Prospective Construction Systems for Mass Housing

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TECHNOLOGY PROFILE

Glass Fibre Reinforced Gypsum (GFRG) Panel Building System

Building Materials & Technology Promotion Council
Ministry of Housing & Urban Poverty Alleviation
Government of India
New Delhi

System in Brief

Glass Fibre Reinforced Gypsum (GFRG) Panel known as Rapidwall is a building panel made-up of calcined gypsum plaster, reinforced with glass fibers. The panel was originally developed by GFRG Building System Australia and used since 1990 in Australia for mass scale building construction. Now, these panels are being produced in India and the technology is being used in India.

The panel, manufactured to a thickness of 124mm under carefully controlled conditions to a length of 12m and height of 3m, contains cavities that may be unfilled, partially filled or fully filled with reinforced concrete as per structural requirement. Experimental studies and research in Australia, China and India have shown that GFRG panels, suitably filled with plain reinforced concrete possesses substantial strength to act not only as load bearing elements but also as shear wall, capable of resisting lateral loads due to earthquake and wind. GFRG panel can also be used advantageously as in-fills (non-load bearing) in combination with RCC framed columns and beams (conventional framed construction of multi-storey building) without any restriction on number of storeyes. Micro-beams and RCC screed (acting as T-beam) can be used as floor/ roof slab.

The GFRG Panel is manufactured in semi-automatic plant using slurry of calcined gypsum plaster mixed with certain chemicals including water repellent emulsion and glass fibre rovings, cut, spread and imbedded uniformly into the slurry with the help of screen roller. The panels are dried at a temperature of 275^{o}C before shifting to storage area or the cutting table. The wall panels can be cut as per dimensions & requirements of the building planned.

It is an integrated composite building system using factory made prefab load bearing cage panels & monolithic cast-in situ RC in filled for walling & floor/roof slab, suitable for low rise to medium rise (single to 10 storeys) building.

Classification	***Class – 1 – Water resistant grade*** – GFRG panel for external walls, in wet areas and / or as floor and wall formwork for concrete filling. ***Class – 2 – General Grade*** – GFRG panels for structural application or non–structural application in dry areas. These panels are general unsuitable for use as wall or floor formwork and ***Class – 3 – Partition Grade*** – GFRG panel as non–structural internal partition walls in dry areas only.
Application	GFRG panels may generally be used in following ways: i) As load Bearing Walling – With cavities filled with reinforced concrete is suitable for multi – storeyed housing. In single or two storeyed construction, the cavities can remain unfilled or suitably filled with non – structural core filling such as insulation, sand, quarry dust, polyurethane or light weight concrete. ii) As partition walls in multi storeyed frame buildings. Panels can also be filled suitably. Such walls can also be used as cladding for industrial buildings or sport facilities etc. iii) As compound walls / security walls. iv) As horizontal floor slabs / roof slabs with reinforced concrete micro beams and screed (T-beam action). This system can also be used in inclined configuration, such as staircase waist slab and pitched roofing.
Dimension	Typical Dimension of GFRG building panel are 12.0m x 3.0m x 0.124m Each 1.0m segment of the panel contains four cells. Each cell is 250mm wide and 124mm thick (see Fig.1).

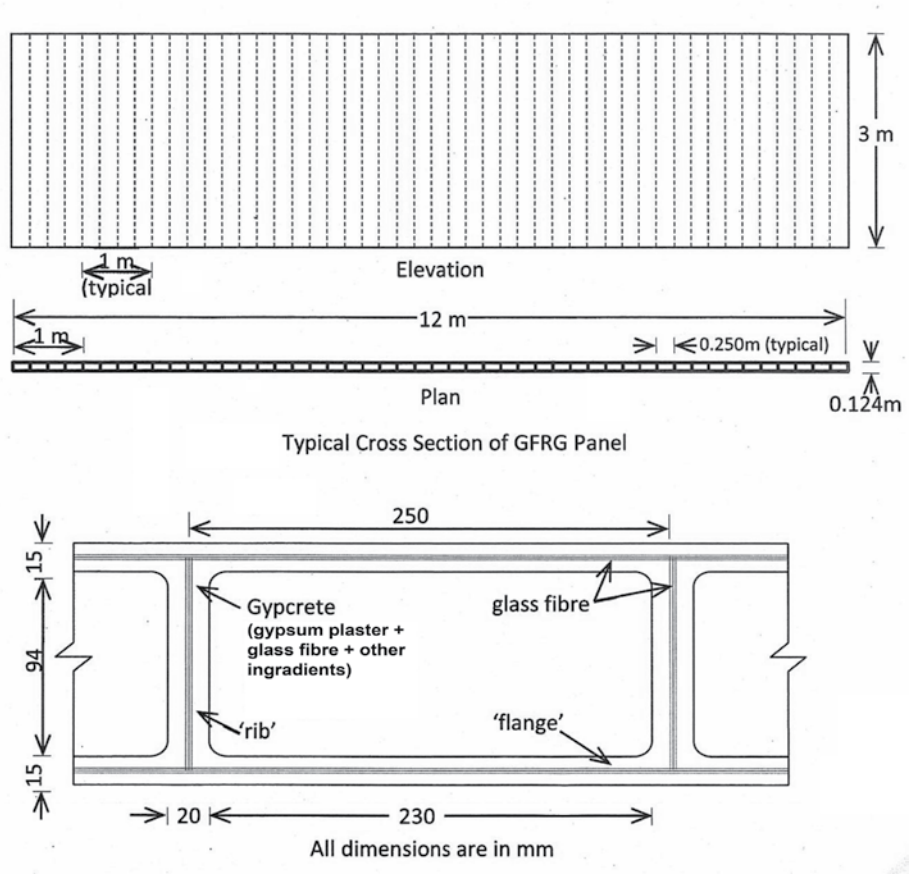


Fig 1 Enlarged view of a Typical Cell

Mechanical Properties (unfilled panels) - based on test results:

Mechanical Properties	Nominal Value	Remarks
Unit weight	0.433 kN/m^2	
Modulus of elasticity, $\mathbf{E_G}$	7500 N/mm^2	
Uni-axial compressive strength, P_{uc}	160 kN/m (4.77 mPa)	Strength obtained from longitudinal compression / tension tests with ribs extending in the longitudinal direction.
Uni-axial tensile strength, T_{uc}	34 – 37 kN/m	
Ultimate shear strength, V_{uc}	21.6 kN/m	
Out-of-plane moment capacity, Rib parallel to span, M_{uc}	2.1 kNm/m	
Out-of-plane moment capacity, Rib perpendicular to span, M_{uc}, perp	0.88 kNm/m	
Mohr hardness	1.6	
Out-of-plane flexural rigidity, **EI**, Rib parallel to span	3.5 x 10^{11} Nmm^2/m	
Out-of-plane flexural rigidity, **EI**, Rib perpendicular to span	1.7x$10^{11}$$Nmm^2$/m	
Coefficient of thermal expansion, Cm	12x10^{-6}mm/mm/^oC	
Water absorption	1.0% : 1 hr 3.85% : 24 hrs	Average water absorption by weight % after certain hours of immersion.
Fire resistance : Structural adequacy / integrity / insulation	140/140/140 minutes	CSIRO, Australia/ IS 3809:1979
Sound transmission class (STC)	40 dB	ISO 10140-3:2010*

** ISO 10140-3:2010 - Acoustics -- Laboratory measurement of sound insulation of building elements -- Part 3: Measurement of impact sound insulation*

Source: GFRG/Rapidwall Building Structural Design Manual

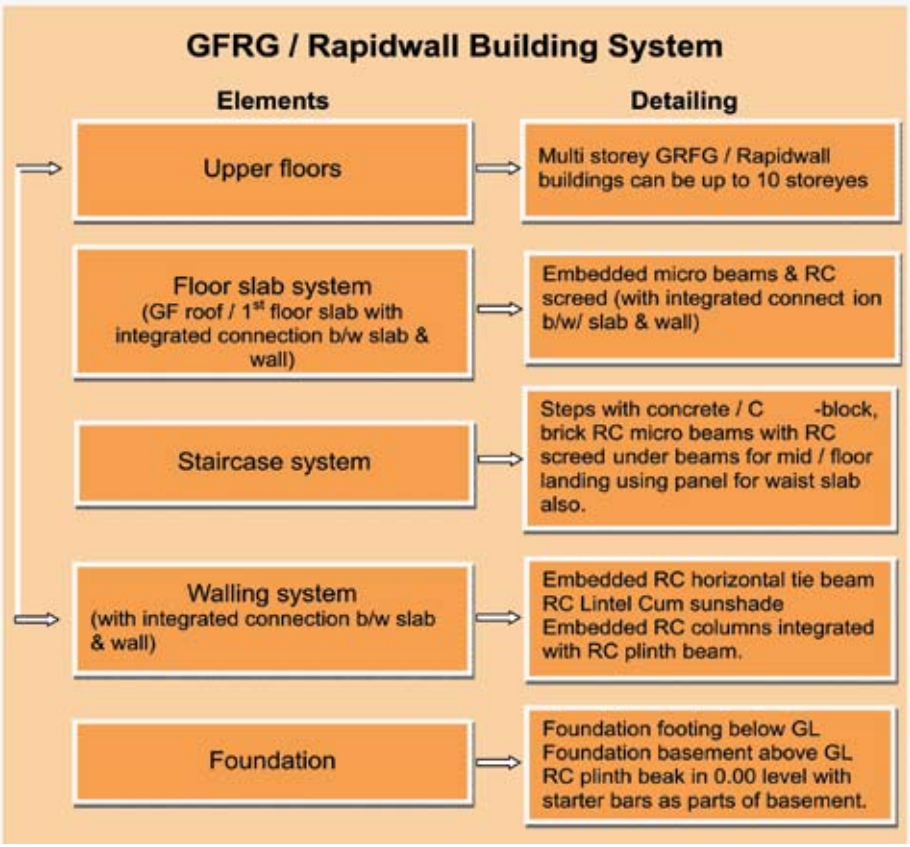
Design

The design capacities are based on limit state design procedures, considering, the ultimate limit state for strength design, treating the 3.0 m high GFRG building panel as the unit material and considering the strength capacity as obtained from the test results. The design should be such that the structures should withstand safety against all loads (as per relevant Indian Standards) likely to act on the structure during its lifetime. It shall also satisfy the serviceability requirements, such as limitations of deflection and cracking. In general the structure shall be designed on the basis of the most critical limit state and shall be checked for other limit states.

Detailed design Guidelines are given in "Use of Glass Fibre Reinforced Gypsum (GFRG) Panels in Buildings - Structural Design Manual" prepared by IIT Madras and published by BMTPC. It may be obtained on request from BMTPC.

Experimental studies and research have shown that GFRG Panels, suitably filled with reinforced concrete, possess substantial strength to act not only as load bearing elements, but also as shear wall, capable of resisting lateral loads due to earthquake and wind. It is possible to design such buildings upto 10 storeys in low seismic zone. (and to lesser height in high seismic zone). However, the structure needs to be properly designed by a qualified structural engineer. Manufacture of GRFG Panels with increased thickness (150 mm – 200 m) with suitable flange thickness can facilitate design and construction of taller buildings.

The basis arrangement of GFRG Panel Building System is as follow:



Transportation	The GFRG panels are transported from factory to site, generally through trucks or trailers. The panels are kept in a vertical position using "stillages" so as to avoid any damage during transportation. The panels after reaching the site are taken out from trucks using cranes. Forklifts can be used for easier movement of panels from one area to another.
Construction	The foundation used in the construction is conventional and is designed generally as strip footing depending upon the soil condition. For superstructure – plinth beams are cast all around the floor, where walls have to be erected. The superstructure is entirely based on prefabricated panels. The procedure mainly include fixing of wall panels and roof panels using mechanical means, preferably a crane and filling the required joint with reinforced cement concrete as per structural design. Waterproofing is an essential requirement of the construction at different stages. Detailed guidelines for waterproofing is require to be followed while constructing the building.
Limitation of Use	• The shorter span of slab (floor / roof) should be restricted to 5 m. • Is ideal if the same floor / roof is replicated for all floors in multi storeyed structure. For any variations, structural designer needs to be consulted. • Curved walls or domes should be avoided. In case it is essential, use masonry / concrete for that particular area. • The electrical / plumbing drawing should be such that most of the pipes go through the cavities (in order to facilitate minimum cutting of panel)

Other Features of the System	
Green Technology	It makes use of industrial waste gypsum. Does not need any plastering. Uses much less cement, sand, steel and water than conventional building. It consumes much less embodied energy and less carbon footprint.
Reduced built area	Panels being only 124 mm thick, for the same carpet area, the built up area and the building footprint is much less than conventional buildings. This is particularly advantageous in multi storey mass housing.
Versatility	Panels can be used not only as walls but also as floors, roofs and staircase.
Speed of Construction	Using the system, the construction of a building can be very fast compared to the conventional building. One building of two storeyed (total 1981 sqft with four flats) was constructed in IIT Madras in one month.
Lightness of structures bringing safety against earthquake forces	These panels are very light weight only 43 kg/m^2. Even after filling some of the cavities with concrete, the overall building weight is much less, contributing to significant reduction in design earthquake forces and savings in foundation and overall buildings cost especially in multi – storeyed buildings.
Manufacturing Plants	Presently two plants are working in India: • Rashtriya Chemicals and Fertilizers Limited, "Priyadarshini", Eastern Express Highway, Sion, Mumbai. • FACT – RCF Building Products Ltd., FACT Cochin Division Campus, Ambalamedu, Kochi (Kerala). The panels manufactured at the above plants are based on the technology transferred through collaboration with GFRG Building System, Australia. BMTPC under Performance Appraisal Certification Scheme has evaluated the Panel manufactured at RCF Mumbai and FRBL Cochin and issued PAC No. 1008-S/2011 and PAC No. 1009-S/2012 respectively. (Available for download from BMTPC website www.bmtpc.org).

Constructed at IIT Madras Campus in one month duration.

Few Building Constructed in India are:

- Residential buildings at Udipti Karnataka owner Mr. Satish Rao, built by Harsha Pvt. Ltd., Udipi, Bangalore.
- Utility Building for Konark Railways at Madgao, South Goa, built by Harsha Pvt. Ltd., Udipti, Bangalore.
- Residential building at Udipti by Harsha Pvt. Ltd.
- 3 storey residential building at Calicut by NMS Rapidwall Construction Company, Calicut (2014).
- Two storeyed building at IIT Madras.
- Residential building at RCF Mumbai.
- Model house at Cochin.

References:

- Performance Appraisal Certification PACs No. 1008-S/2011 issued to M/s Rashtriya Chemicals and Fertilizers Limited, "Priyadarshini", Sion, Mumbai.
- Performance Appraisal Certification PACs No. 1009-S/2012 issued by FACT – RCF Building Products Ltd., FACT Cochin Division Campus, Ambalamedu, Kochi.
- GFRG / Rapidwall Building Structural Design Manual, prepared by IIT Madras, published by BMTPC, New Delhi.
- Schedule of Item & Rate Analysis for GFRG Construction, BMTPC, New Delhi *(to be published)*.
- IS 3809:1979 – Fire Resistant Test of Structures

About BMTPC

Set up in 1990, Building Materials & Technology Promotion Council (BMTPC) an autonomous organisation under the Ministry of Housing & Urban Poverty Alleviation strives to bridge the gap between laboratory research and field level application in the area of building materials & construction technologies.

Vision

"BMTPC to be world class knowledge and demonstration hub for providing solutions to all with special focus on common man in the area of sustainable building materials, appropriate construction technologies & systems including disaster resistant construction."

Mission

"To work towards a comprehensive and integrated approach for promotion and transfer of potential, cost-effective, environment-friendly, disaster resistant building materials and technologies including locally available materials from lab to land for sustainable development of housing."

For more information, kindly contact:

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