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A Study on Feasibility of Rapid Wall Panel for Building Construction

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Abstract- *Housing is a basic need which is most difficult to fulfill considering the rising costs and shortage of building materials. Urban & Rural India has shortage of 90 million housing units by 2015 also the projected population in India by 2026 will be 1,400 million. With the rapid urban migration, the poor have to settle for a life in the streets or in slums in cities. Offering hope in this dismal scene are cheaper alternative building materials. An example is the gypsum wall panels. Recently, FACT &RCF Building Products Ltd. launched gypsum based wall panels in the market, capable of replacing brick walls. The panels are available in 12x3metre and 6x2.8meter size with a thickness of 124 mm. They can be cut to the requirements of the customers. The lightweight panels conform to the green building concept with savings in energy. In this study waste phosphogypsum is used as building material and its feasibility is checked with respect to conventional building material. Along with this other parameter like construction technique of building using rapid wall panels, its advantages over conventional building, benefits to builders and also feasibility w.r.t. environmental aspect, thermal insulation, fire resistance, water proofing studied. Conclusions are drawn based on above mentioned points.*

Keywords: Housing, Rapid wall, Phophogypsum, Solid waste, Environmental pollution, Building material

1. INTRODUCTION

Traditionally materials like clay, sand, stone, gravels, cement,brick, block, tiles, distemper, paint, timber and steel are being used as major building components in construction sector. All these materials have been produced from the existing natural resources and will have intrinsic distinctiveness for damaging the environment due to their continuous exploitation. The cost of construction materials is increasing incrementally. In India the cost of cement during 1995 was Rs. 1.25/kg and in 2015 the price increased five times. In case of bricks the price was Rs. 0.66 per brick in 1995 and the present rate is Rs. 7 per brick. Similarly, over a period of 20 years from the year 1995 the price of sand has increased five times.

Also due to high transportation costs of these raw materials, demand, environmental restrictions, it is essential to find functional substitutes for conventional building materials in the construction industry. The growth in industrial and agricultural activities continued to throw away huge quantities of wastes and by-products such as fly ash from power generation by burning pulverized coal, blast furnace and other slag from iron steel, non ferrous metal smelters, alumina red mud, slate and marble wastes etc. These coupled with calcareous and sulphitic wastes from chemical industries - sugar, paper acetylene, tannery, phosphatic fertilizers,' soda ash etc. amount today to nearly 250 million tons annually.

In India, about 6 MT of waste gypsum such as phosphogypsum, flurogypsum etc., are being generated annually there for it is necessary to set a secondary industries and recycling these waste into useful material. About twelve fertilizer plants in the country produce nearly 4 to 5 million tons of Phosphogypsum as a by-product. While some quantities are utilized for production of ammonium sulphate and few other uses, there are accumulated stocks of more than 10 million metric tons of Phosphogypsum at various plant sites. Major producers are Coromandel Fertilisers (Andhra Pradesh), Fertilisers & Chemicals, Travancore (Kerala), Gujarat State Fertilizer Co. (Gujarat), Hindustan Lever Ltd. (West Bengal), Southern Petrochemical Industries Corporation (Tamil Nadu) & Paradeep Phosphates Ltd. (Orissa). Disposal of Phosphogypsum is not only a serious techno-economic problem but creates environmental pollution and requires large land area for dumping. So by using Gypsum as a building material problem of dumping waste can be solved in eco friendly manner. Gypsum has been in use since ancient times. First known use of Gypsum dates back to 3700 BC in Egypt for the construction of Pyramids. In modern times with the help of advancement in

technology for calcining of gypsum and various innovative production processes a range of gypsum based products and construction applications have been developed. These technologies have shown potential for commercialization and wide spread adoption in building materials production and variety of civil works.

2. MATERIAL

2.1 Generation of Phophogypsum

Phosphogypsum is generated from filtration process in phosphoric acid plants where insoluble gypsum and other insoluble are separated from the product i.e. phosphoric acid as efficiently as possible .Depending on tsshe source of rock phosphate, about 4.5 - 5 Tonnes (dry basis) of phosphogypsum is generated per Tonne of phosphoric acid (as P2O5) recovered.

The quality & quantum of phosphogypsum generation depends upon the quality of the phosphate rock, process route used to produce phosphoric acid, calcium sulphate generated either in di-hydrate (CaSO4.2H2O) or the hemi-hydrate (CaSO4.1/2 H2O) form. Phosphogypsum generation in the Country is about 11 Million Tonnes per annum (based on the assumption that 5 Tonnes of phosphogypsum generated per Tonne of phosphoric acid production). The industry-wise production of phosphoric acid and estimated phosphogypsum scenario in the country as per the information provided by the phosphatic fertiliser units is compiled and given in **Table below**

Table No. 1: Production of Phosphogypsum

Year	Phosphoric acid production*	Estimated Phophogypsum generation**
2000-01	1042.4	4690.8
2001-02	1134.7	5106.15
2002-03	1085.6	4885.2
2003-04	990.1	4455.45
2004-05	1242.5	5591.25
2005-06	1067.8	4805.1
2006-07	1331.8	5993.1
2007-08(p)	1206.5	5429.25
2008-09(p)	1201.7	5407.65
2009-10(p)	1160	5407.65
2010-11(p)	1544.6	5220
2011-12(p)	1740.4	6950.7
2012-13(p)	1394.7	6276.15

Source: Fertilizer Association of India.

* = Out of indigenous production

** = Estimated quantity of phosphogypsum generated

(Apprx. 4.5 tons of phosphogypsum/ton of phosphoric acid produced)

(P) = Provisional;

Note: Phosphoric acid is expressed as 100% $\mathbf{P_2O_5}$

Plaster developed from this waste gypsum has showed improved engineering properties without any harmful effect. Phosphogypsum and lime sludge were recycled for manufacture of portland cement, masonry cement, sand lime bricks, partition walls, flooring tiles, blocks, gypsum plaster, fibrous gypsum boards, and super-sulphate cement Phosphogypsum could also be used as a soil conditioner for calcium and sulphur deficient-soils and it also has fertilizer value due to the presence of ammonium sulphate.

2.2 Manufacturing process:

Phosphogypsum is a byproduct of phosphoric acid plant is calcined in calciner at 140-1500 ^{0}C at the rate of 15MT/hr. This calcined plaster product is stored in silo of having capacity 250MT. With the help of screw conveyors this plaster is transferred to batch hopper and through Entoleter in Rapid wall panel manufacturing area. This area consists of casting tables having dimensions of 3m x 12m One crab having mixer and glass roving delivery system is for delivering slurry and glass roving. The chemically added water is used to form Gypsum slurry. One layer of slurry is laid on the table by the crab followed by a layer of glass roving. This glass roving is embedded in to the slurry with the help of layer of glass roving. This glass roving is embedded in to the slurry with the help of glass roving this layer is pushed inside the ribs with the help of temping bar. Finally a layer of glass roving is laid for the top face of the wall panel.

The casted panel is lifted to ACROBA frame and shifted to dryer for drying. The wall panel is dried at a temperature of 275^0 c for 60 minutes. After drying, the wall panel is either shifted to storage area or on the cutting table. The wall panel is cut as per dimensions supplied by the client and the cut pieces are transferred to still ages which are specially made for transporting wall panel. The waste liquid effluent

generated during manufacturing process can be recycled back in the system for manufacturing of new wall panels, also the solid waste which is generated during manufacturing process is recycled to the calciner after crushing and separating plaster and glass roving in recycle plant.

3. PRODUCT DETAILS

Building panel, presently manufactured as a Rapid wall, for the typical dimensions and material properties described in this manual. Typical dimensions of rapid wall panel 12.0m x 3.0m x 124mm as shown in fig. Each 1.0m segment of the panel has four cells. Each cell is 250m wide and 124mm thick, containing a cavity of 230mm x 94mm as shown in fig. The various cells are inter connected by ribs of 20 mm thick and flanges of 15mm thick comprising gypsum reinforced with 300mm x 350mm glass fiber roving, located randomly but centrally. The skin thickness is15mm and rib thickness is 20mm.

3.1 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 Fiber Reinforced Gypsum (GFRG) Panels in Buildings -Structural Design Manual" prepared by IIT Madras and published by BMTPC (Building Materials and Technology Promotion Council). 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 up to 10 storey's 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.

3.2 Impacts on Construction Process:

In assessing the market penetration of innovative residential building envelope systems—rapid wall panels, RAPID WALLS, insulated concrete forms (ICF), and aerated autoclaved concrete (AAC)—Bashford observes that these systems are marketed as if they were *product innovations*, easily interchangeable with conventional wood-frame construction. However, this method substantially impact the way trade contractors perform their work. Every critical construction performance metric is affected: worker safety, quality/workmanship of the finished structure, labor productivity, construction cycle time, and construction material waste. Worker skill levels and equipment can also be affected. Bashford also points out that any innovation that impacts multiple trades creates even more uncertainty because it can impact existing supply chain relationships. For example, alternative envelope systems interface with other building systems: foundations, roofs, utilities, windows/doors, and interior/exterior finishes. Other trades typically provide these systems.

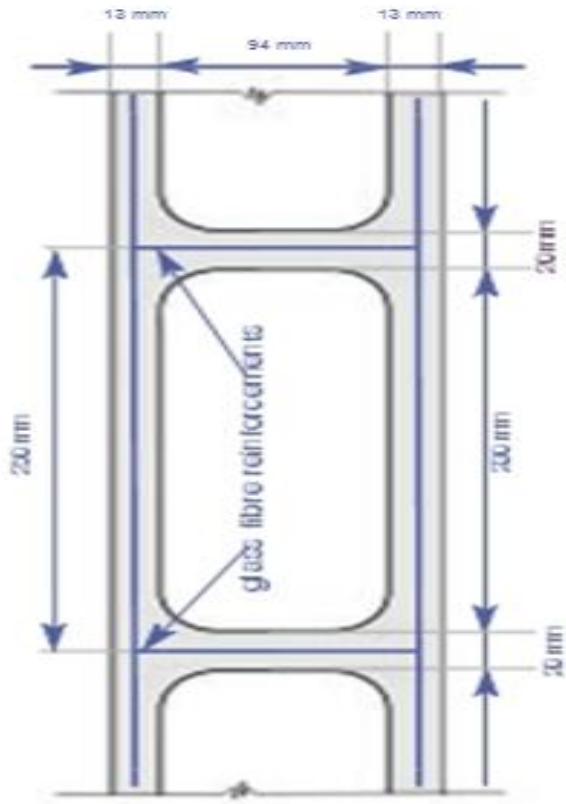

Fig: CROSS-SECTION OF RAPID WALL PANEL

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 fiber roving's, cut, spread and imbedded uniformly into the slurry with the help of screen roller. The panels are dried at a temperature of 275°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 storey's) building.

Table-2: Physical and Mechanical Material Properties

Material/items	Rapid wall Building
Weight- light weight	40 kg/sqm
Axial load capacity	16 tons/m
Compressive strength	73.2 kg/cm2
Unit Shear strength	50.90 kN/m
Flexural strength	21.25 kg/cm2
Tensile Strength	35 kN/m
Ductility	4
Fire resistance 4 hr rating withstood	700-1000 ^{0}C
Thermal Resistance	0.36 kw
Elastic Modulus	3000-6000Mpa
Sound transmission	40
Water absorption	< 5 %

3.3 Work Force and Experience:

Habitat for Humanity is a unique construction environment. Volunteers build each home under the guidance of an experienced home builder. A nationally recognized organisation credited by Building Materials and Technology Promotion Council has been guiding construction of the rapid wall Structures. Various officials who have participated in construction of rapid wall structures were enquired about the type of work force that was employed for construction of rapid wall structure and also about their general experience after participating in a new construction methodology. Participants of the construction process for rapid wall Structure included workforce of different activities such as labours, bar benders, carpenters, masons etc. and construction coordinators. Officials were questioned to asses previous construction experience of the workforce. The findings suggested that the construction experience of volunteers was appreciable. Workforce included participants with a wide range of construction experience, from novices to highly experienced professionals. Approximately five construction professionals participated on construction of the structure. These professionals were supported by approximately twice that number of non-professionals, a few having significant building experience. One important factor not evident in the learning's is that the participants for the rapid wall structure had no prior rapid wall construction experience. The unique nature of the workforce often resulted in near ideal efficiency on the construction site. Panels were moved and handled using crane, so the movement and handling of panels was near ideal, which reflected on related activities. Construction activities were routinely accomplished in series (one-at-a-time), rather than in parallel, it was so as to make up for lack of experience and to both safety and quality.

3.4 Safety and Quality of Workmanship:

Working with rapid wall panels has been proved to be very safe. The whole panel of 12x3 m and 6x3 m size can be lifted by a crane. The fixing and instal.lation of the panels is easy and safe. As there is no brickwork and the concrete pouring activity is very less, the execution becomes very safe and fast. The major precaution is to be taken while lifting the panel by the crane and placing it in the right place. If the panels are being shifted manually, extra care should be taken as to the point from where the panel is being lifted should be proper to have a firm grip.

As we all know, in case of conventional methods of construction, safety is an issue and more concern is required for carrying out activities like brickwork, concreting, etc.

Quality with rapid wall panels is always far better than conventional way, as all the panels are made under the guidance and supervision of highly qualified technical staff ,but in case of conventional methods ,the quality is maintained on the site under partial supervision of technical staff .So it is very difficult to maintain the quality every time.

4. Construction Material Waste:

The primary form of waste for the RAPID WALL structure is generated in form of scrap from cutting the panels to size and cutting window/door openings. These scraps are generated in the factory and to very limited extend on site owing to last minute changes that arise in working drawings. However, these scraps can be reused in construction of parapet wall, deck, etc. thus minimising the wastages.

In conventional method, the wastes account for nearly 5% of the total materials required.

4.1 Equipment Requirements:

With the exception of the forklift, crane, v-shaped funnel, adjustable m.s. props and angles, required for construction of RAPID WALL Structure, both techniques require comparable tools and equipment.

4.2 Advantages over Conventional Buildings:

- Less built-up area for the same carpet area, the wall panels are only 124mm thick.
- Less embodied energy and carbon footprint: significant reduction in use of cement, sand, steel and water; recycling of industrial waste gypsum.
- Lower cost of structure. Due to that we can save the materials.
- Lower building weight (panels weigh only 43 kg/m2), contributing to savings in foundation and reduction in design for earthquake forces, particularly in multi-storied construction.
- Buildings up to 8-10 storeys' can be designed using this load-bearing system, without the need for beams and columns.
- Excellent finishes of prefabricated GFRG panels – used for all the walls, floors and staircases, with minimal embedded concrete: no need for additional plastering.
- The use of prefabricated light-weight GFRG panels not only implies faster overall construction time but also a safer working environment.
- The structure is Light weight and accurate.
- The whole construction is Economical.
- The construction using this panel is Load-bearing
- Rapid wall panel is environmentally positive of environment friendly.
- The structure is Fire proof.
- This construction is Earthquake resistant.
- The structure has good sound attenuation quality

Table-3: Comparative Table

Materials/ items	Rapidwall Building	Conventional building	Saving in %
Bricks	-	965327	-
GFRG Panel	2044	-	-
Water	160000 ltr	666000 ltr	75.98
Construction Time	66 days	200 days	67
Construction Cost	32.73 lakh	44.80 lakh	26.94
Accuracy	MORE	LESS	-
Transportation	MORE	LESS	-

5. Conclusion

Rapid wall construction is more economical. Rapid wall Panel provides a new method of building construction in fast track. Using rapid wall construction we can reduce man power, cost and time of construction. The use of natural resources which are now day not easily available like river sand, water and agricultural land is reduced. It reduces adverse effects on environment. The building constructed using RW panel comes under Green building categories as after constructing it energy requirement for heat insulation, sound insulation, humidity and Temperature inside is less than conventional building. It is very effective technology to beat the current rising cost of construction.

And the most important, this new technology is having potential to provide shelter to the "Homeless Indians".

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