

Technological Appraisal of Prefabricated Glass Fibre Reinforced Gypsum (GFRG) Panels in Building Construction System

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Abstract: Housing is a fundamental human necessity and an integral part of the built environment. Traditional building materials utilised in the housing sector, like steel, cement and burnt clay bricks, are becoming more and more necessary every year. The decrease of the use of these energy-intensive construction materials and the speedy supply of housing units at reasonable rates are the two key challenges facing the mass housing business today. Glass Fibre Reinforced Gypsum (GFRG), a new building material, is used mostly in houses. Building panels called Rapidwall are another name for it. Gypsum plaster that has been changed and strengthened with chopped glass fibres is used to create glass fibre reinforced gypsum panels, or GFRGs. This panel can be used to build walls, floors, and roof slabs because it has voids that can be filled with concrete and reinforced with steel bars for further strength and ductility. It is a cost-effective and environmentally beneficial alternative to common materials like cement blocks, concrete, and bricks. Prefabricated Glass Fibre Reinforced Gypsum (GFRG) Panels are a cost-effective and resource-efficient way to build low-rise homes in poor nations. The case of Prefabricated Glass Fibre Reinforced Gypsum (GFRG) Panels is examined in this research, along with their engineering viability and qualities as a building material. The study finds that GFRG panels are a practical substitute for traditional bricks that have more intangible advantages.

Keywords: Glass Fibre Reinforced Gypsum panels, GFRG, building construction, technology

1. Introduction

Due to the severe housing shortage, which is most acute in urban India, there is a tremendous demand for building materials in that country. And as of now, purchasing a home requires a lifetime's worth of savings. And the majority of us who purchase homes using our life savings are required to make EMI payments until we reach retirement age. India needs sophisticated, high-efficiency building materials for sturdy, long-lasting housing that can be built at a reasonable price to get over this housing barrier. All of these challenges and worries are necessary for sustained and all-encompassing development. GFRG Panel offers quick construction and helps to safeguard the environment. Industry experts have spent a lot of time in the past trying to develop a cheaper alternative to the current construction technology. One such innovation in the building industry, called Glass Fibre Reinforced Gypsum (GFRG), has the potential to cut construction costs by at least 50%. (Singh, 2020).

Glass Fibre Reinforced Gypsum (GFRG) Panel, commonly known as Rapid Wall, is a building panel product used in large-scale building construction that is formed of calcined gypsum plaster and reinforced with glass fibres. The panel has voids that may be left empty, partially filled, or filled with reinforced concrete in accordance with structural requirements. It was manufactured to a thickness of 124mm under carefully monitored conditions and has a length of 12 m and a height of 3 m. The strength of GFRG panels filled with reinforced concrete has been proven through practical tests and research in Australia, China, and India. These panels can be used as load-bearing sections as well as shear walls that can endure lateral loads caused by earthquakes and wind. Glass Fibre Reinforced Gypsum (GFRG) panels can also be used profitably as in-fills (non-load bearing) in conjunction with RCC framed columns and beams in traditional framed construction of a multi-storey building, and there are no restrictions on the number of floors. As floor or roof slabs, you can utilise RCC screed and micro-beams (which work as T-beams). With panels of 150 mm and 200 mm thickness, such buildings can be designed to be load-bearing up to 10 stories in low seismic zones (Adlakha, 2019).

The building industry uses the prefabricated GFRG panel to build living enclosures for residential, commercial, and industrial projects. It is manufactured in factories. The mechanically fabricated 124mm thick hollow-core panels are made of glass-fiber-reinforced gypsum plaster. A typical cross-section of a wall panel is shown in Figure 1. The look of water-re-

sistant GFRG panels is identical to that of regular GFRG panels. However, the water-resistant GFRG's constituents have been altered expressly to offer water resistance whether applied outside or in moist environments like bathrooms or laundry rooms, etc.

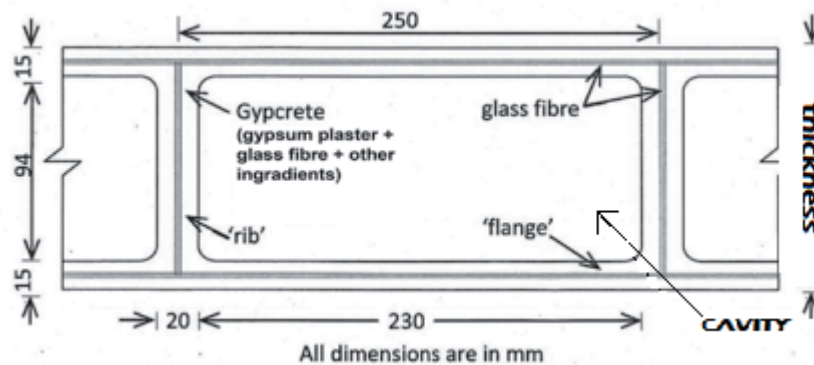


Figure 1. Plan details of a typical cell

2. Grade and Type of GFRG Panels

The GFRG panels are supplied in the following three grades:

2.1 Class 1: Water Resistant grade of GFRG Panels

The water-resistant grade panels that can be used as floor and wall formwork for concrete infill, external walls, and damp regions.

2.2 Class 2: General grade of GFRG Panels

The common grade panels that can be utilised in dry environments for both structural and non-structural purposes. Typically, these panels are not appropriate for use as wall or floor formwork.

2.3 Class 3: Partition grade of GFRG Panels

Only non-structural internal partition walls in dry locations may be constructed using partition grade panels.

3. GFRG Panels Applications in the Building Construction System

The panel may be used generally in the following ways:

- As a light, load-bearing walling in one- to two-story buildings. It is possible to use a non-structural core filler material inside the panel without compromising structural integrity, such as insulation, sand, polyurethane, or lightweight concrete..
- The panel core must be filled with reinforced concrete that is adequately designed to endure the combined impact of lateral and gravity loads since multi-story construction necessitates high capacity vertical and shear load-bearing structural walling.
- As a partition infill wall in a multi-story frame building, where the panel may also be filled with concrete.
- As Horizontal floor/roof slabs with screed for T-beam action and reinforced concrete micro-beams.
- As compound walls and cladding for commercial buildings, as well as pitched (sloped) roofing

4. Technical Specifications of GFRG Panels

The following raw materials are used in the manufacturing of GFRG Panels

- Phosphogypsum: It shall be having purity greater than 90% as CaSO_4
- Glass Roving: The E glass shall be having purity greater than 98%
- Ammonium Carbonate: It shall be having purity greater than 99.14% as NH_4CO_3

Table 1. The mechanical properties of unfilled GFRG panels (BMTPC, 2014)

Mechanical Properties	Nominal values
Unit weight	0.433 kN/m ²
Modulus of elasticity	7500 N/mm ²
Uni-axial compressive strength	160 kN/m (4.77 mPa)
Uni-axial tensile strength	34 – 37 kN/m
Ultimate shear strength	21.6 kN/m
Coefficient of thermal expansion	12x10-6mm/mm/°C
Water absorption	1.0% : 1 hr 3.85% : 24 hrs
Fire resistance : Structural adequacy / integrity / insulation	140/140/140 minutes
Thermal conductivity	0.617
U Value	2.85 W/M ² K
Sound transmission class (STC) ISO 10140-3:2010	40 dB

5. Applications of GFRG Panels in Building Construction

The various applications of GFRG panels in Building Construction are discussed as below.

5.1 Rapidwall for Rapid Construction

A trained structural engineer designed the building's construction based on the Design Manual given by the Manufacturer. Using an automated cutting saw, each wall panel is cut at the factory in line with the building plan and design. In accordance with the building drawing, each floor's panels must also have apertures for a door, a window, a ventilator, an air conditioner, etc. For truck delivery to the construction site, panels are vertically placed at the plant into stillages. The stillages are positioned at the construction site adjacent to the foundation for erection using a crane with the required boom length for the construction of low, medium, and high rise buildings. The Reinforced Cement Concrete (RCC) plinth beam is covered with panels, and concrete is poured in from the top. All of the panels are then built in accordance with the building plan after the notation. Each panel is erected level, plumb, and supported by lateral props to keep it there and to keep it securely in place (Janardhana, 2013). By cutting open the external flange, embedded RCC lintels are given wherever they are needed. The necessary shuttering and support are given along with reinforcement for lintels and RCC sunshades (Figure 2).



Figure 2. Erection of Wall Panels with Temporary Supports

5.2 Concrete Infill

Using a tiny hose that extends at least 1.5 to 2 metres into the cavities, concrete with 12mm aggregate is immediately

pumped into them from a ready-mixed concrete truck. After installing vertical steel reinforcement in accordance with the structural plan and installing clamps at the corners of the walls to maintain the wall panels' precise alignment, this is done. Concrete can be physically poured in modest building construction projects using a funnel. Three layers of concrete, each one metre high, are poured into the panels, with an hour gap between levels. Gravitational pressure causes the concrete inside the watertight compartments to self-compact, eliminating the need for a vibrator.

5.3 RCC tie beam all-around at each roof slab level

An embedded Reinforced Cement Concrete (RCC) tie beam is specified as a requirement at each floor slab level. When placing horizontal reinforcement using stirrups, the web portion is cut and removed to the required beam depth at the top, and the stirrups are then restored once the concrete has been poured.

5.4 GFRG panel for floor/roof slab in combination with RCC

The GFRG panel for the floor/roof slab must be cut to the necessary size and notated. Concrete is poured into the wall joints first, then into additional crevices, cavities, and tie beams made of horizontal Reinforced Cement Concrete (RCC). After a hardwood board between 0.3 and 0.45 metres wide is provided to room span between the walls with support wherever embedded micro beams are present, the roof panels are then raised using a crane. At least a 40mm space separates each roof panel when they are positioned over the wall. This would enable the continuous installation of vertical rods from floor to floor and the construction of a sturdy RCC frame inside the Rapid wall. When embedded micro-beams are present, the top flanges of roof panels are cut to leave at least a 25mm protrusion. Concrete is then poured for the micro-beams and RCC slab once the reinforcement and weld mesh have been installed. The graphical representation of the floor/roof slab system is shown in Figure 3. Figures 4 and 5 show panels with reinforcement being installed in micro-beams and a GFRG floor slab prepared for screed, respectively.

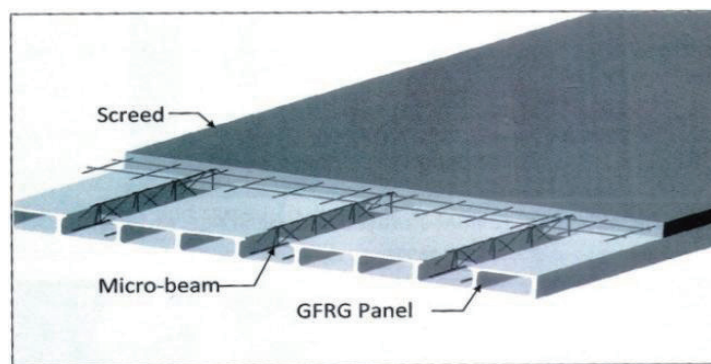


Figure 3. Details of a GFRG Roof Panel showing micro-beams, reinforcement and screed



Figure 4. GFRG Roof panels and the reinforcement being laid in micro-beams

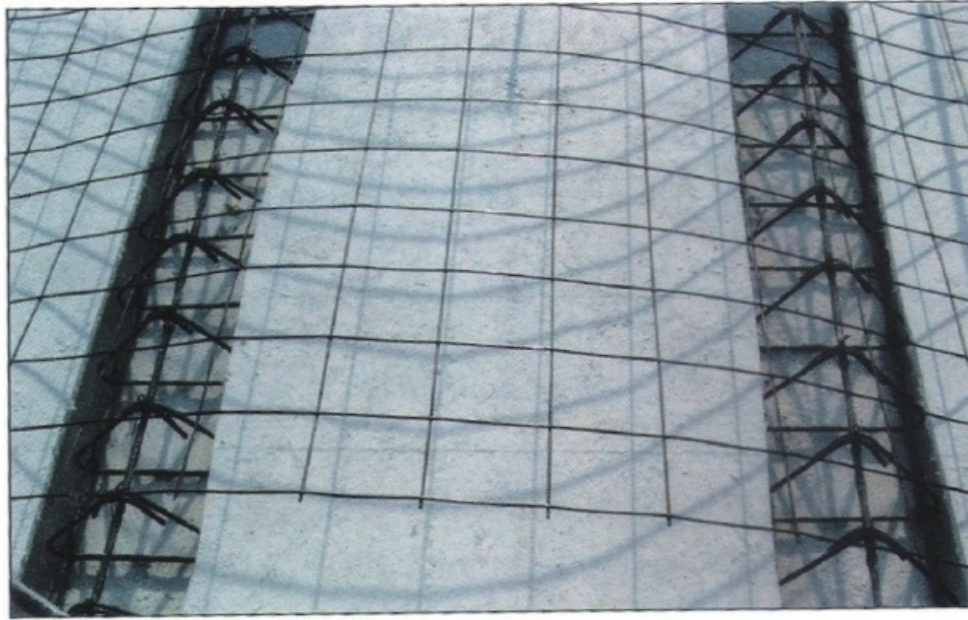


Figure 5. A GFRG floor slab with micro-beam ready for screed

5.5 Erection of wall panel and floor slab for upper floor

The vertical reinforcement of the floor below is given additional length to protrude to 0.45m in order to serve as beginning rods and lap length for the top level. Vertical reinforcing rods, door/window frames, and RCC lintels are cast after the upper level wall panels are constructed. After that, joints are filled and concrete is applied where it is needed. Following that, all of the RCC tie beams are concreted (Figure 6).



Figure 6. Erection of Panels at First Floor

5.6 Finishing work

The wooden planks and support slabs are removed following the fourth day of concreting the bottom floor roof slab. Experienced Plaster of Paris (POP) plasterers must use wall putty to finish the interior walls and corners of the ceiling. Each higher story also undergoes simultaneous electrical, plumbing, and sanitary work, as well as floor tiling, mosaic or marble work, stair work, etc. Before pouring concrete, conduits can be installed in slabs and walls.

6. GFRG Panel Selection and Erection

Depending on how the panels are used, different GFRG panel erection techniques must be used. The method of erection of the panel is as follows:

- Mark the location of the wall's alignment by using line thread.
- After that, secure the standard door frame by plumbing the wall. For each panel, two holdfasts are needed.
- Cut the pocket for the electrical points and conduits that will be put within the Rapid wall cavity at the same time.
- After that, build the panel by using props to support it.
- Repair switch boxes for electricity.
- Attach more panels using the same technique as in step one up to the necessary length.
- Inspect the wall's plumb and line, and then pour concrete into the holdfast gap.
- Fibre tape must be secured with paint to complete the joints of two panels:
 - Create a slot that is 8 mm wide and 2 mm deep at the panel joint.
 - Repair the jointing using fibre tape, then paint the surface with stucco.
 - The joints between a Rapid wall and an RCC column or beam shall be finished with stucco paint reinforced with reinforcing fibre from recycled cement bags..
 - Use stucco paint to fill in the spaces around electrical outlets and between walls and slabs or beams.

7. Glass Fibre Reinforced Gypsum for Load-Bearing Structural Walling

Reinforced concrete filler or R.C. beams are used to connect cross walls, the floor, the roof, and the multi-story construction's conventional use of Glass Fibre Reinforced Gypsum (GFRG) as load-bearing structural walling. All GFRG wall panels must be installed on a system of RC plinth beams that are properly supported by the ground (Figure 7). "Starter bars" must be embedded in the RC plinth beams at the critical locations where the cavities are to be filled with reinforced concrete, with the appropriate lap length. This ensures that the superstructure and foundation are connected at the ground level over the length of the wall and across the network of RC plinth beams (Geethu & Renjith, 2015).

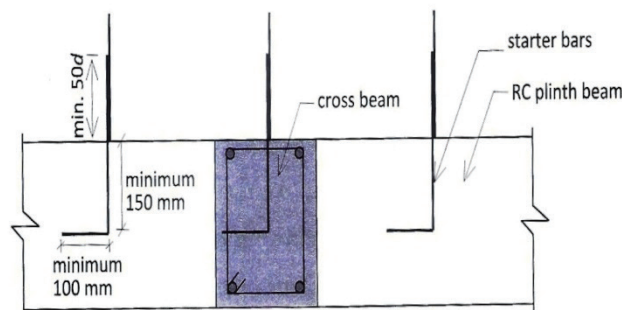


Figure 7. The starter bars in RCC plinth beam for erection of GFRG panels

By employing the proper detailing (insertion of starting bars with anchorage), it is possible to link the GFRG wall and the existing floor when adding a new GFRG floor on top of an existing RC structure, as shown in Figure 8.

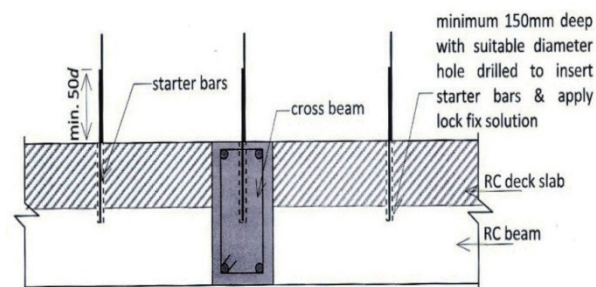


Figure 8. Details of connection between existing floor and GFRG walls

A horizontal RC tie beam that is embedded and placed on top of each wall must be provided when GFRG panels are utilized as structural walling. Cutting and removing the top portion of the GFRG panel web as depicted in Figure 9 leads to the suggestion that the tie beam should be 200 mm deep and 94 mm wide.

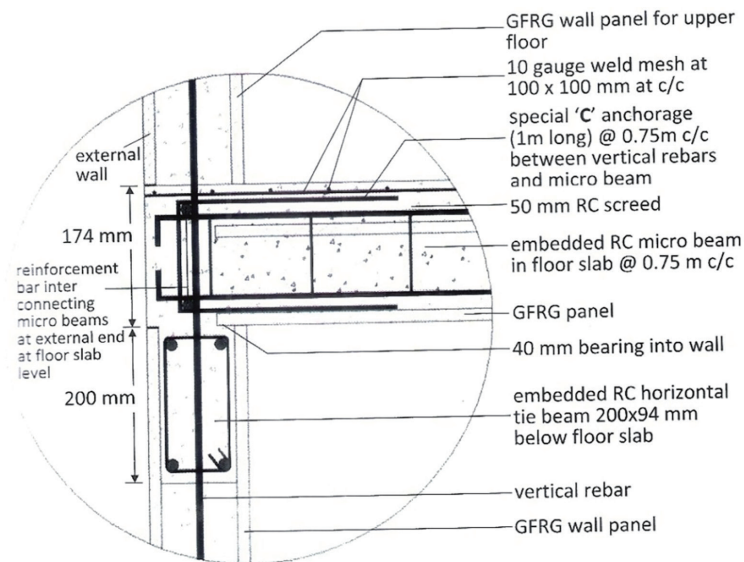


Figure 9. Details of R.C. tile beam and wall junction

8. Glass Fibre Reinforced Gypsum as Floor / Roof Slab

In addition to RCC, GFRG panels can be used for intermediate floor slabs and roof slabs (Figure 13). The strength of GFRG slabs can be significantly increased by using reinforced concrete micro-beams. To supply embedded micro-beams, the top flange of the relevant cavity is cut and removed, leaving a minimum 25 mm flange protruding from both ends. An RC concrete screed with a minimum thickness of 50 mm is placed over the GFRG floor panel, which is reinforced with weld mesh at a minimum size of 10 gauge, 100 mm x 100 mm. The RC screed and micro beam work as a set of embedded T-beams together. The thickness of the RC screed, the reinforcement, and the distance between the RC micro beams are all determined by the span and magnitude of the load. The horizontal tie beam, integrated RC micro-beams, concrete screed, and vertical rods in the GFRG wall are all coupled in a way that perfectly secures the floor/roof slab and walling system. Gypsum wall panels with glass fibre reinforcement as well as slabs in columns and beams. GFRG panels can also be used in high-rise structures. A example high-rise building design combining RC columns and beams and GFRG composite construction is shown in Figure 10. The vertical wall panel above beam must have a clearance margin from the edge of the RC beams, as shown by the dotted lines on the beams.

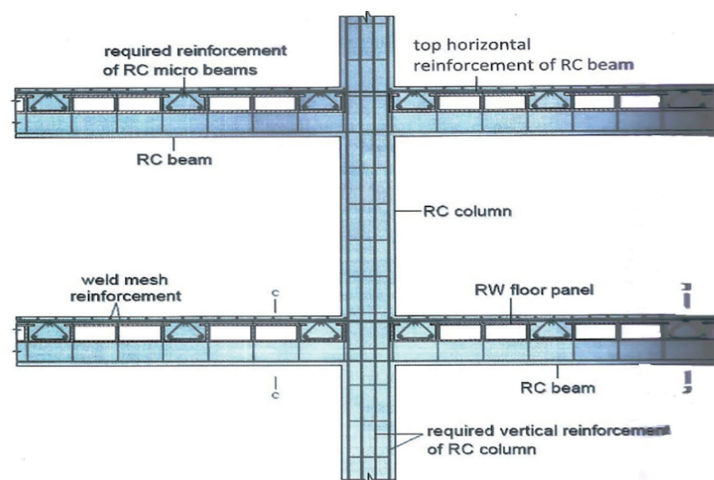


Figure 10. Columns and beams with GFRG composite construction

Figure 11 to Figure 15 shows the joinery details of various structural components with GFRG composite construction methods for tall buildings.

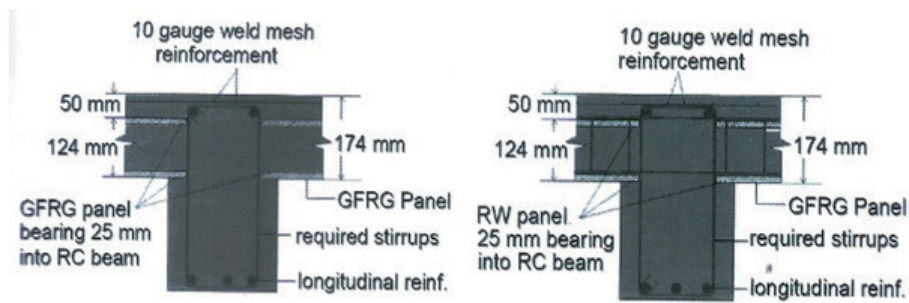


Figure 11. RC Columns and T beams with GFRG composite construction details

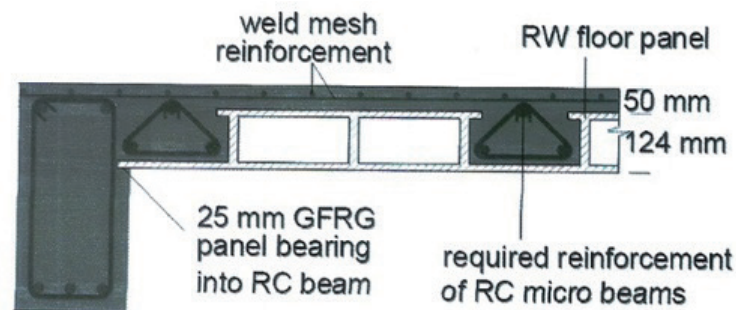


Figure 12. Sectional details of external beams with floor slab across RC micro-beams

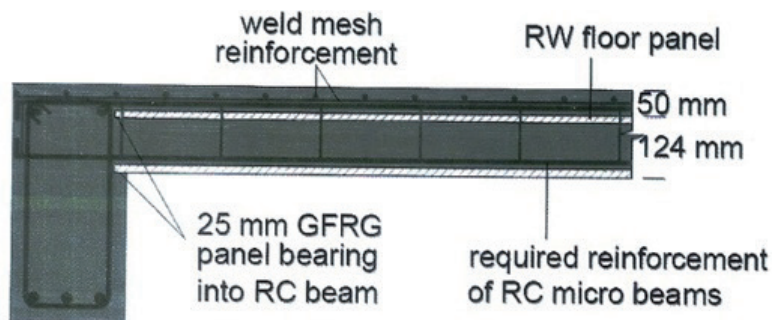


Figure 13. Section details of external beams with slab and longitudinal of micro-beams

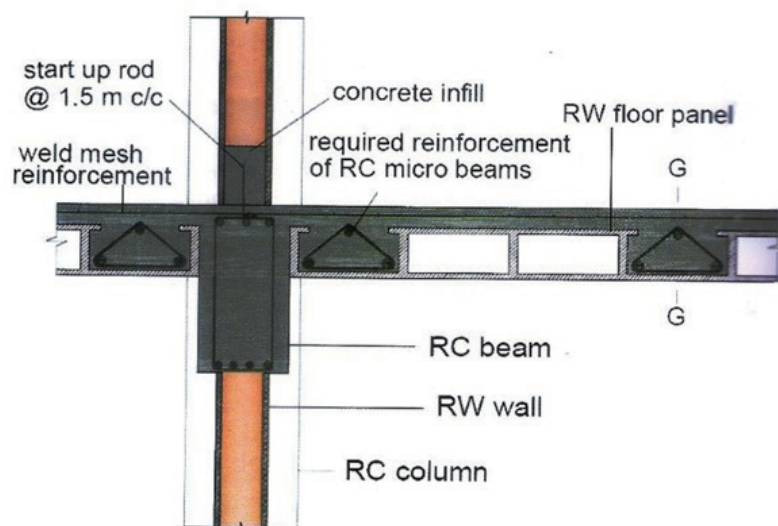


Figure 14. Sectional details of embedded micro-beams

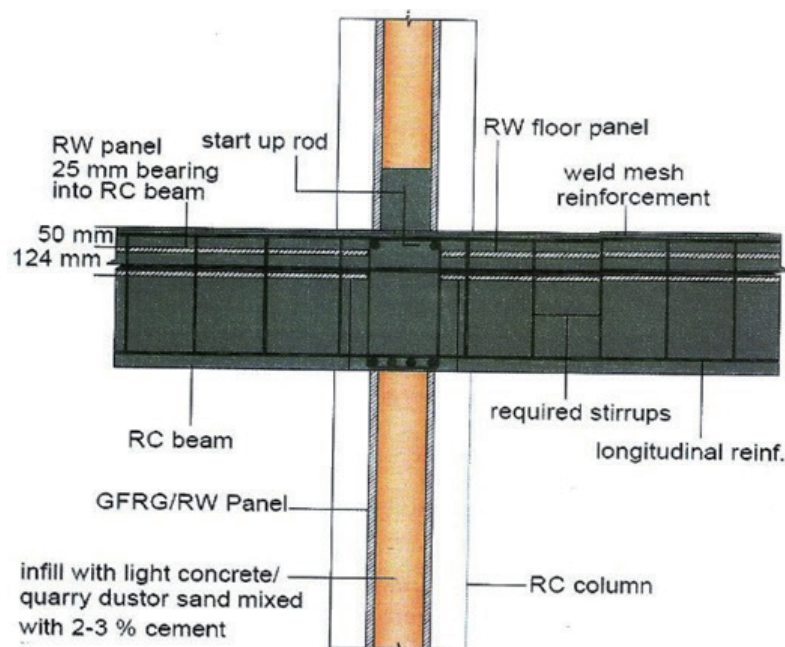


Figure 15. Section through micro-beams and slab beam junction

9. Advantages of Glass Fibre Reinforced Gypsum (GFRG) Panel System

The building's structural weight is significantly reduced as a result of its modest weight. These panels weigh only 43 kg/m², which is quite little. Even after part of the voids have been filled with concrete, the overall weight of the building is still significantly lower, which helps to significantly reduce the seismic stresses in the design and reduce foundation and overall building costs, especially for multi-story buildings (Kamal, 2016). These panels can be used for floors, roofs, staircases, and walls in addition to walls. Building construction proceeds more quickly as a result. In comparison to conventional building, the construction of a building can be completed quite quickly by using these GFRG panel systems. It needs less labour and workmanship. Because the panels are just 124 mm thick, they have a substantially smaller footprint than conventional buildings for the same carpet area (BMTPC, 2014). This is especially beneficial for multi-story mass housing. Given that it is produced using leftover gypsum, it is a green building material. Gypsum from industrial waste is used in it. For walls and ceilings, there is no plastering necessary. uses a lot less water, steel, cement, and sand than traditional construction. It has a lower carbon footprint and uses a lot less embodied energy. According to Kamal and Hussain, it is produced from recovered industrial byproducts. By utilising less scarce natural resources, such as cement, steel, sand, burned clay bricks, and concrete blocks, these glass fibre reinforced gypsum panels preserve energy (Kamal and Hussain, 2015).



Figure 16. Staff housing quarters with the help of GFRG panels at IIT Madras, India

10. Limitation and Disadvantages of GFRG Panels

For walls with circular or greater curvature, the GFRG Panel System cannot be used. For residential buildings, the clear span must not exceed 5 metres; for non-residential buildings, it must not exceed the limits outlined in the Design Manual. On-site cutting of the GFRG Panel requires specialized equipment. A crane needs extra room to manoeuvre during the construction phase. Due to the sophisticated GFRG Panel design, the building approach is less cost-effective. Labourers with a high level of experience and competence are required to install the GFRG panels. The GFRG Panel should be handled carefully when being transported and erected.

11. Conclusions

As long as the construction detailing necessary to deal with shrinkage or expansion is known, the Glass Fibre Reinforced Gypsum Panels are a great building material. A more contemporary approach to building a walling system than the more conventional brick masonry techniques is the use of GFRG panels. In particular, the engineering viability and characteristics of GFRG panels as a walling material in building construction are covered in this study. In many ways, these panels function better than burned clay brick masonry (Kamal, 2023). The production of GFRG panels from the raw material of gypsum, specifically natural gypsum, mineral gypsum, phosphor gypsum or chemical gypsum, with a purity of more than 90%, suggests less energy use when compared to traditional building materials, such as bricks, concrete, etc. Due to the better efficiency of the carpet area and shorter constructing time, the GFRG system has been demonstrated to be highly advantageous in all elements of construction, particularly in time and money. If future study looks at the risk analysis for using the system in repetitive projects, the owner and designer will be able to estimate the cost for the GFRG system during the design process. It is necessary to investigate novel methods for GFRG system cost reduction while maintaining system performance. Future studies on the environmental performance of places utilizing the GFRG panel technology can take the environmental issues into consideration. Additional research might focus on the quality controls for on-site GFRG system installation inspection.

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