A comparative study of GFRG Construction and a Conventional RCC Construction for the Economically Weaker Section

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Abstract

In India, Economically Weaker section group of people miss out on the benefits of owning a home like status, security and Governmental schemes. In this fast-changing world where land prices are reaching sky-high and the current mode of construction adopted i.e. RCC construction, which is time consuming, costly and not environmentally friendly calls for the use of smart construction materials. One such material is GFRG Glass Fiber Reinforced Gypsum Panels. This material is manufactured in a closed environment and perform better when compared to a RCC in many factors. To tell which method is more suitable for today’s changing world especially from Economically Weaker Sections point of view, a comparative study had been made. The study consisted of comparisons drawn between the conventional RCC construction and GFRG construction in terms of their performance during exposure to Seismic loads, Cost of construction and timeline analysis.

Keywords: Glass Fiber Reinforced Gypsum Panels, Seismic behavior, Cost analysis, Economically weaker section EWS, Timeline analysis

1. Introduction

In India, the desire of having one’s own house is very strong as it acts a security for some people, it is a status of accomplishment of a family or an individual and in some cases a home beneficiary can avail Governmental Schemes after owning. This dream of owning a personal house is dreamt by every person irrespective of the economic typology they belong to. A major problem that causes a setback is ‘Affordability’. This makes the dream of owning a house difficult for many, and almost impossible for most who belong to the Middle-Income Group (MIG), Lower Income Group (LIG), and especially Economically Weaker Section (EWS) group due to rising property prices.

It is estimated that only 1.5 crore Indians pay income tax i.e., approx. 1% of total population of India and in this 1% population 57% people are those who are earning less than 2.5 lakhs (annually), 18% are those who are earning up to 5 lakhs (annually) and 17% are earning up to 5 to 10 lakhs (annually). [1] Therefore, the need of an economical housing comes into the play. This need came as a main role when the United Nations added sustainable cities and communities in the 17 sustainable goals to transform the world. The goal tells that by 2030, we need to ensure access to all–to an adequate, safe, and affordable housing with basic services and an upgradation of the slums. [3]

Due to recent advancements in Construction Material technology, Glass Fiber Reinforced Gypsum (GFRG) panels can be adopted over traditional Reinforced Cement Concrete (RCC). The aim is to obtain innovative as well as highly efficient building construction mechanism for strong as well as durable housing in an advanced mode of construction at an affordable cost. GFRG panels aims for rapid construction of an affordable, eco–friendly, and sustainable housing solution mainly planned for EWS.

The problem of increasing carbon emissions and subsequently caused global warming potential cannot be tackled without reducing the embodied carbon emission of buildings. Requirement of rapid construction is one such scenario where Construction cost keeps adding up due to the amount of days it takes to complete a housing project. More number of days meaning more Direct costs like Labor costs, water costs, electricity cost, equipment cost and Indirect costs like wastage of natural resources, Air pollution etc. GFRG panels are also environment friendly as its manufactured of reprocessed / recycled industrial by product, viz., waste gypsum.

GFRG panel, helping to abate pollution and protect the environment. Glass Fiber Reinforced Gypsum (GFRG) wall panel with composite RCC acts as a perfect substitute for traditional concrete houses as the population is increasing the demand for houses are also increasing as highest demand is from EWS category families. To meet this demand Government of India have initiated many Schemes for People, prominent being Pradhan Mantri Awas Yojana (PMAY) and Credit Linked Subsidy Scheme (CLSS).
2. Glass Fiber Reinforced Gypsum (GFRG) panel

GFRG is a lightweight, load-bearing building panel, manufactured using gypsum plaster, glass fiber roving’s and other special additives. These panels are Industry manufactured and can be used for load bearing elements mainly as walls, staircase, parapet wall, compound wall etc [2,4]. GFRG has cavities inside each panel with a dimension of 12.0m × 3m with overall thickness of 124mm. Filling of GFRG panel cavities may be done as unfilled, partially filled, or fully filled with reinforced concrete as per the structural requirement.

Due to the mechanical properties of this material, for constructing a GFRG House can be divided in two types-

Hybrid GFRG Construction – where GFRG panels can be used as infill walls (and slabs) in conventional framed construction.

Traditional GFRG Construction – where GFRG panels are used as Load bearing elements and consecutive horizontal joints are filled with concrete and vertical joints to floor / roof slab (of GFRG too) embedding reinforced concrete micro beams and screed in slab section.

Traditional GFRG Construction method is focused on more in this project. All the service lines like water supply and sewage lines can easily be passed via a hollow section taken through the cavities in the panel. The other cavity can be filled with quarry dust with 5% cement for single story building and with reinforced bar along with M25 cement grade for multi-story building.

This paper aims to analyze the potential of using the GFRG Construction technology and replace it with Traditional Construction method to have an added advantage over following areas-

- Drafting the Economically Weaker Section’ floor plan using computational software of AutoCAD 2018 that comply with Pradhan Mantri Awas Yojana (PMAY) guidelines
- Seismic loading comparisons of a GFRG construction EWS building and a traditional RCC construction building
- A timeline analysis comparison between GFRG construction method and traditional RCC construction building to determine which method when adopted will lead to rapid construction, saving us on raw materials, labor, machinery, environmental pollution costs.
- A direct in detail cost analysis between GFRG building and a traditional RCC to determine which method will lead to maximum saving of cost and materials of the project using SOR Delhi,2020

3. Economically Weaker Section

EWS households are defined as households having an annual income up to Rs. 3,00,000 (Rupees Three Lakhs). Under Pradhan Mantri Awas Yojana, PMAY(Urban) scheme, an all-weather single unit or a unit in a multi-storied super structure having carpet area of up to 30 sq. m. with adequate basic civic services and infrastructure services...
like toilet, water, electricity etc., can be categorized for EWS housing. [1] Figure 3 shows the plan of EWS dwelling used in the present study. The building used in the study is G+4 storey. Economically Weaker Section (EWS) is being benefited via CLSS i.e., Credit Linked Subsidy Scheme. Under this, beneficiaries of the same can seek housing loans from Banks, Housing Finance Companies and other such institutions for new construction and enhancement to existing dwellings as incremental housing. The credit linked subsidy will be available only for loan amounts up to Rs 6 lakhs and such loans would be eligible for an interest subsidy at the rate of 6.5 % for tenure of 20 years or during tenure of loan whichever is lower. The Net Present Value (NPV) of the interest subsidy will be calculated at a discount rate of 9%. Any additional loans beyond Rs. 6 lakhs will be at nonsubsidized rate, Interest subsidy would be credited upfront to the loan account of beneficiaries through.

Figure 3. EWS dwelling plan used in the study

4. Results and Discussions

4.1 Seismic Analysis
A linear static analysis approach has been used in the study in accordance to IS 1893 (2002) [5]. This approach defines a way to represent the effect of earthquake ground motion when series of forces act on a building, through a seismic design response spectrum. This method assumes that the building responds in its fundamental mode. The applicability of this method is extended in many building codes by applying factors to account for higher buildings with some higher modes, and for low levels of twisting. To account for effects due to "yielding" of the structure, many codes apply modification factors that reduce the design forces. In the equivalent static method, the lateral force equivalent to the design basis earthquake is applied statically. The equivalent lateral forces at each storey level are applied at the design ‘centre of mass’ locations. It is located at the design eccentricity from the calculated ‘centre of rigidity (or stiffness)’. Table 1 shows the comparisons between GFRG and RCC building, the types of frame adopted for Seismic analysis and the Base shear values.

|                      | GFRG Constructed House | RCC Constructed house |
|----------------------|------------------------|-----------------------|
| **Number of Storeys**| G+4                    | G+4                   |
| **Length of Building**| 10.8m                  | 10.8m                 |
| **Width of Building** | 7.26m                  | 7.26m                 |
| **Height of Building**| 17.5m                  | 17.5m                 |
| **Z = Zone factor**  | (III) 0.16             | (III) 0.16            |
| **I = Importance factor** | All other buildings 1.0 | All other buildings 1.0 |
| **R = Response Reduction factor** | OMRF = 3.0     | OMRF = 3.0             |
| **T = Natural Time Period** | X direction = 0.49 sec | X direction = 0.49 sec |
|                      | Z direction = 0.58     | Z direction = 0.58    |
| **S_s/g**            | 2.5 for medium stiff   | 2.34 for med          |
| **A_h**              | X direction = 0.066    | X direction = 0.066   |
|                      | Z direction = 0.0624   | Z direction = 0.0624  |
| **Base Shear**       | X direction = 1421.44kN | X direction = 1792.38kN |
|                      | Z direction = 1343.90kN | Z direction = 1694.61kN |

Figure 3. EWS dwelling plan used in the study
From the seismic analysis, the Base shear generated when using GFRG constructed building is 20% less when compared to a traditionally built RCC structure. This is attributed to the low self-weight of the GFRG construction as a bare frame analysis was performed on both the structures.

4.2 Timeline analysis

GFRG Panel (also called Rapid Wall) have advantage of rapid construction compared to RCC house. For a same height of construction of GFRG and RCC structure, GFRG panel construction will tend to finish faster. GFRG panels are lifted using a small crane of 1 - 5 T capacity [6]. At once the panel covers more area in less time compared to RCC where time taken in process like Shuttering, more concrete pouring and curing time gets added. GFRG panel construction requires less labour on site whereas more labours are required on an RCC site where additional day wages need to be paid. A lot of cost in such labour charges, machine operation and maintenance charges add up and overall cost of the project increases. A GFRG method adoption in a large-scale project will lead to a cost reduction and time saving practices.

A comparative study of time taken for construction of a GFRG and RCC building of same plan used in Fig 3 has been performed and following result was observed. In any execution of a project, following tasks are followed.

- Reconnaissance
- Foundation (Wall and column)
- Plinth
- Elevation

For the construction of a house by adopting either of the construction methods, the construction time taken from Reconnaissance till plinth level is same. Time required in Elevation (up to 4 levels in this research paper) is drastically reduced in GFRG constructed method. The computational software – Microsoft Project is used to determine the timeline in both methods.

| Activity            | Time taken in GFRG construction (days) | Time taken in RCC construction (days) |
|---------------------|---------------------------------------|--------------------------------------|
| Reconnaissance      | 3                                     | 3                                    |
| Foundation          | 6                                     | 11                                   |
| Plinth              | 13                                    | 13                                   |
| Elevation for 1st floor | 19                                    | 29                                   |
| Elevation of 2nd floor | 19                                    | 29                                   |
| Elevation of 3rd floor | 19                                    | 29                                   |
| Elevation of 4th floor | 19                                    | 29                                   |

From the timeline analysis MSP output, it was concluded that the GFRG panel construction saved up to 28% – 30% time (in days). The total number of days required for construction using GFRG method was 95 days whereas, the total number of days required for construction using RCC method was 133 days.
4.3 Cost Analysis

The costing factor plays a very important role when comparing which method out of GFRG Construction and RCC Construction. The costing here is determined in phases by first determining measuring’s sheet and Cost of material of each method and then we can determine final cost of the project.

Table 3. Measurement Sheet of RCC constructed building

| Item No. | Description                  | No. | Length (m) | Width (m) | Height (m) | Quantity (m³) |
|----------|------------------------------|-----|------------|-----------|------------|---------------|
| 1        | Column Footing               |     |            |           |            |               |
|          | Concrete for PCC            | 10  | 1          | 0.8       | 0.25       | 2             |
|          | Concrete for slope footing  | 10  | 0.75       | 0.6       | 1          | 4.5           |
|          | Reinforcement = 3% of total concrete vol. | | | | | 0.135 |
| 2        | Wall Footing                 |     |            |           |            |               |
|          | PCC                          | 2   | 17.49      | 0.6       | 0.3        | 6.3           |
|          | Vertical                     | 2   | 13.75      | 0.6       | 0.3        | 4.95          |
|          | Horizontal                   | 2   | 17.49      | 0.4       | 0.2        | 2.8           |
|          | Mortar Required = 15% of total brickwork | | | | | 0.75 |
|          | 1st step Brickwork           |     |            |           |            |               |
|          | Vertical                     | 2   | 17.49      | 0.3       | 0.6        | 6.3           |
|          | Horizontal                   | 2   | 13.75      | 0.3       | 0.6        | 4.95          |
|          | Mortar Required = 15% of total brickwork | | | | | 1.7 |
|          | 2nd step Brickwork           |     |            |           |            |               |
|          | Vertical                     | 2   | 17.49      | 0.3       | 0.6        | 6.3           |
|          | Horizontal                   | 2   | 13.75      | 0.3       | 0.6        | 4.95          |
|          | Mortar Required = 15% of total brickwork | | | | | 1.7 |
| 3        | Brickwork                    |     |            |           |            |               |
|          | 9” wall                      | 5   | 39         | 0.23      | 3          | 134.55        |
|          | 4.5” wall                    | 5   | 15         | 0.12      | 3          | 27            |
|          | Mortar Required = 15% of total brickwork | | | | | 24.3 |
| 4        | Column                       | 10  | 0.3        | 0.23      | 15         | 10.35         |
| 5        | Beam                         | 5   | 53         | 0.25      | 0.3        | 19.875        |
| 6        | Slab                         | 5   | 10.67      | 8.5       | 0.15       | 68.02         |

Table 4. Material Consumption of RCC constructed building

| Material  | Total Quantity (m³) | Cement  | Sand     | Aggregate | Steel | Bricks |
|-----------|--------------------|---------|----------|-----------|-------|--------|
| Concrete  | 116                | 65656 kg| 1610 cft.| 3217 cft. | -     | -      |
| Mortar (1:4) | 26.75              | 12100 kg| 1160 cft.|          | -     | -      |
| Reinforcement | 2.87               | -       | -        | -         | 23200 kg | -      |
| Bricks    | 177.8              | -       | -        | -         | -     | 88900 unit |
Table 5. Measurement Sheet of GFRG constructed building

| Item No. | Description       | No. | Length (m) | Width (m) | Height (m) | Quantity (m$^3$) |
|---------|------------------|-----|------------|-----------|------------|-----------------|
| 1       | Wall Footing     |     |            |           |            |                 |
|         | PCC vertical     | 2   | 17.15      | 1         | 0.3        | 10.29           |
|         | Horizontal       | 2   | 12.34      | 1         | 0.3        | 7.40            |
|         | 1st step Brickwork |     |            |           |            |                 |
|         | Vertical         | 2   | 17.15      | 0.6       | 0.2        | 4.12            |
|         | Horizontal       | 2   | 12.34      | 0.6       | 0.2        | 2.96            |
|         | Mortar Required = 15% of total brickwork | | | | | 1.06 |
|         | 2nd step Brickwork |     |            |           |            |                 |
|         | Vertical         | 2   | 17.15      | 0.4       | 0.6        | 8.23            |
|         | Horizontal       | 2   | 12.34      | 0.4       | 0.6        | 5.92            |
|         | Mortar Required = 15% of total brickwork | | | | | 2.12 |
|         | Screed           | 5   | 10.36      | 8.2       | 0.05       | 21.24           |
|         | Infill cavity    | 40  | 0.23       | 0.094     | 15         | 13              |
|         | GFRG             |     |            |           |            |                 |
|         | Horizontal       | 2   | 17.15      | 0.124     | 15         | 514m$^2$        |
|         | vertical         | 2   | 12.34      | 0.124     | 15         | 370m$^2$        |
|         | Slab             | 5   | 10.36      | 8.2       | 0.124      | 425m$^2$        |

Table 6. Material Consumption of GFRG constructed building

| Material      | Total quantity (m$^3$) | Cement | Sand  | Aggregate | Steel (kg) | Bricks |
|---------------|------------------------|--------|-------|-----------|------------|--------|
| Concrete (M25)| 30.69                  | 17370 kg | 426 cft. | 815 cft. | -         | -      |
| Mortar (1:4)  | 3.18                   | 1438 kg  | 138 cft. | -         | -         | -      |
| Reinforcement | -                      | -      | -     | -         | (980+6800+3400) | - |
| Bricks        | 21.23                  | -      | -     | -         | -         | 10615 units |
| Screed (1:3)  | 21.24                  | 12005 kg  | 883 cft. | -         | -         | -      |
| GFRG          | 1309 m$^2$             |        |       |           |            |        |

Table 7. Cost of RCC building construction

| RCC Construction | Required amount | Rate per unit | Total cost (INR) |
|------------------|-----------------|---------------|-----------------|
| Cement (kg)      | 1,555           | 340 Rs per bag | 528740         |
| Aggregate (kg)   | 3,217           | 40/Cft.       | 128680         |
| Sand (kg)        | 2,770           | 45/Cft.       | 124650         |
| Reinforcement (kg)| 23,200        | 60rs/kg       | 1392000        |
| Bricks (Units)   | 88,900          | 8 Rs/brick    | 711200         |
| Labour and equipment (sqft) | 3,200 | 250 Rs/sqft | 800000 |
|                  |                 |               | **36,85,270/-** |
Table 8. Cost of GFRG building construction

| Material          | Required amount | Rate per unit | Total cost (INR) |
|-------------------|-----------------|---------------|------------------|
| Cement (kg)       | 616             | 340 Rs per bag| 209440           |
| Aggregate (kg)    | 815             | 40/CFt.       | 32600            |
| Sand (kg)         | 1447            | 45/CFt.       | 65115            |
| Reinforcement (kg)| 980+6800+3400   | 60 Rs/kg      | 670800           |
| Labour and equipment(sqft)| 3,200 | 100 Rs/sqft | 320000          |
| GFRG             | 1309            | 1200 Rs/sqm   | 1570800          |
|                   |                 |               | **28,68,755/-**  |

Table 3 and 5 show the measurement sheet for RCC and GFRG building, respectively. Similarly, Tables 4 and 6 show the material consumed in the construction process. The final cost of construction in accordance with the raw materials used in the study are shown in Table 7 and 8. It can be concluded that a conventional RCC building construction will cost Rupees **36,85,270** whereas GFRG building will cost us Rupees **28,68,755** making an average saving of around 20% -30 % depending upon the type of foundation adopted and location of the building.

5. Conclusions

From the comparative study between Conventional RCC construction and the GFRG construction, following conclusions have been drawn

- GFRG building outperforms RCC building in earthquake analysis as base shear generated can be up-to 20% less because GFRG unit weight is less than that of RCC.
- The cost analysis of GFRG building and RCC building conclude that the direct and indirect costs of up-to 20 -30% can be saved in comparison to RCC construction.
- It can also be concluded that GFRG building outperforms RCC building in Time-line analysis as erection of GFRG panel is faster as time and area undertaken for 7-14 days curing as well as shuttering is saved.

GFRG Housing solution for Economically weaker section would be a great alternative to RCC building keeping in mind safety, cost, environmental benefits, time taken to construct etc

Acknowledgements

This Research paper attempt would not have been possible without GFRG/Rapid Wall Building Structural Design and Guidelines from IIT Madras (Structural Engineering Division Department of Civil Engineering) and BMTPC (Building Materials & Technology Promotion Council Ministry of Housing & Urban Poverty Alleviation Government of India).

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