building design, Construction industry.

1. Introduction

Glass fiber reinforced concrete is an engineered material that contains cement, polymers, and glass fibers that are ingrained in the cementitious matrix [1]. Basically, GRC is an ultra-strong composite made of Portland cement infused with randomly dispersed glass fibers that reinforce the concrete and increase its load-bearing capacity. GRC has all the characteristics of regular concrete. A number of additional qualities, however, give GRC significant advantages. Most obviously, GRC is up to 80% lighter than concrete, **so it's easier to work with and install. Despite its light weight**, GRC also boasts superior strength and durability, making GRC a material that can stand the test of time. Add the fact that GRC is easily molded into intricate and detailed designs in a wide selection of colors, forms and textures, and it is a perfect replacement for precast concrete and an ideal material for a range of creative projects [2].

As an engineered material, the properties of GRC can vary depending upon mix design, glass content and production methods. Glass fiber used in GRC has a higher tensile strength than steel. As a general rule, the higher the fiber content, the higher the strength. A typical mix with 5% glass fiber has a compressive strength of 6,000 to 8,000 psi [1].

2. Historical perspective of GRC

The concept of using fibers as reinforcement is not new. Fibers have been used as reinforcement since ancient times. Historically, horsehair was used in mortar and straw in mud bricks. In the early 1900s, asbestos fibers were used in concrete, and in the 1950s the concept of composite materials came into being and fiber reinforced concrete was one of the topics of interest. There was a need to find a replacement for the asbestos used in concrete and other building materials once the health risks associated with the substance were discovered. By the 1960s, steel, glass (GRC), and synthetic fibers

such as polypropylene fibers were used in concrete, and research into new fiber reinforced concretes continues today[3]. GRC was originally developed in the 1940's in Russia, but it wasn't until the 1970's that the current form came into widespread use [4].

4. Effect of fibers in concrete

Glass fiber reinforced composite materials consist of high strength glass fiber embedded in a cementitious matrix. In this form, both fibers and matrix retain their physical and chemical identities, yet they produce a combination of properties that can not be achieved with either of the components acting alone. In general fibers are the principal load carrying members, while the surrounding matrix keeps them in the desired locations and orientation, acting as a load transfer medium between them, and protects them from environmental damage. In fact, the fibers provide reinforcement for the matrix and other useful functions in fiber reinforced composite materials. Glass fibers can be incorporated into a matrix either in continuous lengths or in discontinuous (chopped) lengths. The most common form in which fiber reinforced composites are used in structural application is called a laminate. It is obtained by stacking a number of thin layers of fibers and matrix and consolidating them into the desired thickness. The fiber orientation in each layer as well as the stacking sequence of various layers can be controlled to generate a wide range of physical and mechanical properties for the composite laminate. The design of GFRC panels proceeds from a knowledge of its basic properties under tensile, compressive, bending and shear forces, coupled with estimates of behavior under secondary loading effects such as creep, thermal and moisture movement. There are number differences between structural metal and fiber reinforced composites. For example, metals in general exhibit yielding and plastic deformation whereas most fiber reinforced composites are elastic in their tensile stress strain characteristics. However, the dissimilar nature of these materials provides mechanisms for high energy absorption on a microscopic scale comparable to the yielding process. Depending on the type and severity of external loads, a composite laminate may exhibit gradual deterioration in properties but usually would not fail in catastrophic manner [3].

5. Applications of GRC

Commercially, GRC is used to make large, lightweight panels that are often used as façades. These panels are considered non-structural, in that they are designed to support their own weight plus seismic and wind loadings, much in the way glass window curtain walls are designed. The panels are considered lightweight because of the thinness of the material, not because GRC concrete has a significantly lower density than normal concrete. On average it weighs about the same as ordinary concrete on a volume basis. Façade panels are normally bonded to a structural steel frame which supports the panel and provides connection points for hanging [4].

GRC can be used as wall panels, window surrounds, spandrels, column covers, soffits, cornices, brackets, quoins, railings, pilasters, copings, domes, etc. The basic flexibility of use makes this an ideal use for many landscaping jobs. Uses in landscape as well as hard scape include site furnishings, planters, bollards, urns, tables, fountains, marine structures, pools, and rock formations. GRC is used in historical restorations and renovations, for the replication of building ornaments of terra-cotta, carved stone and even wood.

GRC panels have the color, texture and shape versatility to faithfully reproduce almost any existing non glazed exterior façade and are up to 80% lighter than precast concrete panels, and can often be installed directly over existing facades without imposing excessive superimposed loads on the building structure [1].

6. Sustainable design

Building sustainably aligns with health care's broader goals by promoting the health of building occupants, the surrounding community, as well as the global environment. High-performance green buildings promote a healing environment for patients and a more comfortable and productive workplace for staff. They also have clear business benefits, reducing energy use, and lowering operating costs over the lifetime of the building [5]. The design world today is faced with myriad choices when it comes to **sustainable design and construction. "Green" materials and techniques are no longer a novelty**; they are practically ubiquitous, present in every stage of design, construction, operation and maintenance. Big business is embracing green building, governmental bodies are rewarding sustainable efforts, and individuals across the globe are making everyday decisions about materials and methods that will impact generations to come [6].

6.1. Fiber Glass and sustainability

The GRC materials are themselves easy on the environment. The glass elements are from reclaimed or recycled materials, and the cement mix includes fly ash, which is the waste produced by industrial smokestacks. The finishes are ecologically friendly water-based materials that give off no pollutants or toxins when produced. Using GRC is friendly on the environment and goes hand-in-hand **with the current "green building" push.**

GRC contains materials that, taken from the soil, have no adverse effect on the environment. Concrete's components include Fly Ash, Silica Sand, Portland cement and aggregate. In GRC we introduce the component of fiberglass as well as other natural chemicals in order to produce a super strong and flexible material. The process of producing the water based material produces no chemical off-gas or byproducts. GRC is a green material in many ways. Primarily, the use of recycled aggregates such as recycled glass, metals and other recycled materials give GRC a modern look. The aspects of GRC which make it a green material include its composition of natural materials such as sand, and other aggregates [1].

6.2. GRC, the safe and sustainable insulation

Fiber glass offers proven thermal and acoustic performance. One of the most thoroughly tested building materials; fiber glass has been proven safe for both workers in your facilities and those who ultimately use the products you offer. Fiber glass is also sustainable, made with both readily available local materials and recycled content [7].

Over the years, fiber glass has been rigorously studied by government and independent research organizations. Their conclusions show that fiber glass is safe as a finished product or as a product component, and it is safe for workers who make or install the product when they follow simple work practices to avoid temporary mechanical irritation.

Fiber Glass compared to other insulation materials [7]

BUILDING INSULATION

Insulation Type	Thermal Conductivity	Noise Reduction Coefficient (NRC)	Limited Combustibility
Fiber Glass	++	+++	yes
Mineral Wool	++	+++	yes
Foam			
Closed Cell	+++	+	no
Open Cell	+	++	no
Cellulose	+	+++	—
Note: Comparison of relative performance in typical applications. + = Good, ++ = Better, +++ = Best Source: Industry data			

6.3. Environmental impact of raw material acquisition

Fiber glass is made from an abundant and rapidly renewable resource (Sand) and recycled post-consumer glass. Slag wool insulation is made from recycled blast furnace slag - a by-product of other industries [8].

6.4. Lightweight products

Although GRC has a similar density to concrete, the products made from it are many times lighter due to the thin 10-15mm skin thickness used. A cladding panel manufactured from 100mm thick precast concrete would weigh 240kgs per m2 compared to a similar GRC panel of 40-50kgs/m2. In fact many GRC products can be lifted and carried by hand.

6.5. Corrosion and rot proof

GRC products do not contain mild steel reinforcement and the problems associated with corrosion of reinforcement do not apply. GRC is unaffected by external exposure and will not rot.

6.6. Incombustible

Most GRC formulations comply with non-combustible criteria for UK and EU standards. Polymer GRC is not classed as non-combustible but conforms to the requirements of Class O defined by the British Building Regulations.

6.7. Appearance

GRC has a wide flexibility in design and manufacture, which enables it to reproduce most architectural styles and features. It can replicate virtually any surface detail and reproduce the appearance of materials such as stone, slate, terracotta and marble. Carved stonework involves specialized skills and is slow to produce making the end product expensive. GRC can match stonework in appearance and as it can be produced in thin sections it is easier to handle and fix [7].

6.8. GRC and energy efficiency

GRC SIP's (Structural Insulated Panels) provides with 12 inch thick foam walls. Imagine how much you would save year in and year out. The GRC SIP will pay for itself in no time.

GRC has become a popular material that is used for several applications. There are numerous advantages of using it, as explained below:

- * GRC is prepared from minerals and will not easily burn. When exposed to a flame, the concrete functions as a thermal regulator. It protects the materials fixed with it from the flame heat.

- * These materials are comparatively lighter when compared to the conventional materials. Their installation is therefore fast, and normally simple. Concrete may be produced in thin sections.

- * GRC may be cast to almost any shape of columns, moldings, wall panels, fireplace surrounds, and domes.

- * High strength can be obtained by using GRC, being tough and resistant to cracking. It has a high ratio of strength-to-weight. Therefore, the products are durable and light. The transportation costs are reduced significantly being of less weight.

- * Since GRC is internally reinforced, other types of reinforcement which may be difficult to use with complex molds are not necessary.

- * Suitable consolidation of mix is achieved for GRC that is sprayed, without any vibrations. Use of rollers or vibration, to attain consolidation, is simple for GRC that is poured.

- * A good surface finish is obtained, without voids, since it is sprayed and such defects do not appear.

- * Since the materials have a fiber coating, they are unaffected by the environmental effects, corrosion attacks, and other harmful effects.

Strength of the product is developed due to high contents of alkali resistant glass fibers and acrylic polymer. Since the cement contents are high, and the ratio of water to cement is low, the strength under compressive loads is high. These materials also possess great tensile and flexural strength. The performance of these materials is better than the normal concrete. The high fiber content bears the tensile loads, while the concrete is flexible due to the polymers. Applications of GRC are vanity tops, wall panels, and other comparable products.



In some cases, landscape elements from the **customer's** property are incorporated into the design, from actual fern leaves and tree branches to stones and Miniature Rivers. All painted details are done by hand, with rollers and sponges to intricate brushwork for the final touches [9].

7. Conclusion

A sustainable building is constructed of materials that minimize life-cycle environmental impacts such as global warming, resource depletion and human toxicity. GRC is a green material and there are many reasons for using GRC when considering a material that is light, strong, weather resistant, attractive and fire retardant material is required.

This sort of material has no environmental impacts as GRC is an inorganic material as well as there not being a health risk. GRC is itself easy on the environment. The glass elements are from reclaimed and recycled materials, and the mix design includes fly ash or other pozzolans that are produced from waste products. The finishes are ecologically friendly water-based materials that give off no pollutants. Therefore, in order to obtaining of sustainability in building industry, usage of GRC is advised.

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