LOW COST HOUSING WITH GLASS FIBER REINFORCED GYPSUM PANELS

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ABSTRACT

Low Cost House is a unique concept relates with affordable costing and it deals in decreasing the construction cost with the use of materials available locally and improved technology without losing the structure's performance and the structure's life by adopting various techniques. There is big misunderstanding that housing with low cost is only for low class population and they are built by using building materials of cheap quality. The reality is that housing with Low cost is done by proper management of materials and resources. Reduction in the cost is achieved by improved design or by selection of effective materials. Research has found gypsum to be a durable material. Experts says that the life span of a building which made by using GFRG panels will be upto 60 years. A Building constructed with GFRG panels did not require RCC beams and columns. GFRC has advantage as it is light in weight and decreasing the total construction cost and achieving economy in construction. GFRC uses fibres of Glass for reinforcement instead of steel in concrete. The fibers cannot corrode like steel and also no need to provide a concrete cover to prevent corrosion. GFRG buildings uses very less quantities of cement, water, sand and steel as compared to normal RCC buildings. The overall objective of this project is to study the various techniques and different materials to construct a innovative, energy efficient, eco-friendly housing at affordable cost. The aim of study also includes architectural and structural designing of a house and cost comparison of GFRG panel structure with conventional structure.

Keywords: *Low cost housing, affordable housing, rapid, sustainable, energy efficient, innovative, GFRG, GFRG panel.*

1. INTRODUCTION:

Housing is the basic human needs along with education, food and clothing. Like other developing countries there is a vast increasing building materials requirement in our country due to shortage of Housing. As per National Building Organization's estimates, there is a deficiency of 24.7 million existing housing units {2007} mostly for the groups of low income in urban India. The total estimated housing shortage for Urban & rural areas of country in 2012 is 68.53 million units. The excess of housing is expected to cross to 41 million in some recent years. The picture is dismal at the economic ladder's lower end. The United Nations Human Settlement Programme recently takes a study which reveals that over 100 million of people are having no homes. The economic survey of India for 2012-17 indicates that in 2012, there were about 0.53 million homeless households in the country and the number has further grown in the upcoming period. The urbanization rate is very rapid from the survey of India 2011, as nearly 377.10 million people shifted from rural areas to urban areas in between 2001 and 2011. The population of people without home is increasing very fastly due to which they can't be fit in existing number of temporary shelter and so most of these people are enforced sleep on the footpaths. To overcome this problem Government of India has aimed to fulfill the basic needs of every citizen by providing a permanent shelter. This idea is implemented by the scheme, 'Pradhan Mantri Awas Yojana'.

Even for low income and middle income families, rates of land and costs of construction is increased due to rapid urbanization. This forces most of new middle income families to resolve to buying houses on the outskirts of towns where urban amenities are rarely available, if available at all or to live on rent within the city.

1.1 Existing Finance System for Housing in India

As compared to the European situation, the existing pattern of finance for housing in India represents an absolutely different picture. The growth of the finance in housing sector in our country in the form of an institutionalized and formal superstructure is of recent origin. Earlier to the starting up of the HUDCO (Housing and Urban Development Corporation) in 1970, as an financing company of government for the task of financing and undertaking urban development projects and housing by mostly focusing on Low Income groups and Economically Weaker Section, the organized institutional finance or housing was imaginary in the country.
The existing housing finance system, consists of two distinct components : the informal sector and the formal sector. The formal sector includes budgetary allocations of state and central Government, assistance from financial institutions like Life Insurance Corporation, National Housing Bank, General Insurance Corporation, commercial banks, Unit Trust of India, Housing Development Finance Corporation, provident funds.

1.2 Role of Governmental as Facilitator

Realizing the urgent need of increase of investment in housing sector, the National Housing Policy (1992) has predict that 20% of the need of investment in housing is to be met by institutions o specialized housing finance, banking sector and insurance, mutual fund, provident fund etc. Above all, Indira Awas Yojana, a fully subsidized rural housing programme, is presently being handled by the rural development ministry as part of rural development programme and the Jawahar Rozgar Yojana for supplying houses to freed bonded labour and SCs/STs.The government's participation in the housing sector will be the only way of removing legal and procedural constraints, increasing the credit from formal institutional sector and popularization of locally available building materials. Besides, expansion of basic infrastructure facilities to facilitate housing would lie with the government. Direct support from the government is to be restricted to improvement of slum areas in the urban areas and support both in cash and kind to the poorer segments. To achieve the above goal, the government's assistance will have to be increased from banks by a massive dose of assistance.

1.3 Problem Statement

Our country is having shortage of housing.

- Society needs safe, serviceable, durable and economical type of house.
- Nowadays the most research oriented field is the field of construction materials.
- Use of waste materials as construction material has been mostly adopted in field of fly ash, slag, gypsum, plastics etc.
- Irregularity in quality work and lack of skilled labour forced the construction industry to go for mechanization. In current time projects are dependent on time. Cost of labour and materials has gone high so, eco-friendly materials demand is increasing.
- There is a need to study the advancement in the technology which is in use worldwide, so that an inexpensive house can be constructed

1.4 Objectives

The overall objective is to study the various techniques and different construction materials to construct an innovative, energy efficient, eco-friendly housing at affordable cost for low income population.
The primary objectives of the ongoing study are to:

- To study different techniques and strategies to construct low cost housing.
- To design a building by in Reinforced Concrete Structure and Glass Fiber Reinforced Gypsum panels.

- To compare the construction cost of building constructed by Reinforced Concrete Structure and Glass Fiber Reinforced Gypsum panels.
- To compare the time of construction by using Glass Fiber Reinforced Gypsum (GFRG) panel with construction of RCC method.

2. MATERIAL AND METHODS

The research methodology is mainly divided into three parts; Theoretical aspect, Design aspect and Economic aspect. Firstly we discuss about the theoretical aspect. In this part we will mainly study about the Glass Fiber Reinforced Gypsum panels. Various literatures based on the low cost housing, GFRG panels are studied. In this part we have studied the different techniques of construction to reduce the cost of house. There are tremendous changes in technical advancement of housing from last few decades. Right from past centuries to the present century the changes in construction industry are also studied and detailed information about it is given here. After that we have studied about various properties of GFRG panels from various literatures. We have discussed detailed procedure of installation of GFRG panels. The construction process of house by using GFRG panels is described briefly in this part.

2.1 Various Techniques for Low Cost Housing

2.1.1 Foundation

The cost of foundation is generally about 10% to 15% of the total cost of building. So it is advisory to adopt arch type foundation in ordinary soil for reduction in construction cost up to 40%.

2.1.2 Wall Construction

2.1.2.1 Hollow Concrete Block

Hollow concrete blocks are as a replacement for stone and conventional bricks. They are easy to place, and light in weight than conventional bricks. The standard sizes of hollow bocks are 400 X 200 X 100 mm, 400 X 200 X 150 mm, 400 X 200 X 200 mm. The compressive strength of block is about 39 to 147 KN/m. Standard machines are used for casting of these blocks like hand held type block machine, stationary block machine, standing type block machine. Advantages of these blocks are good quality, less labour required, durable.

2.1.2.2 Aerated Concrete Block

Aerated autoclave concrete blocks was first developed between the year 1920-32 by a Swedish engineer. Aerated concrete is a light weight concrete which neglects the coarse aggregates and includes high percentage of void. A foaming agent is applied in the mix before the materials are poured in the moulds. Density is reduced to 500Kg/m^3. Advantages of these blocks are high wall area/block, low thermal conductivity, less moisture penetration, lighter than convectional concrete blocks.

2.1.3 Roof and Floor Construction

2.1.3.1 Filler Slab

A filler slab material may be a waste material, used to ensure advantage over RCC slab. It is simple and innovative technique for construction of roofing. Steel is best in tension and concrete in compression. Materials are placed in such a way that strength is not decreased, so removing undesirable concrete from below, so decreasing the material quantity and increasing the economy, cost saving, and decrease in dead load. Different types of materials are used as filler material like Mangalore tiles, coconut shells, etc. Advantages are less costly, increased thermal coefficient, reduced carbon emission by 20%, and better appealing, material recycled.

2.1.3.2 Flat Slab

Flat slab is a slab that directly supported on columns without any intermediate beams. For span of slab between 5 to 9 m thin flat slab is preferred, whereas slab having span more than 9 m post tensioning should be done. Advantages are easy formwork required, construction time is less, easy concreting.

2.2 Glass Fiber Reinforced Gypsum (GFRG) Panels

Glass fiber reinforced gypsum (GFRG) walls may also known as Rapid wall in the construction industry. This is new building material developed in Australia in 1990s. GFRG walls are panels which are machine-made with empty cores and are made of gypsum plaster and reinforced with the pieces of glass fibers. Glass fiber reinforced gypsum (GFRG) wall is one of the green product which can construct a structure rapidly by prefabricated method. GFRG walls may be used in low rise buildings as load-bearing walls and as walls in high-rise building by filling with concrete in the empty cores. The application of GFRG wall is restricted for its poor lateral stiffness even if it is filled with concrete in its empty cores. Finding new idea to enhance its lateral stiffness and to make it suitable for small high-rise residential buildings.

2.2.1 Characteristics of GFRG Panels

A typical cross-section of a GFRG panel is shown in Figure 1.The Glass fibers of about 300 to 350 mm in length are arbitrarily assigned inside the skin of panel and ribs during the process of manufacturing. The volume of fibre in panel is about 0.80 kg/square meter of surface area of wall. Some general properties of the standard GFRG panels are listed in Table 1.

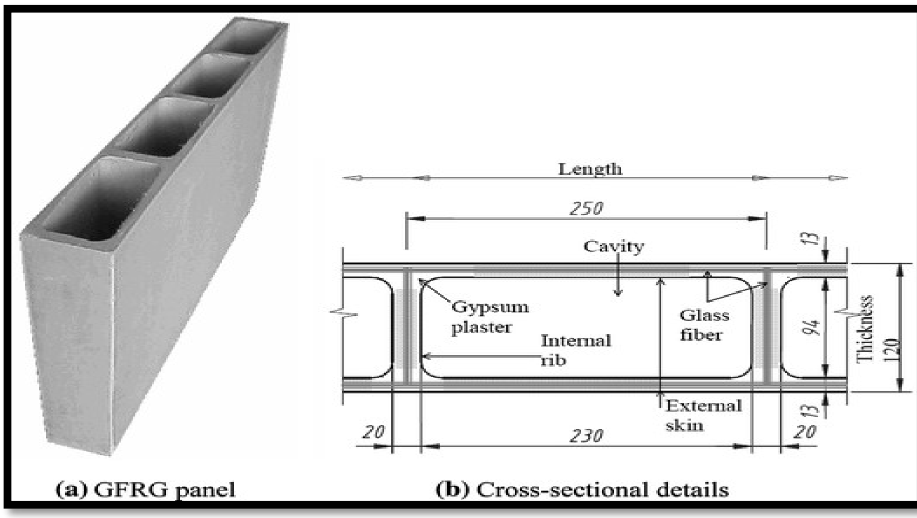

Figure 1. Cross-section of GFRG Panel

In building construction, the standard huge panels are cut in the factory into different components that may have window and door openings. These parts are then transported to the site of construction and erected at site by using cranes. The empty cores inside the panel are filled with various materials, such as concrete or insulation materials, to serve various purposes, such as to improve the thermal and sound insulation of the wallsor to increase the strength.

Table 1. Standard properties of GFRG Panels

Axial load capacity	16 Tons/m (160 KN/m)
Unit Shear strength	50.90 N/m^2
Compressive strength	73.2 Kg/cm^2
Tensile Strength	35 KN/m

Ductility	4
Flexural strength	21.25 Kg/cm^2
Thermal expansion coefficient	12×10-6mm/°C
Fire resistance	700-10000°C
Sound transmission (STC)	40
Thermal conductivity	0.617
Elastic Modulus (E)	3000-6000Mpa
Water absorption	< 5%

2.2.2 Construction Process using GFRG panels

GFRG panel system enables fast method of construction. Conventional building construction includes various activities and time consuming processes, like i) masonry wall construction, ii) casting of RCC slabs requiring cantering and scaffolding and curingiii) cement plastering requiring curing, iv) removal of cantering and scaffolding and v) plastering of ceilings and so on. It also contributes to environmental degradationand pollution due to debris remaining on the site. In contrast, GFRG panel construction is much easier and faster. There will be no waste left at site. Construction time is minimized to 15 to 20%. Instead of brick construction, panel construction enables wall by wall construction. GFRG panel wall does not require plastering as both surfaces are smooth and even and ready for application of special primer coat and finishing coat of paint.

2.2.2.1 Foundation Work

For Rapid wall Housing a standard foundation like spread footing, raft or pile foundation,RCC column footingis used as per the condition of soil and loading on it. RCC beams are provided at the plinth level all around the building. Vertical reinforcement of 12 mm dia. and 0.75m in length and of which 0.45m length extends up is provided for erection of panel as wall and remaining portion with 0.15m bend is placed into the RCC beams at plinth level before casting. These start up rods are placed at 1m centre to centre.

As per the plan of building, each wall panel is cut at the factory with mm precision using an automated cutting saw. Panels are loaded in the factory on trucks for transporting to the construction sites. The panels are placed on the construction site near to the foundation for erection using vehicle mounted crane or other type of crane. Lifting tools suitable to lift the panel are used by inserting into the empty cavities and sticked into webs, so that handling of panels will be safe. Panels are erected on the RCC beam of plinth level and concrete is filled from top.

Each panel is erected with plumb and level and supported by props to keep the panel in plumb, level and secure in position. After wall panels are erected, window and door frames are fixed in position using standard clamps with concrete filled in cavities on either side. Reinforcement for lintels and RCC chajjas is provided with shuttering and support and after that concreting is done.

2.2.2.2 Concrete Infilling

As per structural design vertical reinforcement is inserted and clamps are provided to keep wall corners in perfect position. Concrete of aggregate 12 mm in size will be filled from top into the empty cavities by using a small hose pipe to go down at least 1.5 m to 2 m into the empty cavities. For construction of small buildings, concrete can be poured manually using a funnel. Panels are filled in three layers each having 1 m height with a gap of 1 hour between each layer. Because of gravitational pressure inside the water tight cavitiesthere is no need to use vibrator.

Figure 2. Erection of GFRG Panel

2.2.2.3 Embedded RCC tie beam in roof slab

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

Figure 3. Embedded RCC tie beam

2.2.2.4 Construction of roof slab in combination with RCC

The ribs of GFRG panel are aligned in the direction of bending and designed as a one-way slab system, by reinforcing the cavities. GFRG-RC slab systems is used effectively in floor slabs and roof slabs. The ribs are oriented along the shorter span, supported on GFRG wall panels. RC concealed beams are provided by filling cavities at regular intervals generally, every third cavity or every alternate cavity and suitably reinforced, combined with a screed concrete of thickness not less than 50 mm, which provides a flanged-beam action.

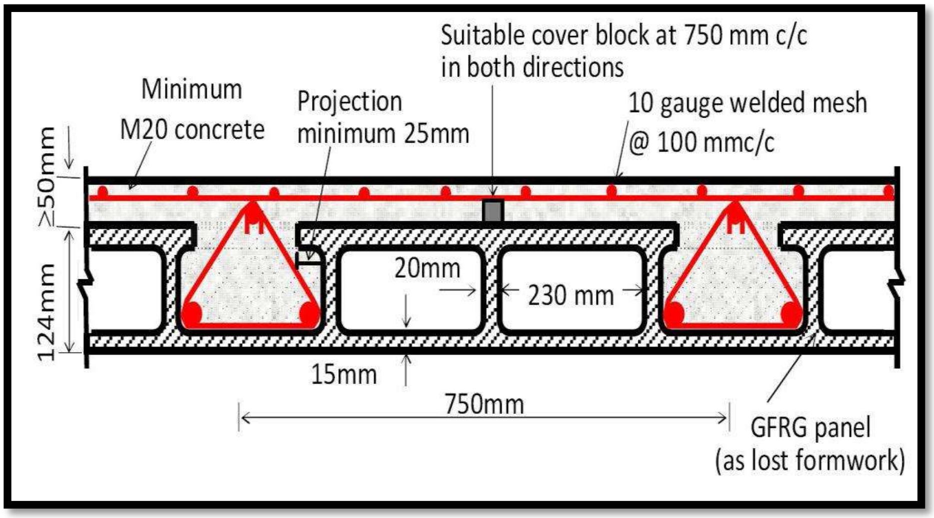

Figure 4. Cross section of GFRG-RC slab

Minimum 50-60 mm thickness screed concrete is to be provided for slab. For screed concrete reinforcement of suitable welded wire of required gauge and spacing is provided, so as to avoid thermal and shrinkage cracks. Cover blocks at 750 mm spacing in both directions are to be provided. Installation of slab panels are to be with suitable support system like acrospans with adjustable vertical props. The acrospans are laid perpendicular to the direction of ribs direction. The panels are then lifted horizontally means of by means of spreader bars attached with soft slings. Place the floor slab panels in position over the support system, with a minimum of 40 mm bearing on all supporting walls.

2.2.2.5 Erection of wall panel for upper floor

On next day, erection of GFRG panels for the next floor is to be arranged. Vertical reinforcement from floor below is provided with extra length so as to extend to 0.45 m to serve as start up bar and lap length for next floor.

2.2.2.6 Finishing Work

After the concreting of ground floor roof slab, After 4 to 5 days, wooden planks with supported props of ground floor are removed. By using wall putty or special plaster finishing of internal wall corners and ceiling corners can be done. Simultaneously, water supply,electrical work, sanitary work, floor tiling, staircase work etc can also be carried out. Every upper floor can be finished in the same way.

2.3 Design of GFRG Building

By load bearing systems GFRG buildings are designed. So that all the walls are to be started from the foundation or plinth beam upto the terrace. Design of GFRG building can be done upto 10 storey in low seismic zones. In this system the foundation is constructed as per standard RCC design and other structural elements are constructed using GFRG panels. Limit states design procedures are used for the design of GFRG buildings, considering the ultimate limit state for strength design, as well as serviceability requirements. The partial safety factors for reinforcing steel and the GFRG panel (with and without concrete infill) is taken as $\gamma s = 1.15$ and $\gamma m = 1.50$ respectively, as recommended in IS 456: 2000

2.3.1 Design of foundation GFRG Building

The foundation is designed base on the safe bearing capacity of soil and soil profile at the particular site and the number of storeys of the structure. Generally, strip footing is used, as the superstructure consists of load bearing walls. Starter bars are inserted in the plinth beam and above which GFRG panel are erected. This ensures connection of superstructure of building with the substructure foundation. A network of RC plinth beams has to be constructed as per the structural design drawings and the top has to be at a perfectly horizontal level.

2.3.2 Design of GFRG Walls

The GFRG walls are designed to in-plane bending moment, Shear force and gravity loads. The capacity of bending of walls mainly depends on length of wall, provided reinforcement as well as lateral shear and axial force. Design curves are developed for various length of GFRG panels from1.0 m - 3.5m wide panels, reinforced with M20 concrete and 2 reinforcement bars in each cavity. A typical design P-M interaction curve for 2.0 m length panel is given in fig. 5

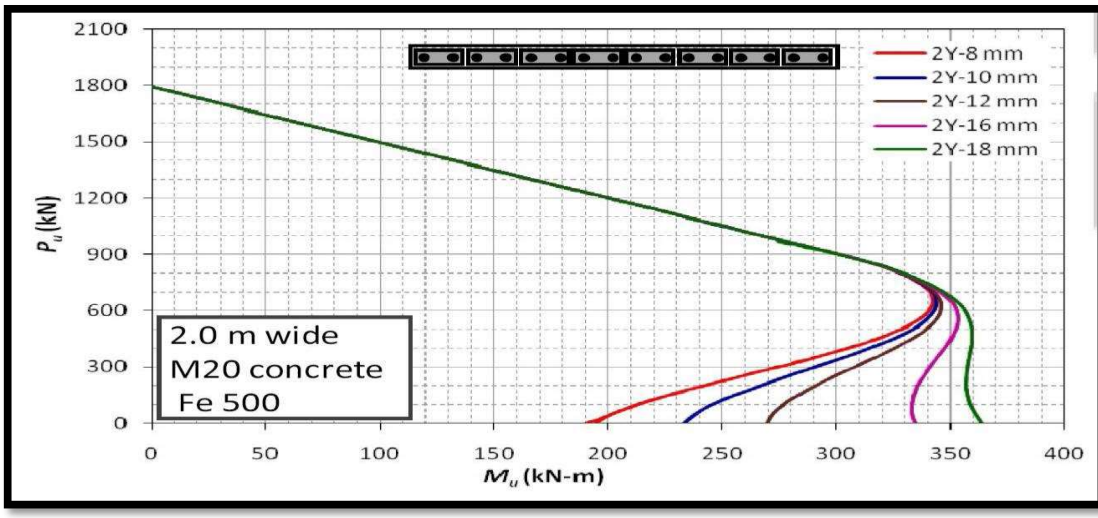

Figure 5. Design P_{ud} - M_{ud} plots for 2.0 m wide GFRG panel

Depending on the structural design and the design curves, the interval of concrete infilling and size of reinforcement to be provided in walls are decided. The empty cavities in the GFRG wall panels shall be filled with concrete of grade not less than M20 where structurally required, using aggregate of size less than 12 mm. For low rise GFRG buildings up to 3 storey, no need structural requirement to fill all cavities with reinforced concrete, although it is desirable to fill all cavities with plain concrete or quarry dust with cement, in view of public perception of safety against intrusion, and also facilitate nailing, drilling, fastening of non-structural components etc. Reinforcing bars may be provided where required, but in no case, more than 3 adjoining cavities shall remain unreinforced.

3. RESULTS AND ANALYSIS

3.1 Design Aspect

The modular Row housing unit of 9 houses in a row is designed in such a way that they have a common central wall in between. Each house is consists of 2 bedrooms, kitchen and hall by following the government rules for size and margins. The main aspect of architectural design is to provide most pleasant development while maintaining the low cost of construction. For optimizing the cost and delivering the low cost housing these units can be constructed on large scales. This design is prepared by taking in mind to fulfill all the requirements of a family with minimum cost of housing.

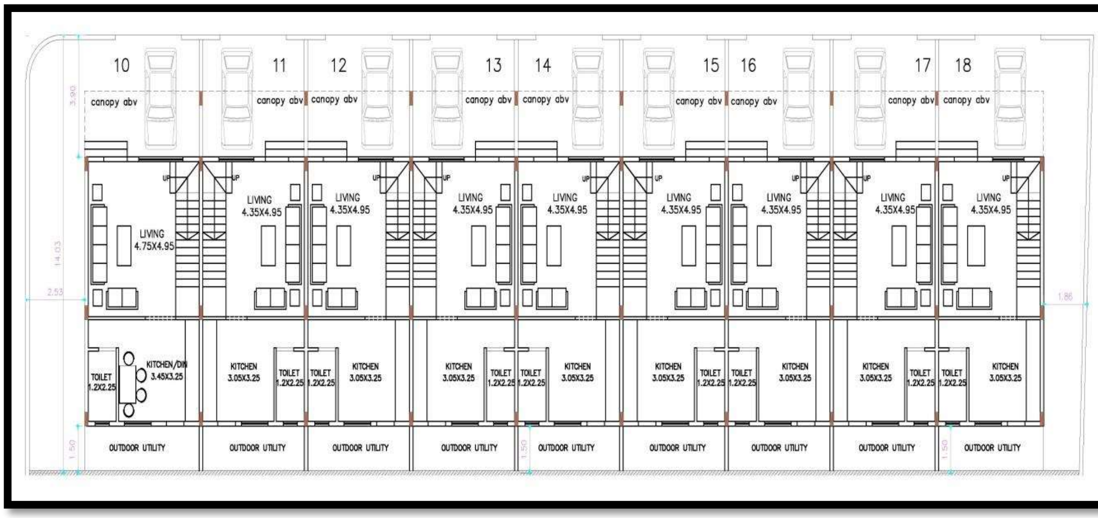

Figure 6. Ground Floor Plan

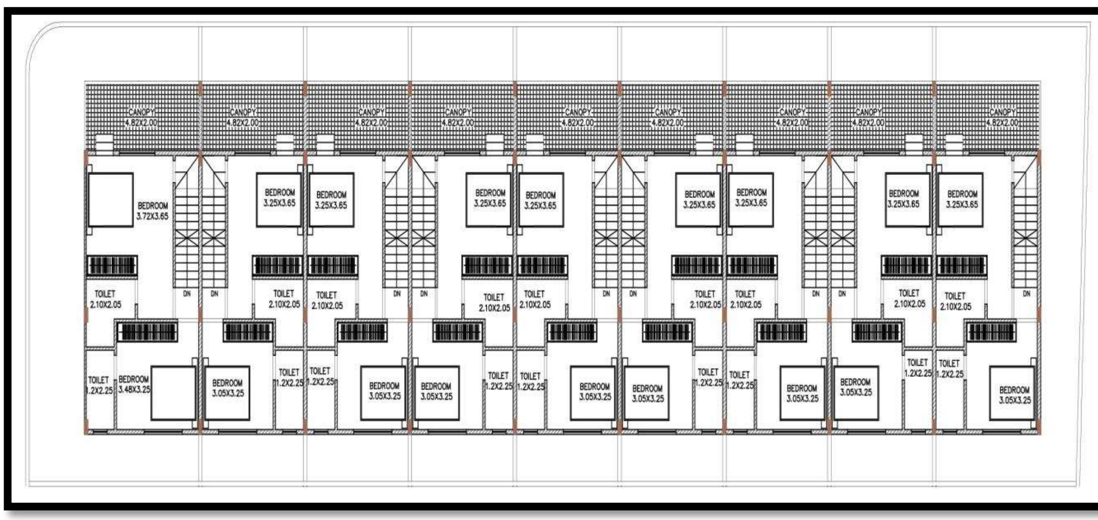

Figure 7. Ground Floor Plan

3.2 Economical Aspect

Various activities are included in the construction of conventional RCC housing unit. For the above building plan detailed estimate of all the activities is prepared with the current market rates of particular region. The carpet area of 1 house is 760.00 square feet. For construction of 1 house by RCC method costs about 8,36,000.00 to 9,88,000.00 Rupees. So the cost of construction with RCC structure is about 1100 Rs. To 1300 Rs./square feet. This cost is very high for low income groups.

4. CONCLUSIONS

GFRG panels can be effectively used for the construction of all building units like walls, staircases, slabs, parapets etc. The GFRG panel system have many advantages over conventional system. This system have potential to overcome the challenge of providing mass affordable housing. The key advantages sustainability, rapidity and affordability have generated interest in this technology. Buildings upto four storeys with such material are now being constructed across

the country. The use light weight GFRG panels reduces the self weight of building, which makes them appropriate material to be use in seismic zone.
The GFRG system reduces the use of bricks and concrete mostly from building construction. GFRG is an ecofriendly building material, making use of recycled industrial waste gypsum or natural gypsum and reduces the use of cement, sand, steel, water and labour. This technology is now gaining interest in India.

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