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Case Study on Glass Fiber Reinforced Gypsum Panel in Mass House Economics

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***Abstract* - GFRC has advantage of being light weight and reducing the overall cost of construction bringing economy in construction. GFRC is concrete that uses Glass fibers for reinforcement instead of steel. The fibers cannot rust like steel, there is no need for a protective concrete cover thickness to prevent rusting. With the thin, hollow construction of GFRC products, they can weigh a fraction of weight of traditional precast concrete. This paper aims to determine compressive, flexural and tensile behavior of the glass fibers reinforced concrete and to contribute to the classification and specification of glass fibers reinforced concrete (GFRC) and to deal with the question if structural glass fibers reinforced concrete as a special kind of glass fibers reinforced concrete is suited for use in load – bearing members. Despite excellent material properties, the use of glass fibers in a concrete matrix is carried out so far only in non-structural elements or as a modification for the prevention of shrinkage cracks.**
***Keywords:* Glass Fiber, Gypsum, Mass House, Economics**

I. INTRODUCTION

GFRG is the abbreviation for glass fibres reinforced gypsum. It is the name of a new building panel product, made essentially of gypsum plaster, reinforced with glass fibres, and is also known in the industry as Rapid wall. This product, suitable for rapid mass-scale building construction, was originally developed and used since 1990 in Australia. GFRG is of particular relevance to India, where there is a tremendous need for cost-effective mass-scale affordable housing, and where gypsum is abundantly available as an industrial by-product waste. The product is not only eco-friendly or green, but also resistant to water and fire.

The aim of project work is the use of alkali-resistant macro glass fibers as concrete reinforcement in structural elements as an alternative. In the future, structural glass fibers reinforced concrete shall provide a simple and visually appealing alternative to conventional steel bar or steel fibers reinforced concrete. The glass fibers can also be used in combination with conventional reinforcing bars or mat reinforcements.

II. GLASS FIBERS REINFORCED GYPSUM

GFRG panels are presently manufactured to a thickness of 124 mm, a length of 12m and a height of 3m, under carefully controlled conditions. The panel can be cut to required size. Although its main application is in the construction of walls, it can also be used in floor and roof slabs in combination with reinforced concrete. The panel contains cavities that may be filled with concrete and reinforced with steel bars to impart additional strength and provide ductility. The panels may be unfilled, partially filled or fully filled with reinforced concrete as per the structural requirement.

III. LITERATURE REVIEW

Glass fibres lose a proportion of their pristine strength when placed in a Portland cement environment. AR fibres have a superior performance to other types, and are likely to retain long term tensile strengths of about 1000-1200 N/mm2 at ambient temperatures in a cement environment.

This includes not only an assessment of fibre content and matrix strength, but also such details as fibre distribution, orientation, and effectiveness of bonding. Possible manufacturing or materials faults can also be diagnosed. Also it shows that the MOR and LOP in drying condition test have higher result than wet condition around (1- 5) MN/m2 difference.

The main difference between dewatered and non-dewatered GRC is the difference in density which has two effects. Firstly although the fibre content by weight is the same, the higher density of the dewatered board gives a higher fibre volume fraction giving higher strengths. Secondly the dewatered board has better compaction and reduced porosity giving better fibre/matrix bond strength.

Cement, when reinforced with glass fibre, produces precast elements much thinner typically 10 mm—than would be possible with ©gopalax-International Journal of Technology And Engineering System(IJTES): Jan–March 2011- Vol.2, No.2. 123 traditional steel-reinforced precast concrete, where 30mm or more concrete cover to the steel is essential as protection against corrosion.

Thinner sections are also made possible by the low water: cement ratio of the material, the lack of coarse aggregate, and its low permeability. As a result, panels of equal strength and function of precast concrete can be produced with thinner sections and therefore less weight.

IV. METHODOLOGY

The research methodology is divided in two parts; theoretical aspect will discuss the building design using Glass Fibres Reinforced Gypsum panels according to design manual, installation manual, and system requirements. Practical aspect concerning cost of Glass Fibres Reinforced Gypsum during operation process, In addition to that, data was gathered from different projects using GFRG system concerning construction cost & installation procedures on site. The cost analysis for Glass Fibres Reinforced Gypsum during construction process can be classified into three categories, cost per meter square of panel, cost per number of panels and cost with respect to building foot print & building built-up area as shown.

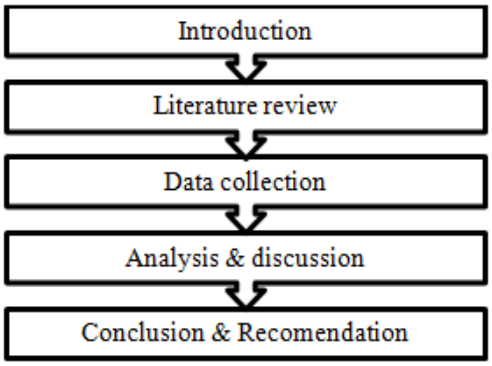

Fig. 1 Methodology

A. Overview of (GFRG) wall panel system

Glass fibre reinforced gypsum, abbreviated as GFRG (better known as Rapid wall in the industry) is the name given to a new building panel product, made of gypsum plaster, reinforced with glass fibres. GFRG is of particular relevance to India, where there is a tremendous need for cost-effective mass-scale affordable housing, and where gypsum is abundantly available as an industrial by-product waste. The product is not only eco-friendly or green, but also resistant to water and fire. GFRG panels are presently manufactured to a thickness of 124 mm, a length of 12m and a height of 3m. Although its main application is in the construction of walls, it can also be used in floor and roof slabs in combination with reinforced concrete. IIT Madras has been involved, since 2003, with the development of building systems (especially with respect to use of GFRG panels as floor slabs and earthquake resistant design) for use in India.

B. Manufacturing process

1. Phosphors gypsum which is a byproduct of phosphoric acid plant is calcined in calciner at 140-1500 C at the rate of 15MT/hr. of calcined plaster. This calcined plaster is stored in product silo having capacity of 250MT.
2. The plaster is then transferred to batch hopper by screw conveyors and through Entoleter in wall panel manufacturing area.
3. This area consists of 6 casting tables having dimensions of 3m x 12m, one crab having mixer and glass roving delivery system is for delivering slurry and glass roving for three tables. The chemicals are added in water & mixed and then plaster is added & mixed to form slurry.
4. 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 screen roller.
5. Another layer of slurry is poured followed by a layer 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.
6. After getting final Gilmore wall panel is lifted from the casting table to ACROBA frame and shifted to dryer for drying. The wall panel is dried at a temperature of 275OC for 60minutes.
7. 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 consumer and the cut pieces are transferred to stillage's which are specially made for transporting wall panel.
8. The liquid effluent generated during manufacturing process is recycled back in the system for manufacturing of new wall panels.
9. The solid waste which is generated while manufacturing wall panels is recycled back to the calciner after crushing and separating plaster & glass roving in recycle plant.
10. The above system is a batch process. Six wall panels can be manufactured in eight hour shift per table. Similarly, 36 wall panels can be manufactured in eight hour shift with 6tables.
11. Flow diagram of the system showing the manufacturing process is attached herewith.
12. The manufacturing machine is as shown in figure.

C. Properties of GFRG

1. Axial load capacity - 160 KN/m (16 Tons/m)
2. Compressive strength - 73.2 Kg/cm2
3. Unit Shear strength - 50.90 N/m2
4. Flexural strength - 21.25 Kg/cm2
5. Tensile Strength - 35 KN/m
6. Ductility – 4
7. Fire resistance - 700-10000°C
8. Thermal Resistance (R) - 0.36 K.W
9. "U" Value - 2.85W/M2K
10. Thermal conductivity - 0.617
11. Elastic Modulus (E) - 3000-6000Mpa
12. Sound transmission (STC) – 40
13. Water absorption - < 5%
14. Coefficient of thermal expansion- 12×10-6mm/°C.

C. Installation of Glass Fibre Reinforced Gypsum

GFRG installation system will be installed as the following steps.

1. Prior to delivery of the panels the surveyors establish and mark all main grid lines on the foundations or the concrete suspended floor onto which GFRG panel is to be positioned.
2. Using the Architectural layout drawings the erection crew marks out the wall positions in reference to these grid lines.
3. Holes are drilled in the concrete foundation, starter bars inserted and waterproof membrane applied.
4. Pre-cut GRFG panels are lifted by crane onto the prepared concrete floor or foundation.
5. Using GFRG lifting jaws, the pre-cut GFRG panels are decanted, one by one, from the stillage and placed into their final position, propped and screwed together.
6. Plumbing and electrical services are installed in the voids and if required, concrete is poured or insulation inserted into the cavities.
7. Post construction the GFRG panels are finished in a conventional manner.
8. Each panel has (A) and a (B) side. Normally the smoother (A) side is installed internally whereas the (B) side is used externally.
9. External renders or decorative facings can be added externally and internally the panels flushed and finished ready for primers.

V. COMPARISON OF DATA COLLECTIONS

A. Project Details

We have chosen a building in the Kochi which is a 2 storey building and was constructed by a Kerala based company Sheghram Nirman Pvt. Ltd, Kerala. We have observed the construction procedure and techniques are being used for GFRG panels construction, complete cost and estimation of building, relevant procedures used for panel manufacturing, analysis and duration of the every element of building. We have done a detailed case study of comparison between the conventional building and GFRG panel building in the two main aspects

1. Cost
2. Time
3. Quality
4. Quantity

B. Type of Building: 2 Storey Building

C. Type of Construction: Rapid wall construction with GFRG panels

D. Area: 1500 Sq.ft

India is the developing country and in the economy of country construction projects and industries play a vital role. Time and cost are two main concerns in a construction and they are used for planning a project. This has increased the importance of time and Cost optimization in construction projects is necessary to estimate the cost and time of each activity through which the whole duration and total cost of the project are determined to complete the planning task.

TABLE I COMPARISION BETWEEN RAPIDWALL (GFRG) AND CONVENTIONAL BUILDING

Materials/items	Rapid wall building	Conventional building	Savings in %
Cement	16 tons	32.55 tons	50.8
Steel	1800 kg	2779 kg	35.2
Sand	20 cum	83.87 cum	76
Granite	38 cum	52.46 cum	27.56
Brick	-	57200	
GFRG panel	500 sqm	-	
Water	50000 ltr	200000 ltr	75
Labour	389 man days	1200 man days	67.59
Construction time	21 days	120 days	82
Wt. of superstructure	170 tons	490 tons	65
Construction cost	Rs. 13.25 lakhs	18.27 lakhs	61.5

TABLE II COMPARISON OF CONSTRUCTION TIME

S. No.	Item of Work	RCC (in Days)	GFRG (in Days)
1	Earth work Excavation	2-4	2-4
2	C.C Bed 1:4:8	2-3	2-3
3	Brickwork in Foundation	5-7	5-7
4	Plinth Beam with DPC	2-4	2-4
5	Columns	9-10	-
6	Walls (Brick / GFRG)	10-15	2-4
7	Beams	15-18	-
8	Lintels and Sunshades	4-5	2-3
9	Slab	28	14
10	Plastering	10-12	-
11	White Wash	3-4	-
12	Colour Wash	2-3	2-3
13	Flooring	3	3
	Total Duration	98-120	34-44

VI. APPLICATIONS OF GFRG

GFRG building panels are generally used in the following ways.

1. As load bearing walls in buildings, to resist gravity load.
2. As partition or infill walls in multi-storeyed framed RC structures.
3. As compound walls in combination with minimum quantity of concrete.
4. As shear walls, to resist both gravity load and lateral load from earthquakes and wind also as walls of lift-well and parapet walls.
5. As floor slabs / roof slabs, pitched roof slabs and also as staircase waist slabs and mid-landing slabs.

VII. ADVANTAGES OF GFRG

1. High speed of construction.
2. More carpet area for the same built-up area: thickness of wall panels is only 124mm.
3. Less embodied energy and carbon footprint significant reduction in use of steel, cement, sand and water, recycling of industrial waste gypsum.
4. Less cost of construction: savings in materials; no cement plastering.
5. Less building weight (panels weigh only 44 kg/m2), thereby reduction in design for seismic forces and savings in foundation, especially in multi-storeyed buildings.
6. 8 to 10 storeyed buildings can be designed using GFRG panels, without the need of conventional RC beams and columns.
7. Very good finishes of GFRG buildings: use of factory made panels for all the walls, floors and staircases.
8. Less CO2 emission compared to other conventional building materials.
9. Better thermal comfort inside GFRG building compared to conventional buildings.
10. Since gypsum is a hard material there is no creep in the GFRG panel so it is major asset of this type of construction.
11. In this Rapid wall system, there is no volume change even at high temperature.
12. The movement of moisture through concrete structures is dampness**.** There is no dampness problem in GFRG panel wall system.
13. The durability of this rapid wall system is same as the RCC construction.

VIII. DISADVANTAGES OF THIS TECHNOLOGY

Although theoretically there are no drawbacks of using this technology, a few practical issues do arise

1. You do need some expertise in order make a house using this technology. The handing, fixing and equipment requirement for these panels is fairly different from conventional style. Although it is not very difficult to learn the right techniques, it will eventually take time for becoming and industry trend
2. The Panels are customized according the design and drawings of your house when manufactured. Unfortunately, you cannot make a lot of changes during fixing stage. Hence planning is important. Also the doors, windows and other openings are made by cutting through the panels, hence the planning for placing doors and windows also needs to be extensive.
3. In India, if you looking to do a construction in a normal populated area, it is very likely that your plot is already surrounded by built house. The GFRG technique needs empty space around the plot so that cranes can be placed while fixing panels. Also the panels need special care while storing them and need more space as compared to cement/blocks. These 2 factors make it difficult for a full scale implementation in India Empty space to store and move Panels is needed.
4. The fact that panels are specifically made for a design and transported from factory, the price of each type of panel goes done significantly only when used on a large scale. Comparatively you can save 25–30% compared to that of conventional building method and even more if used on large scale.

IX. CONCLUSION

From this we conclude that conventional buildings are more costlier when compare to panel system. The panels has good life span as same as concrete structures. Nowadays the use of panels for construction evolves gradually. But still most of the people are not aware about this type of construction practices for residential buildings. From this project we can create some awareness about the construction of panel systems about the cost, time management, resource allocation and quality and quantity of GFRG. The main motto of this project is to create awareness among people about the construction at affordable price.

GFRG can be effectively used for the entire superstructure of buildings, including all walls, slabs, staircases, parapets, etc. This building system has many advantages over conventional buildings. GFRG buildings have the potential to meet the challenge of providing rapid affordable mass housing. This is an eco-friendly and sustainable building system, making use of recycled industrial waste gypsum or natural gypsum and minimising the use of cement, steel, sand, water and labour input. This technology is now gaining acceptance in India and other Asian countries.

X. RECOMMENDATIONS

1. This research aims to study direct cost for GFRG, it neglects the indirect cost for this system. For further cost analysis, future research needs to study the indirect cost which will result for more accuracy calculation of GFRG cost during design phase for the project.
2. The future research needs to study the Risk analysis for using of GFRG system in repetitive project; this will help the owner/ designer to anticipate the cost for GFRG system during design phase.
3. Future research needs to inspect new techniques to decrease the cost for GFRG system with same performance for system.
4. Environmental aspects can be addressed in future researches to study environmental performance for spaces using GFRG system.
5. Future studies can address the quality procedures for installation inspection for GFRG system on site.

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