

GLASS FIBRE REINFORCED GYPSUM LOAD BEARING (GFRG) PANELS FOR AFFORDABLE HOUSING IN FAST TRACK & ENVIRONMENTAL PROTECTION

ABSTRACT

There is a huge growing requirement of building materials in India due to the existing housing shortage of 24.7 million units{ 2007} mainly for the low income groups in urban India. Estimated urban housing shortage in 2012 is 26.53 million, while the housing shortage of rural India in 2012 is 42 million units. Thus total estimated housing shortage for Urban & rural India in 2012 is 68.53 million units. To meet this challenge, India requires innovative, energy efficient building materials for strong and durable housing in fast track method of construction at affordable cost. It is also important that housing and buildings are disaster resistant to protect the lives and properties of people. All these concerns are involved in sustainable and inclusive development. Rapidwall Panel provides rapid or faster construction and contributes to environmental protection, providing a solution to many of the above issues and concerns. The paper describes the method of construction using Rapidwall panels based on construction manual prepared by IIT Madras to suit Indian situation. FACT & RCF, two fertiliser giants under public sector are together setting up Rapidwall and plaster products manufacturing plant at Ambalamugal using Rapidwall technologies of Australia called **FACT RCF Building products Ltd. (FRBL)**. FACT has about 7 million tons of industrial by product gypsum. By setting up Rapidwall & Plaster products plant, they intend to produce 1.4 million sqm or 15 million sq ft panel per year and about 50000 tons of superior quality wall plaster and wall putty.

INTRODUCTION

The threat of climate change caused by the increasing concentration of greenhouse gases in the atmosphere is pushing the whole world into a catastrophic crisis situation with universal concern. The need of the 21st century is for energy efficient and eco-friendly products. The building industry accounts for 40% of CO₂ emissions. Building construction causes CO₂ emissions as a result of embodied energy consumed in the production of energy intensive building materials and also the recurring energy consumption for cooling and heating of indoor environment.

Rapidwall, also called gypcrete panel is an energy efficient green building material with huge potential for use as load bearing and non load bearing wall panels. Rapidwall is a large load bearing panel with modular cavities suitable for both external and internal walls. It can also be used as intermediary floor slab/roof slab in combination with RCC as a composite material. Since the advent of innovative Rapidwall panel in 1990 in Australia, it has been used for buildings ranging from single storey to medium - high rise buildings. Light weighted Rapidwall has high compressive strength, shearing strength, flexural strength and ductility. It has very high level of resistance to fire, heat, water, termites, rot and corrosion. Concrete infill with vertical reinforcement rods enhances its vertical and lateral load capabilities. Rapidwall buildings are resistant to earthquakes, cyclones and fire.



Fig.1 : Worlds' largest load bearing lightweight panel being used in Australia

PHYSICAL AND MATERIAL PROPERTIES

Rapidwall panel is world's largest loadbearing lightweight panels. The panels are manufactured with size 12 m length, 3m height and 124 mm thickness. Each panel has 48 modular cavities of 230 mm x 94 mm x 3m dimension. The weight of one panel is 1440 kg or 40 kg/sqm. The density is 1.14g/cm³, being only 10-12% of the weight of comparable concrete /brick masonry. The physical and material properties of panels are as follows:

Weight- light weight	40 Kg/ sqm
Axial load capacity	160 kN/m{ 16 tons/ m }
Compressive strength	73.2 Kg/cm ²
Unit Shear strength	50.90 kN/m
Flexural strength	21.25 kg/cm ²
Tensile Strength	35 KN/ m
Ductility	4
Fire resistance	4 hr rating withstood 700-1000 ⁰ C
Thermal Resistance R	0.36 K/W
“U “Value	2.85W/M ² K
Thermal conductivity	0.617
Elastic Modulus	3000-6000Mpa
Sound transmission{STC}	40
Water absorption	< 5%

The vertical and lateral load capability of Rapidwall Panel can be increased many fold by infill of concrete after placing reinforcement rods vertically. As per structural requirement, cavities of wall panel can be filled in various combinations (See Fig.2.)

JOINTS:

Wall to wall ‘L’, ‘T’, ‘+’ angle joints and horizontal wall joints are made by cutting of inner or outer flanges or web appropriately and infill of concrete with vertical reinforcement with stirrups for anchorage. Various construction joints are illustrated in Fig.3.

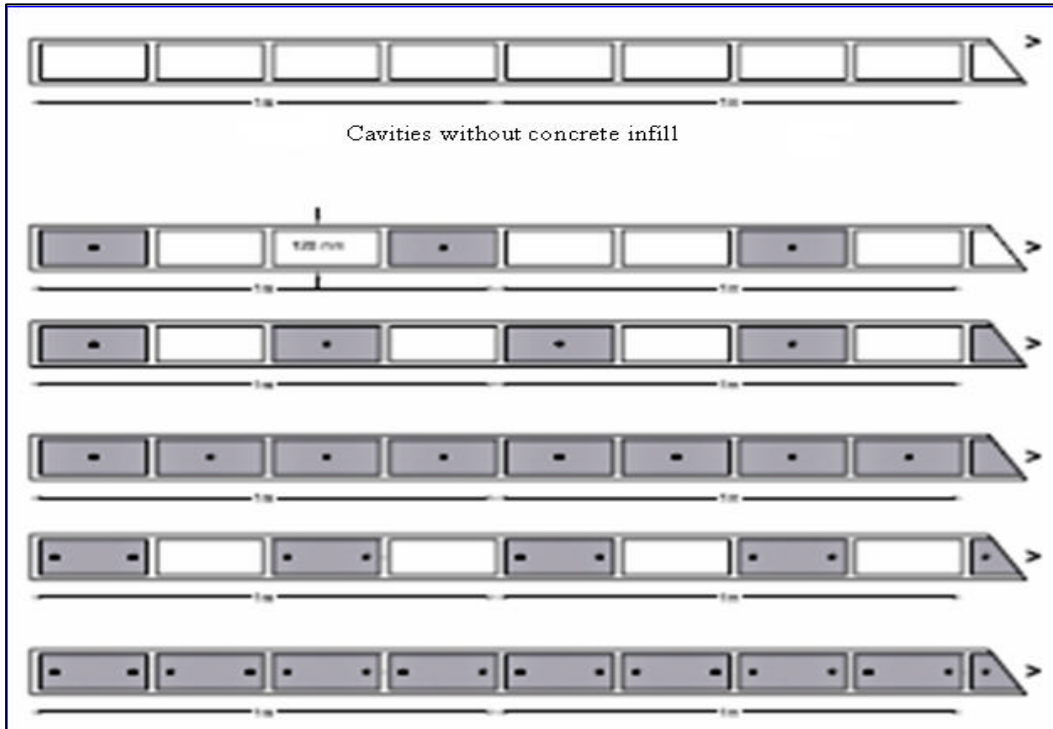


Fig.2 : RCC infill to increase load capability

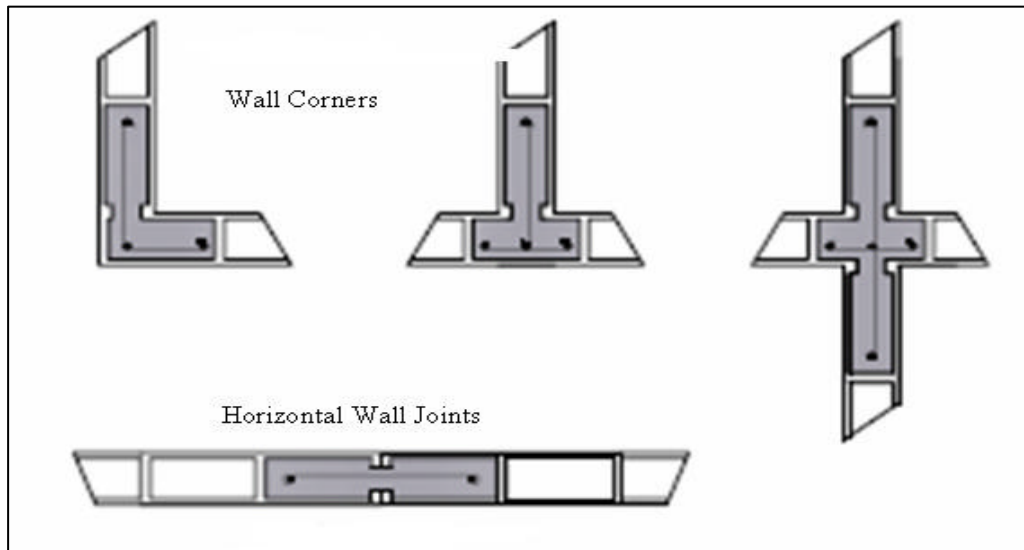


Fig.3 Various construction joints

Rapidwall Panel can also be used for intermediary floor slab / roof slab in combination with embedded RCC micro-beams and RCC screed concrete (Fig.4).

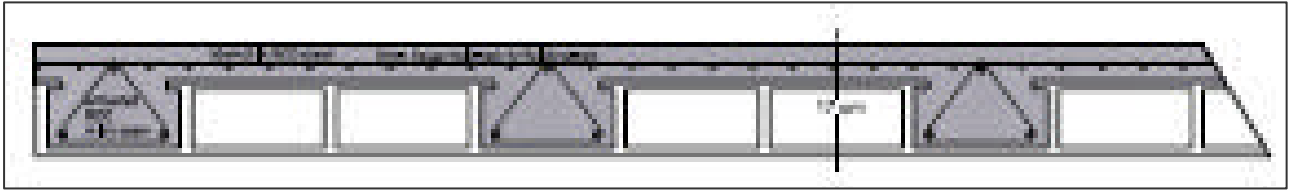
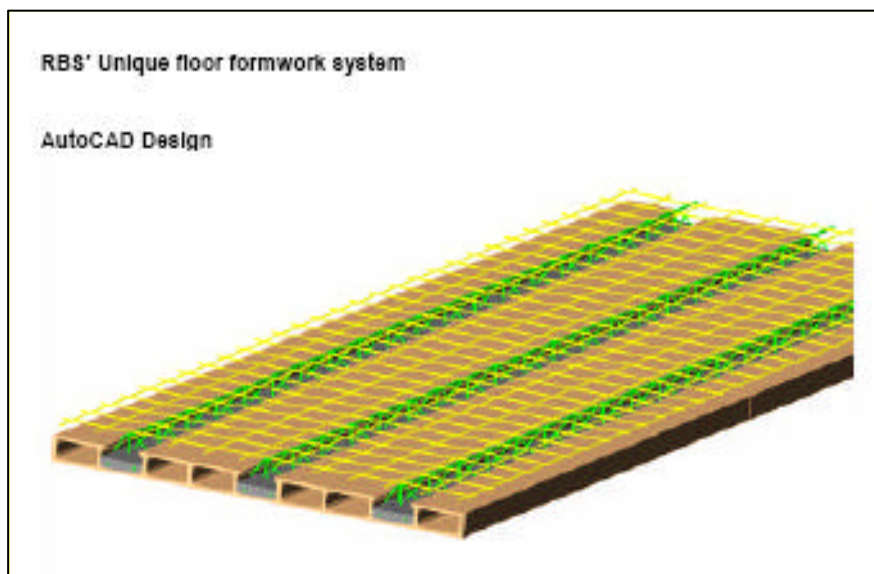
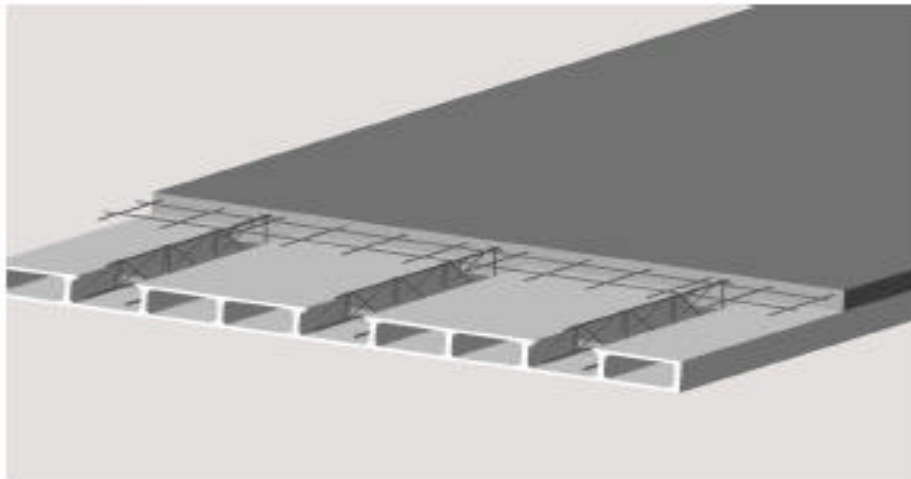


Fig.4 GFRG embedded with RCC micro beams and RCC screed concrete

Visual depiction



FOUNDATION:



Fig 5 : Foundation

For Rapidwall buildings/ Housing a conventional foundation like spread footing, RCC column footing, raft or pile foundation is used as per the soil condition and load factors. All around the building RCC plinth beam is provided at basement plinth level. For erection of panel as wall, 12 mm dia vertical reinforcement of 0.75m long of which 0.45m protrudes up and remaining portion with 0.15m angle is placed into the RCC plinth beams before casting. Start up rods are at 1m centre to centre.

RAPIDWALL FOR RAPID CONSTRUCTION

Rapidwall enables fast track method of construction. Conventional building construction involves various cumbersome and time consuming processes, like i) masonry wall construction ii) cement plastering requiring curing, iii) casting of RCC slabs requiring centering and scaffolding and curing iv) removal of centering and scaffolding and v) plastering of ceilings and so on. It also contributes to pollution and environmental degradation due to debris left on the site.

In contrast, Rapidwall construction is much faster and easier. There will be no debris left at site. Construction time is minimized to 15-20%. Instead of brick by brick construction, Rapidwall enables wall by wall construction. Rapidwall also does not require cement plastering as both surfaces are smooth and even and ready for application of special primer and finishing coat of paint.

Rapid Construction Method

As per the building plan, each wall panel will be cut at the factory with millimeter precision using an automated cutting saw. Door/window/ventilator, openings for AC unit etc will also be cut and panels for every floor is marked relating to building drawing. Panels are vertically loaded at the factory on stillages for transport to the construction sites on trucks.

Each stillage holds 5 or 8 pre-cut panels. The stillages are placed at the construction site close to the foundation for erection using vehicle mounted crane or other type of crane with required boom length for construction of low, medium and high rise buildings. Special lifting jaws suitable to lift the panel are used by inserting into the cavities and pierced into webs, so that lifting/handling of panels will be safe. Panels are erected over the RCC plinth beam and concrete is infilled from top. Protruded start up rods go inside cavities as can be seen from Fig. 5.

All the panels are erected as per the building plan by following the notation. Each panel is erected level and plumb and will be supported by lateral props to keep the panel in level, plumb and secure in position. Once wall panels erected, door and window frames are fixed in position using conventional clamps with concrete infill of cavities on either side. Embedded RCC lintels are to be provided wherever required by cutting open external flange. Reinforcement for lintels and RCC sunshades can be provided with required shuttering and support.

Concrete infill

After inserting vertical reinforcement rods as per the structural design and clamps for wall corners are in place to keep the wall panels in perfect position, concrete of 12 mm size aggregate will be poured from top into the cavities using a small hose to go down at least 1.5 to 2 m into the cavities for directly pumping the concrete from ready mix concrete truck. For small building construction, concrete can be poured manually using a funnel. Filling the panels with concrete is to be done in three layers of 1m height with an interval of 1 hr between each layer. There is no need to use vibrator because gravitational pressure acts to self compact the concrete inside the water tight cavities.

Embedded RCC tie beam all around at each level floor/roof slab:

An embedded RCC tie beam to floor slab is to be provided at each floor slab level, as an essential requirement of national building code against earth quakes. For this, web portion to required beam depth at top is to be cut and removed for placing horizontal reinforcement with stirrups and concreted.

Rapidwall for floor/ roof slab in combination with RCC

Rapidwall for floor/roof slab will also be cut to required size and marked with notation. First the wall joints and other cavities and horizontal RCC tie beams are in-filled with concrete ; then wooden plank of 0.3 to 0.45 m wide is provided to room span between the walls with support wherever embedded micro beams are there; finally roof panels will be lifted by crane using strong sling tied at mid-diagonal point, so that panel will float perfectly horizontal (See Fig.5)



Fig 5 Floor/roof panel

Each roof panel is placed over the wall in such a way that there will be at least a gap of 40 mm. This is to enable vertical rods to be placed continuously from floor to floor and provide monolithic RCC frame within Rapidwall. Wherever embedded micro-beams are there, top flanges of roof panel are cut leaving at least 25mm



projection. Fig 6 : Cutting of top flange

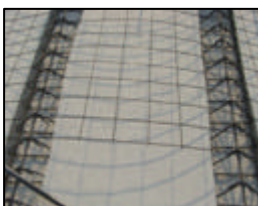


Fig 7 : Reinforcement

Reinforcement for micro-beams is placed and weld mesh as reinforcement is placed (Fig 7). Concrete is poured for micro-beams and RCC slab. This results in the embedded RCC micro beams and 50 mm thickness screed concrete becoming a series of “T” beams.

Erection of wall panel and floor slab for upper floor

The following day, erection of wall panels for the upper floor can be arranged. Vertical reinforcement of floor below is provided with extra length so as to protrude to 0.45 m to serve as start up rods and lap length for upper floor. (See Fig.8)

Once the wall panels are erected on the upper floor, vertical reinforcement rods are provided, door/window frames fixed and RCC lintel cast. Then concrete is filled where required and joints are filled. Then RCC tie beam all around are concreted. Roof panel for upper floor is repeated same as ground floor. For every upper floor the same method is repeated.



Fig 8 : Erection of upper floor panel

Finishing work

Once concreting of ground floor roof slab is completed, on the 4th day, wooden planks with support props in ground floor can be removed. Finishing of internal wall corners and ceiling corners etc can be done using wall putty or special plaster by experienced POP plasterers. Simultaneously, electrical work, water supply and sanitary work, floor tiling, mosaic or marble works, staircase work etc can also be carried out. Every upper floor can be finished in the same way.

Monolithic RCC framed structure inside Glass Fiber Reinforced Gypsum Panel.

In Rapidwall building an embedded monolithic, thin RCC framed structure is formed by i) bottom RCC plinth beams, ii) vertical columns of infilled cavities, iii) vertical wall corner joints iv) inter-connected horizontal RCC tie beams, integrated with v) embedded RCC micro-beams and RCC screed in all floors. In effect this RCC frame is moulded inside the GFRG Panel. (See Fig. 9)

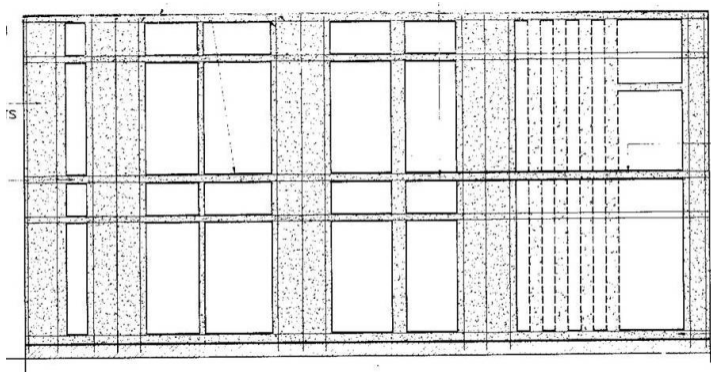


Fig 9 :Monolithic RCC framed structure

Testing of Rapidwall in Australia and by Tianjin University, in Zhandong Province, China found that “the lateral resistance of the concrete filled GFRG walls come from two different actions viz i) the shear resistance of the Rapidwall and ii) the lateral resistance

of internal reinforced concrete cores” as per the paper published by Yu-Fei Wu and Xiang in RILEM 2007(1).

The strength of building to take care of axial load and lateral/ flexural/ shear loads from wind or cyclone or earthquakes is due to the combination of inside RCC frame and Rapidwall Panel. Since the reinforced steel also encased within the GFRG panel, it is protected from corrosion.

Rapidwall building/ housing is cooler

Conventional building materials like concrete have high thermal conductivity and low thermal resistance. Conventional concrete roof and walls radiate heat inside the building. Heavy electrical energy is to be used to maintain indoor comfort level. There will be high electric energy for heating the indoor during winter.

In contrast Rapidwall panel have low thermal conductivity and high thermal resistance. A comparative research study by Mohd Peter Davis et al in 2000 in Universiti Putra Malaysia, Selangor, found that in summer indoor temperature of Glass Fiber Reinforced Gypsum Panel building is cooler by 5 to 6 degrees Celsius as compared to concrete building (2). The high thermal resistance of Rapidwall will keep interiors cooler in summer and warmer in winter, saving substantial recurring energy use.

Rapidwall is energy efficient

Low energy consumption for mass production of building material and reduced use of recurring energy for operational use is very critical to achieve carbon emission reduction to save the environment and fight global warming. This is the need of the century.

The main raw material is calcined superior quality gypsum plaster with purity more than 90%. Gypsum plaster, also called Plaster of Paris, is produced by calcining natural mineral gypsum rock ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) or by calcining industrial waste by-product gypsum available abundantly in India at various locations across the country. The use of advanced low energy based green & cleaner technology in reprocessing / recycling the raw material into GFRG panels consumes very low energy and helps to protect the environment. Environmental protection is economically priced now through carbon emission reduction (CER) trading under Kyoto Protocol linked through special market mechanism (CDM - Clean Development Mechanism).

This makes Rapidwall Panel mass production very suitable to meet the challenge of affordable housing for the deprived. According to the Ministry of Housing, Govt of India in Dec 2007 urban housing shortage has been estimated at about 24.7 million units at the end of the 10th Five Year Plan (2006-07) and 99% of the shortage pertains to the economically weaker sections and low income groups.

Rapidwall is for affordable quality housing

Access to adequate shelter at affordable cost by low income section and common people is very important for India for inclusive development.. The booming of real estate and construction industry has indeed shot up the cost of construction due to the ever increasing cost of cement, steel, bricks, river sand, concrete materials and labour cost. In this situation, safe and good quality housing will become unaffordable to all the sections.

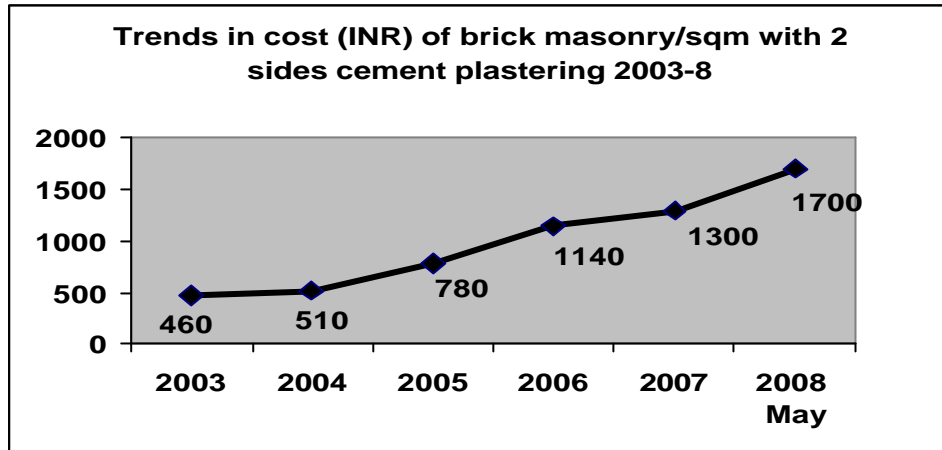


Fig.10 Cost of construction of 1 sqm (10.76 sft or 8.12 cft) 9” thick quality brick wall in cement mortar 1:6 and both sides (2 sqm or 21.52sft) plastered in cement mortar 1:5

Commonly used walling in India is brick masonry. Cost of brick wall with two sides cement plastering has increased by almost 4 times during the last 5 years as seen in Fig.10. Brick wall construction cost was Rs 460/sqm in 2003. This increased to Rs 1700 /sqm in 2007. In view of likely increase in cost of energy, bricks, cement, river sand, water, labour and hire charges for scaffolding etc, the cost of masonry made of bricks or concrete blocks will continue to rise in future. This will make Rapidwall panel much cheaper and affordable to the building industry while it will also help to protect the environment, as one sqm panel will save carbon emission reduction of about 80Kg.

Rapidwall panel has excellent acoustic properties. Testing of panel by IIT Madras found that the panel belongs to a class of STC 40 with respect to air-borne sound insulation. Infill of cavities with locally available cheaper materials like quarry dust mixed with cement (1:20) and water or sand and cement (1:20) up to lintel/ window height can make the wall solid and address security-related concerns.

Other than Australia and China, India is set to benefit from the technology as Rapidwall panels are to be manufactured and marketed in Mumbai within few months by RCF, one of the largest fertiliser company of Govt of India . FACT, another large public undertaking fertiliser company in joint venture with RCF is also setting up another Rapidwall plant in Cochin. A Rapidwall plant near Chennai is also commissioning and marketing the product shortly.

In Rapidwall construction, especially in repetitive type mass housing, time for construction will be reduced by 75-80% thereby reducing overall overhead establishment costs with reduced lock up investment period and less labour component. Comparative study of Rapidwall building and conventional building (2 storey 1500 sft) shows significant savings in Rapidwall buildings. Embodied energy of Rapidwall building is only 82921 kWh, while conventional same size building would have 215400 kWh, thereby saving 61.5% embodied energy. (See Table 1)

Materials/ items	Rapidwall Building	Conventional Building	Saving in %
Cement	16 tons	32.55 tons	50.8
Steel	1800 kg	2779 kg	35.2
River sand	20 cum	83.37 cum	76
Granite metal	38 cum	52.46 cum	27.56
Bricks	-	57200	
GFRG Panel	500sqm	-	
Water	50000 ltr	200000ltr	75
Built Area	143 sqm	154.45sqm	8
Labour	389 mandays	1200 mandays	67.59
Construction Time	21 days	120 days	82
Total Weight of superstructure	170 tons	490 tons	65
Construction Cost	Rs 13.25 lakhs	Rs 18.27 lakhs	27.47%
Embodied energy in kWh	82921	215400	61.5

Table 1: Comparison of Rapidwall vs conventional building

Uses of Rapidwall

The most valuable use of Rapidwall is its use as load bearing wall in multi storey construction in combination with RCC. Rapidwall can also be used **as non load bearing and partition wall in RCC framed structures**. IIT Madras has recently developed method of fixing panel in between RCC columns, beams and floor slab with clamping system. By this panel can be fixed to floor slab and panel at bottom using screws, which will be embedded within flooring and skirting. At top clamps will be fixed to panel and ceiling slab or beam. On sides also clamped at bottom to RCC column, floor slab and panel. Plastering of walls can also be saved thereby saving time and cost. If this is taken into account at design stage itself, dead load reduction of more than 50% can be made. This will save in foundation, RCC columns and beams, in turn steel and concrete. This will make substantial savings in cost of construction.

RCC Columns, beams with Rapidwall floor and walls in high rise building:

One of the leading architects based in Mumbai proposed an innovative method of construction of high rise building with RCC columns and beams to take load, while panel is to be used for walls and floor slab with micro beams. For this specially designed shuttering for RCC columns and beams will be in position in such a way that wall panel and floor slab panel of ground floor will be in position. Concreting of columns, beams, infill of required cavities, micro beams, and screed will be done simultaneously. This process will be repeated on each upper floor. Walls of each floor construction will be done along with rising up structure. It is estimated that this method will reduce 50% dead load which will reduce substantial steel and cement, 8% increased carpet area and saving of 60-70 % time.

Scattered small and row houses:

Quality small houses and row houses for low income and common people which can resist natural disasters at affordable cost is essential for inclusive development. Housing of the masses as well as other segments along with infrastructure alone will determine growth and development of the society or the nation. One BHK housing from 300-500 sft at affordable cost @ Rs 600-700/ sft can be a reality with Rapidwall.

At a time when the real estate market is on the downslide due to the economy in recession, many builders who have embarked on mega residential schemes may find affordable housing as a catalyst to tide over the recession period. It need not mean that they need to build houses for low income or middle class alone, but with structures built at affordable cost using Rapidwall and carry out superior finish to meet the requirement of up market and luxury segment may be a good solution and response. While provide more comfortable living, this will also save energy, contribute to environmental protection and fight global warming.

Construction of compound wall:

Rapidwall can be used for construction of compound wall and security wall.

FACT & RCF tie up:

FACT & RCF, two fertiliser giants under public sector are together setting up Rapidwall and plaster products manufacturing plant at Ambalamugal using Rapidwall technologies of Australia called **FACT RCF Building products Ltd. (FRBL)**. FACT has about 7 million tons of industrial by product gypsum. By setting up Rapidwall & Plaster products plant, they intend to produce 1.4 million sqm or 15 million sq ft panel per year and about 50000 tons of superior quality wall plaster and wall putty. RCF is already setting same capacity plant in their Chembur plant to meet the huge demand of Mumbai market. Gypsum based wall plaster and wall putty will be alternative to cement plaster for interior walls and ceiling. This will save river sand, cement and water. It will also provide fine finish. Gypsum based wall putty will be superior product than currently marketed brands of wall putty. These products will also be very useful to the real estate and housing industry.

Conclusion

Rapidwall Panel provides a new method of building construction in fast track, fully utilising the benefits of prefabricated, light weight large panels with modular cavities and time tested, conventional cast-in-situ constructional use of concrete and steel reinforcement. By this process, man power, cost and time of construction is reduced. The use of scarce natural resources like river sand, water and agricultural land is significantly reduced. Rapidwall panels have reduced embodied energy and require less energy for thermo-regulation of interiors.

Rapidwall buildings thereby reduce burdening of the environment and help to reduce global warming. Rapidwall use also protect the lives and properties of people as these buildings will be resistant to natural disasters like earthquakes, cyclone, fire etc. This will also contribute to achieve the goal of much needed social inclusive development due to its various benefits and advantages with affordability for low income segments also. Fast delivery of mass dwelling/ housing is very critical for reducing huge urban housing shortage in India. Rapidwall panels will help to achieve the above multiple goals.