SEISMIC ANALYSIS OF A MULTI-STOREY BUILDING USING STEEL BRACED FRAMES

A Thesis Submitted
in Partial Fulfillment of the Requirements
for the Degree of

MASTER OF TECHNOLOGY

In

Structural Engineering

By

Siddhant Singhal
(University Roll No. 1170444014)

Under the Guidance of

Mr. Bilal Siddiqui
(Assistant Professor)

BABU BANARASI DAS UNIVERSITY
LUCKNOW

2018-19

COMPARATIVE STUDY BETWEEN RCC STRUCTURES AND PREFABRICATED STRUCTURES

A Thesis submitted
In partial fulfilment of the requirement
For the degree of

MASTER OF TECHNOLOGY

in

Structural Engineering

By

Siddhant Singhal
(University No. 1170444014)

Under the guidance of

Mr. Bilal Siddiqui
(Assistant Professor)

BABU BANARASI DAS UNIVERSITY

LUCKNOW

2018 - 2019

CERTIFICATE

Certified that **SIDDHANT SINGHAL** (1170444014) has carried out the research work presented in this Thesis entitled **"COMPARATIVE STUDY BETWEEN RCC STRUCTURES AND PREFABRICATED STRUCTURES"** for the award of **MASTER OF TECHNOLOGY (Structural Engineering)** from BABU BANARASI DAS UNIVERSITY, LUCKNOW under my supervision. The Thesis embodies results of original work, and studies are carried out by the student himself and the contents of the Thesis do not form the basis for the award of any other degree to the candidate or to anybody else from this or any other University/Institution.

(Signature)	(Signature)
Mr. BILAL SIDDIQUI	**Mr. ANUPAM MEHROTRA**
(Assistant Professor)	(Head OF Department)
Department of Civil Engineering	Department of Civil Engineering
BBDU Lucknow	BBDU Lucknow

Date -

DECLARATION

I hereby declare that the Thesis entitled **"COMPARATIVE STUDY BETWEEN RCC STRUCTURES AND PREFABRICATED STRUCTURES"** in the partial fulfillment of the requirements for the award of the degree of Master of Technology (Structural Engineering) of **BABU BANARASI DAS UNIVERSITY**, is record of the own work carried under the supervision and guidance of **Mr. BILAL SIDDIQUI** to the best of my knowledge this Thesis has not been submitted to **BABU BANARASI DAS UNIVERSITY** or any other University or Institute for the award of any degree.

(Signature)

Siddhant Singhal

Roll No. 1170444014

Structural Engineering

Dept. of Civil Engineering

BBDU, Lucknow

ABSTRACT

Precast concrete is a well-known technology in which some standardized units, which are manufactured in factories, are used for fast construction. However, the technology was developed many years ago but the implementation is not up the mark in our country. In this study, we will carry out detailed study of various concepts of precast; go through number of literature and methods associated with it. We will take one building as a case & Design the same building as a precast building & Traditional Cast in-situ building. Here we will make cost analysis as well as feasibility check on basis of costing & Duration.

For study that is more practical, we will make models for each type of construction technology considered for comparison for the same building plan. From the earlier studies, it is estimated that the performance of the building would greatly improve in terms of cost reduction, duration of construction, quality and performance of the building. Technology of the prefabrication was developed many years ago but the execution is not up the mark in our country. From the literature review we can conclude that the precast concrete system is economical than conventional cast in place method but still there are some conditions which we have to take care of while using precast, those are quantity of construction, Distance of site from manufacturing unit, Type of building etc.

Precast concrete systems represent an efficient alternative for building construction. The behaviour of a precast system depends on connections and it should be modelled properly in the computational models for analysis and design. This study presents the modelling of connections in a wall type precast building system. A case study on a 4-storey building, made up of precast wall panels and slabs, to study the modelling of vertical joints in terms of shear transfer, would be presented in the thesis. Two computational models were investigated to find the effect of modelling the vertical joints between the wall panels, on the drifts and the generated forces in the walls. The provisions of tie reinforcements, reinforced shear keys and dowel bars provide the required structural integrity for the precast system to avoid progressive collapse.

The objective of this thesis is to complete the first task of the research project discussed above. There are two specific objectives:

(1) To study current modular construction practices to identify advantages, disadvantages, and key differences from conventional construction practices.

(2) To identify opportunities to advance the technology and methodology of modular construction.

Building cost in India is increasing at around 50% over the average inflation levels. It have registered amplification of up to 15 % every year, mostly due to cost of basic building materials such as steel, cement, bricks, timber and other inputs as well as cost of labor. Consequently, the cost of construction using conventional building materials and construction is becoming further away than the affordable limits particularly for low-income groups of population as well as a large division of the middle – income groups. Hence, there is an urgent need to adopt cost-effective construction methods either by up-gradation of traditional technologies using local resources or applying modern construction materials and techniques with efficient inputs leading to cost-effective solutions. This has become the most relevant aspect in the context of the large volume of housing needed in both rural and urban areas and the consideration of limitations in the availability of resources such as building materials and finance. Each state in India is currently investigating the developments in the prefabricated system and its potential to overcome the shortages of housing accommodation in this country. The Indian government, involved through its agency, the Building Materials and technology promotion council (BMTPC) and National Urban Housing and Habitat Policy (NUHHP) has been persistently pushing the construction industry to utilize the prefab method of construction since the year 2016. It is a part of an incorporated venture to further improving the aptitude, potential, efficiency and competitiveness of the industry as well as to diminish the industry's dependence on natural resources and unskilled labour. It is an attempt by the Indian construction industry to encourage positive inroads in matters related to construction-site safety concerning a working environment that is cleaner, more convenient and more organized. This thesis makes an overview of the housing status in India and adoption of suitable and cost effective technologies in the country.

Being a civil engineer it is our priority to provide cost effective solutions to our clients. With the escalating prices, the houses are becoming unaffordable with the current technology and hence we needed to explore another types of construction systems to reduce the cost of construction. This work is an attempt made to give an idea as to how can we reduce the construction cost as well as reduce the construction time using the prefabrication technology. This thesis compiles and retrospect the developments in the field of prefabricated building systems using GFRG construction technology also known as Rapidwall© construction technology in India. Glass fibre reinforced gypsum panels, manufactured in standardized parts are sections prepared for rapid erection of buildings, as they are ready-made gypsum structural panels with hollow cavities. This Rapidwall is employed in residential as well as commercial constructed establishments. GFRG walls can be used both for esthetical as well as structural component as walls and slabs, with no external columns and beams needed. It has currently found great utilization, even without exercising complicated codes of structural design, largely for the reason that they are environmental friendly. For the cost comparison, the fundamental materials considered were three types of building construction method such as low cost building using prefabrication technology as GFRG wall panel system and Conventional building construction systems like SMRF structure and Load bearing wall structure.

ACKNOWLEDGEMENT

I wish to express my sincere thanks to all those who have contributed to the completion of my PG research. I sincerely thank my Guide Assistant Professor Bilal Siddiqui for providing guidance and encouraging me towards the completion of this Endeavour. His mentoring and counselling have helped me in improving various areas of my academic life. He extended valuable support through tough times. I owe a deep debt of gratitude towards my guide for his constant support and encouragement.

I would also like to thank the supporting teachers at dept. of civil engineering, Babu Banarasi Das University. I am grateful to all of my friends from the Post Graduate for providing moral support during this tenure. I would like to extend my regards to all the evaluators and contractors, who selflessly helped me in obtaining the data correctly and paved the way to the results.

Finally, I would like to thank my family, as I am very much indebted to my family for their patience, love, support and encouragement. I would not have reached this stage without their support.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Chapter 1

Introduction

This chapter initiates the thesis and presents the general idea of the research that has been undertaken. It provides a background to the research topic, which is comparative study between RCC structures and prefabricated structures. It discusses about the current challenges and opportunities of the conventional construction industry in India. It also particulars the research problem, aim, objectives and the need for research. The chapter provides the evidence to support the need of wide usage of prefabricated structures in India.

1.1. BACKGROUND TO THE RESEARCH

Previously Roman builders utilized concrete for building of culverts, tunnels etc. Now a day's pre-cast technology include a variety of architectural and structural applications, which can be used in various element of building. The process was invented by city engineer John Alexander Brodie, Actually idea was not taken up broadly in Britain Yet, it was adopted all over the world, The Precast Concrete industry focuses on utility, underground, and other non-pre-stressed products, and is represented primarily by the National Precast Concrete Association. In this study, we have gone through precast structural conception, structure suitability, achievability, & cost & time analysis of precast structure. We have also made comparison of both precast & Traditional cast in situ construction method based on selected papers. The detailed design of precast & RCC building were prepared & costing of both were compared.

In India, RCC Structures are used for Residential as well as commercial Buildings but at a very small scale. Post-tensioned Pre-stressed beams are rarely used for the same Buildings, or we can say for short Span Buildings. Two Decade ago there was a big problem of Skilled Workers for Pre-Stressing work. But now there are so many agencies for execution of the same work. In RCC Beams, depth of beam increases with increase in Span, because of deflection limitation. Depth of beam can be reduced in Pre-stressed section, for longer span pre-stressed beams are cheaper.

1.2. PRECAST SYSTEMS:

Depending on the nature of members used, the precast systems can be classified into bearing wall system, ordinary moment resisting frame system and hybrid dual system. In wall system, the construction is mainly composed of structural walls, which transmit the vertical and horizontal forces to the foundation. The transfer of flexural capacity requires continuity of vertical reinforcement through the height of the wall and it can be provided with coupling of bars or vertical post– tensioning. Ordinary moment resisting frame system includes beams and columns in which the links are either equivalent monolithic or jointed. Hybrid Dual system is a combination of shear walls and OMRF to counter the lateral loads. The strength for the structure is supplied by shear walls/cores.

Connections are the vital part in precast structures. The major challenge in designing precast systems is to find an cost-effective and practical method to connect the members with adequate strength and ductility for the seismic loading. The behavior of the structure mostly depends on the behavior of connections. FIB Bulletin 27 (2003) largely classifies precast links into two categories as “equivalent monolithic (emulative)” connections and “jointed” connections. This classification is based on the nature of connections between the members. In equivalent monolithic systems, the connections between the members are designed to emulate the behavior of cast-in-place concrete construction.

The protruding longitudinal reinforcing bars from the members are spliced, welded or mechanically connected and then concrete is cast in the joint region. This is also termed as a wet connection. As in any other system, seismic considerations are crucial in precast buildings. Precast concrete can be used successfully in structures designed for earthquake resistance, provided careful attention is given to conceptual and detailed design, and to fabrication and erection. The seismic performance of a structure is mainly related to its lateral strength, stiffness, ductility and unity of the components.

The structural behavior of a precast concrete system is greatly different from that of a comparable monolithic cast-in place system. The main structural differentiation among cast-in-place buildings and precast buildings holds in their structural continuity. The structural continuity of conservative cast-in-place buildings is inbuilt while in the precast systems, members should be accumulated and associated to produce a structural system capable of resisting gravity loads and the lateral forces due to wind or seismic loads. The design and detailing of the connections are especially important to the performance and integrity of the precast structural system.

Low rise buildings were generally selected in India as common option but now a days in India population is rapidly increasing and due to that the requirement of construction of medium and high rise buildings is also increasing. Reinforced concrete members are mostly used in framing system because this system is most convenient and economical for low rise buildings. But for medium and high rise buildings this type of structures are no longer economical because of hazardous form work, less stiffness, span restriction, and increased dead load. Composite structure can be suitable in that case. Composite construction is having wide range of scope. It is very crucial to select appropriate type of building as per necessity of owner as well as building site.

As compared to other developing countries, the use of steel for construction purpose is very less in India. Steel structural members are prone to local and lateral buckling. Concrete structural members are generally thick and less likely to buckle but they are subjected to creep and shrinkage with time. Steel is more ductile material and so it can absorb more shocks and impact loadings. Thus composite structure is built to take the advantage of both of the materials. It is shown that the performance of building during an earthquake depends upon several factors like stiffness, ductility, lateral strength and simple and regular configuration. So to come on a final decision of comparison all three types of buildings should be compared by displacement, base shear, storey drift and lateral force.

CONVENTIONAL CONSTRUCTION SYSTEMS

Some of the prevalent construction systems in India are:

1.2.1. **Load bearing Structure**: In this system, walls are constructed using bricks/stone/block masonry and floor/roof slabs are of RCC/stone/composite or truss. It is cast in-situ system and called load bearing system as load of structure is transferred to foundation and then to ground through walls.

1.2.2. **RCC Framed Structure**: In this cast in-situ system, the skeleton of a structure is of RCC column and beam with RCC slab. The infill walls can be of bricks/blocks/stone /panels. The load of the structure is transferred through beam and column to the foundation.

1.2.3. **Steel framed Structure**: Here RCC beam and columns are replaced by hot rolled steel sections.

1.3. SCOPE OF RESEARCH

Modular construction methods can be widely investigated for a wide variety of construction types, including:

(1) Bridge, (2) Industrial,

(3) Light industrial/commercial, (4) Prison,

(5) Residential (6) Ship

and from a variety of perspectives, including:

(1) Fabricator, (2) Project manager,

(3) Architect, (4) Structural engineer,

(5) Engineer, (6) Erector

(7) Manufacturer

Modular construction includes methods in which materials and/or prefabricated components are joined together offsite or onsite before being installed to their Final position. The three levels of "special construction methods", which include:

(1) Prefabrication: A manufacturing process, generally taking place at a specialized facility, in which various materials are joined to form a component part of the final installation.

(2) Preassembly: a process by which various materials, prefabricated components, and/or equipment are joined together at a location away from the final point of assembly for subsequent installation.

(3) Module: a product resulting from a series of offsite assembly operations; it is usually the largest transportable unit or component of a facility.

This research investigates the three modular construction methods, but focuses more specifically on:

(1) Offsite prefabrication

(2) Onsite preassembly, which involves assembling components onsite at ground level and then erecting them into their final position, and

(3) Modularization, which involves the construction of complete 3-dimensional large-scaled modules that are fabricated and assembled offsite, transported to the construction site, and erected into their final position with minimal fabrication and assembly work onsite.

1.4. RESEARCH PROBLEM STATEMENT

Following are some of the reason that provoked my interest this topic for my thesis work –

1. To check its Suitability to Indian climatic and hazard conditions.
2. Cost effectiveness of the emerging technologies in comparison with conventional construction system (RCC and masonry construction)
3. To reduce the dependency on cement, aggregates and water in constructions. In particular, the fine aggregate (sand) and water.
4. To standardized the construction process on manufacturing line to improve the quality of construction due to the shortage of skilled labor.

5. To check Structural stability.
6. To analyze Material specification and its durability
7. To analyze Joints and connections specially for prefabricated system
8. Speed of construction and quality
9. Scale of minimum number of houses
10. Compatibility and adherence of the system to established standards
11. In addition, traditional construction cannot be green buildings normally. But green buildings are the order of the day, in view of energy scarcity and, fast depletion of precious natural materials.

1.5. RESEARCH AIM AND OBJECTIVES

1.5.1. Aim

This research aims to develop an understanding for usage of prefabricated building system in the Indian subcontinent with being environmental friendly hand in hand reducing construction carbon footprints.

1.5.2. Objectives

The above aim can be reached through following objectives:

1. To understand and document the prefabrication building paradigm and influencing cause through literature review;

2. To explore the drivers and barriers towards the adoption of prefabricated construction in India and document existing practices in our country;

3. To conceptualize a building framework to assess the maturity level and awareness of construction organizations for adopting prefabrication practices in India;

4. To test and authenticate proposed panel system in construction organizations in India;

5. To display findings, reach a conclusion and suggest recommendations.

The growth of Indian construction is going to turn out to be a fast to fulfill (meet) the need of upcoming generation, time efficient and achieving advance method. The project work based on time evaluation of precast concrete vs. cast-in-place (i.e. traditional) concrete. How the total time of building construction by precast concrete system is less than the time by use of conventional system. Time of any construction system directly varies with cost of construction. The time essential for steel binding, shuttering, concreting then after time required for curing will be minimize (7 days). The Precast is manufactured in factory floor (i.e. in controlled environment) with required quality, easily mix, and cured until good quantity is achieved with desired strength. Precast concrete is manufactured in plant and transported to site.

The strength of precast concrete is achieved on greater extent by using better technology and controlled system. For precast construction less labor is required, as labors are required only to joint precast members. That way time required for excavation, PCC, bar binding, shuttering and de-shuttering is abolished. Precast members are cured in factory until desired strength is achieved so no need to cure on site, result into saving in time of curing. There gives the time (in days) is saving in construction site. Precast construction system enhanced the quality of work, saves time, and reduces the cost of construction required for maintenance of work. The time for shuttering and de-shuttering is eliminated by using precast, which will result into saving total time of construction. The time of rework due to improper work, faulty construction method, unskilled labor, material quality, onsite environmental problem can also be eliminated by using precast members.

The idea of precast (also known as “prefabricated”) construction includes those buildings where the majority of structural works are standardized and formed in plants in a location away from the construction, and then transported to the site for assemblage. These components are manufactured by industrial methods based on mass fabrication in order to build a large number of houses in a short time at low cost.

This type of construction requires a reformation of the entire conventional construction process to enable interaction among the design phase and production planning in order to advance and speed up the construction. One of the main premises for achieving that purpose is to design buildings with a regular arrangement in plan and elevation.

In general, precast construction systems are more economical when compared to usual multifamily housing construction (apartment buildings) in many countries.

- Analyze the rate of switching from cast in place to precast concrete. This will include:
    - Immediate actual cost of both systems
    - Long term cost of both systems
    - Construction cost of each system
    - Equipment used
    - Material used
    - Machinery needed
    - Storage Area cost
    - Labor cost
    - Transportation Cost of both systems
    - Analyze Structural Load.
    - Analyze Mechanical Load.
    - Compare Duration impacts of both systems on the project schedule. The Factors included:
        - Labor differences
        - Placing time (installation)
        - Efficiency of workers
    - Analyze other factors such as safety concerns, logistics and sequencing of both systems

1.6. STRUCTURE OF THE THESIS

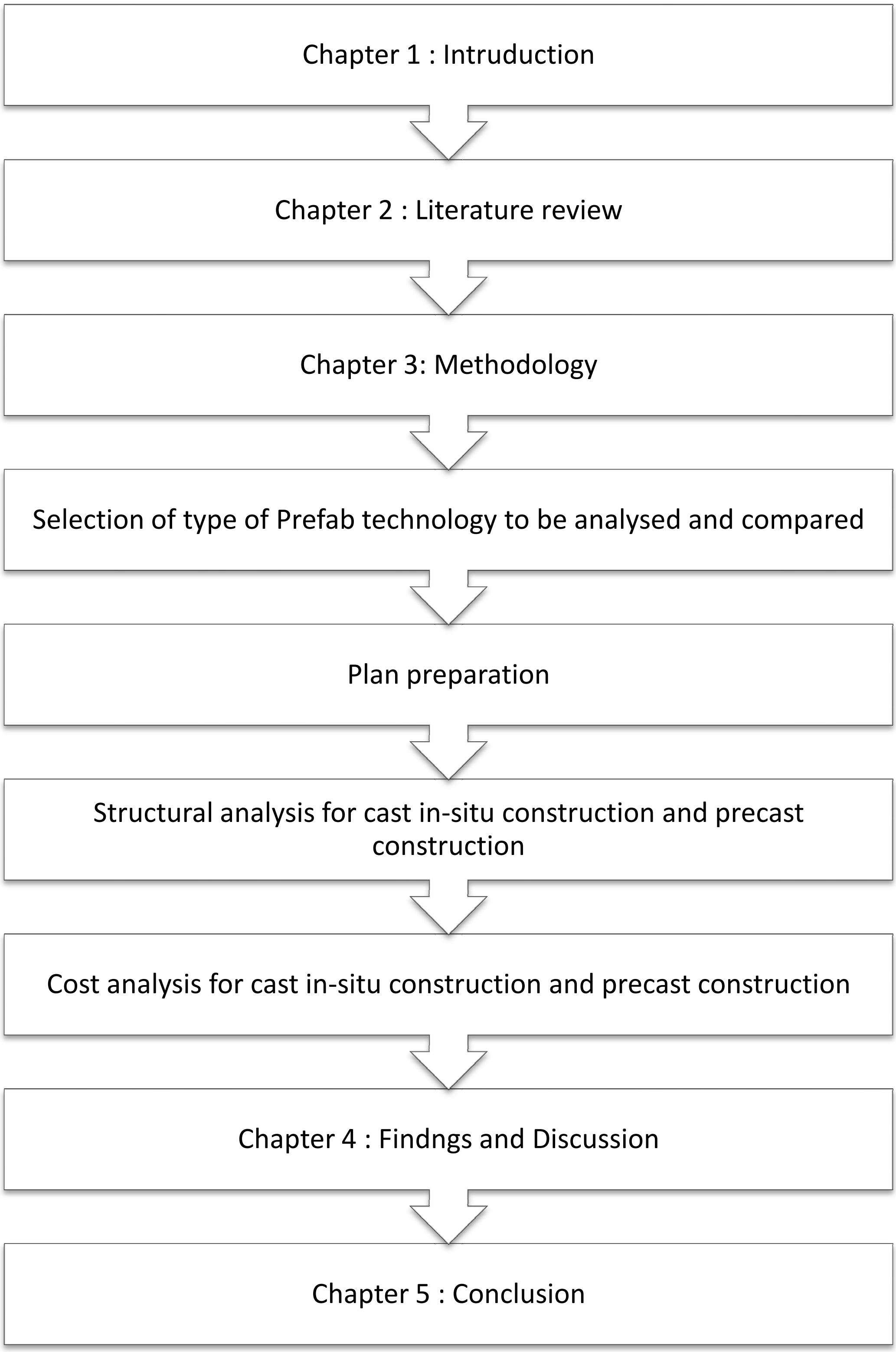


Fig 1 – Structure to the thesis

Chapter 2

Literature Review

A study of literature and a survey of industry is conducted. The literature study includes the review of technical magazines, journals, and reports, and books. The survey of industry would mostly revolve around residential and a little around commercial construction. Examples of modular construction projects and general modular construction practices are identified from the literature review. The papers that were reviewed will range from Indian Universities and local authors to foreign universities and foreign authors and architects.

This chapter presents an understanding of Prefabricated structures and the different expressions from the existing literature. The first part documents the relevant literature on Prefab, the terminology, the various practices appropriate for Indian subcontinent and development strategies. The chapter portrays the larger picture of the application of prefabrication techniques across the globe, and attempts to identify the similarities that can be inked with respect to the current research area, India. In detail, it provides a discussion of the major types of prefabrication, the various methods involved, the benefits, the influencing factors, the drivers and barriers towards prefab adoption and the critical success factors of panel system.

The second part covers the literature review in regards to the definition of prefabrication, and the various building models in the construction industry, their processes and methods. Comparison of both modular and conventional construction methods was done to identify the key differences.

2.1 BACKGROUND

Going through the earlier works and papers published the conclusion driven from the referred papers are as follows:

[1] Radhakrishna G. Pillai - India and most other developing countries are witnessing significant Urbanization-Migration. Because of this, most of the developing countries are facing huge housing shortage. Cast-In-Site (CIC) construction is not adequate to meet the current and future housing demands. Precast Concrete Construction (PCC) is a feasible technology that can be adopted to provide affordable mass housing and reduce the housing shortage. It was found that various stakeholders have different opinions and there exist no consensus among them on the factors hindering the growth of PCC in India.

[2] Bindurani. P - The emulative monolithic wall system seems to be adequate in moderate seismic zones. The provisions of tie reinforcements, reinforced shear keys and dowel bars provide the required structural integrity for the precast system. The modeling of vertical joints without considering the shear transfer through the shear keys, reinforced with shear links, lead to a conservative design. Non-linear shear springs can be incorporated in the model to get more realistic wall forces. This will lead to a more economical design.

[3] Bhavin H. Zaveri - Following factors should be considered to decide structural suitability.

i. Seismic performance of the structure
ii. Deformations
iii. Resultant Forces and Moments
iv. Cost
v. Weight
vi. Fire performance

[4] U. D. Dabhade – The study shows that the time savings of 55.3% is achieved due to use of steel framed composite floor construction rather than precast framed with precast concrete floor and 14.3% time than that of steel framed with precast concrete slab. The construction of steel framed composite floor building saves time, which leads to an overall savings in net cost.

[5] Krish R. Villaitramani - An effort has been made to show that the prefabricated housing innovation system provides a useful organizing tool to enhance the standard of living of slum dwellers. Prefabrication has the capability to make a difference within the Indian construction industry in economic, social and environmental terms. It is essential that the potential benefits of this innovation are yielded so that required development can take place.

[6] A.R. Santhakumar - Every effort is being taken up to reduce the cost of construction in India (especially for the major housing schemes envisaged in the Fourth Five Year Plan) by the Government and non-Govemment organizations. The work of National Building Organization in promoting the Experimental Housing Schemes for effecting economy in building construction and the efforts taken by the Indian Standards Institution in bringing out the National Building Code to rationalize the methods adopted have been briefly explained.

[7] Prasad Bhamare - As we have seen various methods of precast, Design, case studies of precast & it is found that, the design comes out as economical if proper care while designing is taken. We have design the same building by traditional & precast method & Notice the Cost & completion duration It is remarkably seen that the cost of precast building is significantly reduces & duration of construction is also much lesser than traditional method. Type of building etc. we have identified that for standard & Repetitive work precast is the best option to choose. In observation the most important thing is to be observed project is in precast construction technique is the time effective it require less time to construct.

[8] A. K. Jain - There is an array of technology options available for various elements of building construction, leading to cost-effectiveness and at the same time not affecting the performance characteristics expected from a decent house. It is desirable to have increased understanding of the various materials and technology options, its structural and functional characteristics and efficiencies and more importantly the methodologies for implementation. Series of follow-up measures to enable application of the same would need to be taken. These would cover work related to regulatory measures, organizational development needs and also technology transfer mechanisms evolved.

[9] A.Sattainathan Sharma – In present Indian construction sector, there are very less cold-formed trapezoidal profiled steel deck manufacturers. Obviously due to less competition, material rates are much higher. But from present status and already announced investment, future of Indian steel production industry is very bright for cold-formed steel deck sections. So in near future definitely, steel prices will be reduced and steel framed composite floor construction will become competitive in Indian construction sector.

[10] P. Rathna Priya – The Stiffness of the composite structure is found greater when compared with RCC structure. Presents work shows that by using Concrete Filled Steel Tublar (CFST) column in design of tall buildings provides good results when compared to R.C.C and conventional steel building and also economically serve as a better solution for tall buildings.

[11] N.Dineshkumar – The prefab construction for individual double storey residential building cost is 13% more than the conventional construction. This is main drawback for prefab construction which is not economical to construct in this case. At the same time the prefab construction is easy to work and reduces the project duration, is reduced by 63 days when compared to the conventional. It's the main advantages for prefab construction and also it helps when there is labour shortage. As a result of survey we had known that the prefab construction have more advantages and procurement in industrialized, heavy infrastructures.

[12] Md Azree Othuman Mydin - The prefab system proved to be a success. Not only it was efficient in accelerating the construction of housing projects, but it also improved the quality and affordability of the projects in which the IBS was deployed. Based on different reference materials accepted by authorities in the construction fraternity, we have several ways of defining the prefab system. Despite the prefab system being well-known and accepted by most construction firms due to its theoretical advantage in terms of speed, safety and quality, wet construction method is still widely regarded in Malaysia as a conventional and safe option regardless of incurring higher costs and slower production rates.

[13] Fred Edmond Boafo – The building industry is refabricating architecture through prefabrication. Similar to the automobile, shipbuilding, and aerospace industries, the construction industry aims to deliver an integrated prefab architecture that meets design requirements according to budget, quality specifications, as well as being on time. Using a case study based methodology, this study was designed to review the classification and actual performance of assorted prefabricated architecture. The earliest prefabricated buildings date back to the early seventeenth century, when houses were fabricated in England and shipped abroad

[14] Ryan E. Smith – Prefabrication technology has not transferred as easily when compared with other technologies because it is a production technology or knowledge based and not a consumption technology or product based. Technology transfer of prefabrication is not as pertinent to architects as it is to manufacturers of building products, but we are caretakers of culture in the AEC industry. In many cases we are asked to help with many of the transfers that are occurring by way of global practice or working for multi-national firms that are producing prefabricated components and entire buildings for India and elsewhere.

[15] Xudong Zhao - In recent years, prefabrication has been widely used in the building market worldwide, particularly in American, Germany, Scandinavia and Japan. Use of the prefabrication techniques in UK house building is still lower, but the rate of growth for application is significant. The key issue for promoting prefabrication is to seek for potential low cost techniques, including using sustainable/recycled materials, such as rammed earth, blast furnace slag, fly ash, or straw, increasing the size and reducing the number of the components used, use of modular design of house components, factory based mass production, advanced machinery technique, as well as intelligent computer aided design.

[16] Alireza Baghchesaraei - To accomplish the genuine advantage for building administrations gear and conveyance, construction must frame a principal piece of the incorporated and composed configuration system for the building. It is possible to say that further improvement of prefabrication systems will prompt a closer joining between building construction and future potential of prefabrication.

2.2 BASE PAPER

"Comparative Study on Prefabrication Construction with Cast In-Situ Construction of Residential Buildings."- N.Dineshkumar, P.Kathirvel

The construction boom in India is developing at a fast rate of growth. It provides wide opportunity in India for a new entrant in prefab sector. At present precast concrete buildings are the advanced construction techniques available over worldwide. Being its wide applicability, the total precast concrete buildings systems are becoming a popular choice for many construction.

Precast concrete available in many shape, sizes, including structural elements and unreinforced pieces. The prefab industry is the backbone for the development of new ideas in construction business of any country; Factory buildings, residential buildings and the industrial township are needed practically by all the sectors, either to support the manufacturing or services of any industry.

Importance of Precast Construction

The precast construction has the following benefits:

2.2.1 Precast concrete is comfortable

The material has intrinsic properties of thermal inertia (allowing a more constant temperature both in cold and hot regions) and acoustic insulation.

2.2.2 Precast concrete is safe

Everybody knows that concrete does not burn! Not only is the structural stability maintained for longer periods, but concrete construction prevents the spread of the fire from one building to another. It is sufficiently strong to resist impacts, blasts and natural catastrophes like earthquakes, tornadoes and floods.

2.2.3 Precast concrete is versatile

Factory production allows a wide choice of surface finishing, color range and special shapes. Precast concrete has another advantage: its mould ability, which entails designers to copy classical details like keystones and capitals or match the finish of materials like weathered stones. The precast concrete industry can source a wide range of aggregates locally and offer a tremendous variety of colors and visual effects.

Fig.2 – Parts of prefabricated structure

2.2.4 Precast concrete is healthy

Indoor air quality is a concern for all of us. Precast concrete is stable throughout its life and does not need chemical treatment to protect it against rot and insect attack: this means that there are no emissions in the internal environment.

2.2.5 Precast concrete is optimized

Advanced technologies used in the pre-casting plants create an improved quality product (i.e. reduced tolerances, thinner sections, engineered solutions) compared with cast-on-site concrete. Additionally this quality can be checked before a unit is inserted into the structure or site work!

2.2.6 Precast concrete is durable

Egyptian and Chinese people used an ancient form of concrete for buildings and structures that still exist today. Concrete is used where the structural stability has to be maintained for long periods. Effective design detailing helps to lengthen the life of a concrete building; precast manufacturers can offer guidance on designing for durability.

2.3. WORK STEPS

The research has been separated into two main tasks, as follows:

(1) Task l: Investigate current modular construction practices.

• *Task* 1.1 - Investigate current modular construction methods through a study of literature and a survey of industry.

A study of literature and a survey of industry. The literature study includes the review of technical magazines, journals, and reports, and books. The survey of industry would mostly revolve around residential and a little around commercial construction. Examples of modular construction projects and general modular construction practices are identified from the literature review. The papers that were reviewed will range from Indian Universities and local authors to foreign universities and foreign authors and architects.

• *Task* 1.2 - Compare both modular and conventional construction methods to identify the key differences.

It was accomplished by developing descriptions of modular construction activities from the literature and comparing them with those of conventional construction to identify important differences in a project's planning and construction activities.

• *Task* 1.3 - Identify the broad advantages, driving forces, and broad disadvantages of modular construction methods.

It identifies the broad advantages, driving forces, and broad disadvantages of modular construction, is based on information gathered from the study of literature and a survey of industry.

• *Task* 1.4 - Identify the key characteristics of successful modular construction projects.

This task will be accomplished by analyzing the results of tasks 1.1 through 1.3

• *Task* 1.5 – Structural analysis of the building systems

(2) Task 2: Selection of type of Prefabrication technology

Since prefabrication is a very large concept at hand and with the restrictions of time, a particular type of prefabrication system was selected for the comparison to limit the research area. Identify opportunities to advance modular construction technology and methodology with emphasis on building frame construction based on analysis of the findings from Task 1.

(3) Task 3: Plan preparation

Now the plans for the building to be analyzed would be made, which would be similar for all types of construction technology to be compared for a genuine comparison on basis of structural performance and cost analysis.

(4) Task 4: Data Collection

Now the Data required for the analysis from different construction methodologies would be collected and compiled and fed into the software for the next step of analysis of the building.

(5) Task 5: Structural Analysis of the Building

After all the data acquired and fed into the system the building is analyzed for different type of construction technologies for structural stability and cost efficiency and a final report would be generated.

(7) Task 7: Cost analysis of the building

For the current building plans and technology used a comparative study would be done for the cost efficiency of the building to see if the technologies considered here are economically feasible and can justify their cost with respect to their benefits to the client and the environment.

(10) Task 10: Data Compilation

All the data and results obtained would be arranged in a systematic and chronological order for the research work and compilation for the thesis work would be started right after the paper publication.

(11) Task 11: Conclusion

after the completion of all the work, results and conclusion will be presented in th end, including views of the author.

2.4. EXISTING SYSTEMS IN COUNTRY

The prevalent construction systems in India are:

- Load bearing Structure - In this system, walls are constructed using bricks/stone/block masonry and floor/roof slabs are of RCC/stone/composite or truss. It is cast in-situ system and called load bearing system as load of structure is transferred to foundation and then to ground through walls.
- RCC Framed Structure - In this cast in-situ system, the skeleton of a structure is of RCC column and beam with RCC slab. The infill walls can be of bricks/blocks/stone /panels. The load of the structure is transferred through beam and column to the foundation.
- Steel framed Structure - Here RCC beam and columns are replaced by hot rolled steel sections.

2.5. PREFABRICATION SYSTEMS

The Architects, engineers, contractors and planers are still unable to switch from conventional construction systems even after such a heavy and urgent demand. Its due to lack of awareness, support from authorities and distrust on the new technological advancement because of unavailability of sufficient and proper design guides and provision in IS codes and structural analysis software giants like STAAD.PRO, ETABS, Autodesk Revit, etc.

Although the Building Materials & Technology Promotion Council (BMTPC), Ministry of Housing & Urban Poverty Alleviation, Government of India has taken an initiative in this direction to provide support to Architects and engineers to adopt new building technologies. BMTPC took an initiative to study/select emerging technologies suitable to Indian geo-climatic conditions.

The conventional construction systems are primarily cast in-situ slow pace construction systems and cannot meet the present requirement of housing shortage.

Therefore, it is call of the day to adopt new construction systems, which are fast track and at the same time meet functional and structural requirements, which includes Constituted Technology Advisory Group for identification, evaluation and selection of the suitable technologies/ systems, comprising of eminent experts from Government, CSIR, academic and private agencies.

As a professional community of engineers, designers & planners, we must be using-

- Building materials which have less dependence on natural resources
- Building materials which are based on agricultural & industrial waste
- Construction systems which optimizes the use of cement, sand & steel i.e. prefab systems, factory made building components
- Less dependence on water, sand, aggregates during construction
- Technologies, which are not dependent on fossil fuels
- Zero construction & demolition waste
- Dust free technologies
- Materials & systems based on renewable resources
- Wood substitutes based on plantation timber

2.6. NEED OF PREFABRICATION

It is envisaged to construct 20 million houses by 2022 in urban area and about 10 million houses in next 3 years in rural areas (urban : 2.5 million houses a year, 7000 houses per day). Such a heavy requirement puts a very massive load on the natural resources and conventional building materials, which may cause the following consequences:

- Cost escalation leading to increased cost of shelter.
- Rapid & irrationally managed utilization of finite natural resources.
- Environmental degradation; Enhanced use of fertile top-soil, Deforestation, Lime-quarrying, Surface working in stone belts
- Factory made products like cement, steel etc. calls for high energy input
- Enhanced cost because of transportation.

So that brings us to consider alternative new technologies for mass housing, keeping in mind Speed, Quality, Safety, Life Cycle cost, Thermal, acoustics, Fire, etc. In addition, the need of the hour suggests use of renewable resources for building materials, use of raw materials resources based on waste products, efficient use of existing conventional materials by producing factory made (pre-cast) building components, affordability and sustainability, Industrialization of housing sector.

These new systems are precast concrete construction, hot and cold form steel construction, large formwork systems, sandwich panel construction, factory made prefabricated systems etc. These systems are being practiced world over and some of the developing countries have successfully met the huge housing demand using them.

Requirements for mass housing are Quality of construction, Time required for construction and Cost of construction.

2.7. EVALUATION OF TECHNOLOGIES

Broad Parameters for evaluation of technologies-

a. Safety of the structure against anticipated live loads and safety and stability with respect to the prevailing wind loads and with respect to the possible earthquake loads and other loads such as snow, cyclone etc.
b. Performance of the structure during its life span
    i. Thermal efficiency of the construction during summer and winter
    ii. Acoustics efficiency, Damp proof-ness of the construction during rains
    iii. Efficiency of the joinery systems, Fire resistance characteristics of the structure
c. Durability of the structure
    i. Deterioration of components with age
    ii. Deterioration of components due to atmospheric pollutions
    iii. Deterioration of foundation system due to polluted/chemically adverse soil media
    iv. Life expectancy (*Our normal housing constructions are designed for a life of 60 years and above*).

2.8. TYPES OF PREFABRICATION IN INDIA

Since prefabrication, systems is a very broad topic and "What are the alternative technologies we can use?" is a very broad area of study. So, some of the most preferred construction systems were shortlisted for initial study which are as follows-

2.8.1. Monolithic Concrete Construction Technology-

Fig.3 – A Typical working of a Monolithic Concrete Construction Technology

The conventional mode of construction is RCC framed structure with infill masonry walls whereas in this system, all walls, floors/slabs, stairs together with door & window openings are cast in-situ monolithically using specifically custom designed modular formwork made up of aluminum/plastics/steel/ composite.

The appropriate grade of concrete and reinforcement is used as per design and the entire casting of a modular unit is done in a single pour. Being modular predesigned formwork system, it acts as a assembly line production and enables rapid construction of multiple/mass scale of units of repetitive type.

In the Monolithic concrete construction with aluminum /plastic /steel /composite forms system, Concrete walls and slabs are cast monolithically at one pour. The system allows reduction in thickness of concrete members below the minimum value than the conventional construction, thus reducing the consumption of natural resources.

A Typical plan is of a Single floor with built up area of about 300 sqm. This can be completed in two days using the aluminum formwork system. The technology reduces the cost of repair and maintenance compared to conventional system. Walls and slabs are cast in one operation in specially designed light weight form/ moulds in concrete. Concrete is poured in the forms & forms are removed after the setting of concrete takes place, resulting in box like cubical structure of required architectural design. The pre-designed formwork also acts some sort of assembly line production and enables rapid construction of multiple units of repetitive type.

2.8.2. Light Gauge Steel Framed Structure (LGSFS)

Light Gauge Steel is cold form steel which has an advantage over hot rolled steel as it is lighter in weight and on thin sections of any form can be manufactured. Normally, LGSFS is factory made galvanized light gauge steel components assembled as panels at site and suitable for 3 to 4 storey structures. The infill walls can be of any material ranging from precast boards, blocks, EPS panels or an external layer of insulation material and outer leaf of CP Board or dry mix shotcrete. The floor/roof can be RCC/ Steel truss /Steel deck on joists as per the requirement.

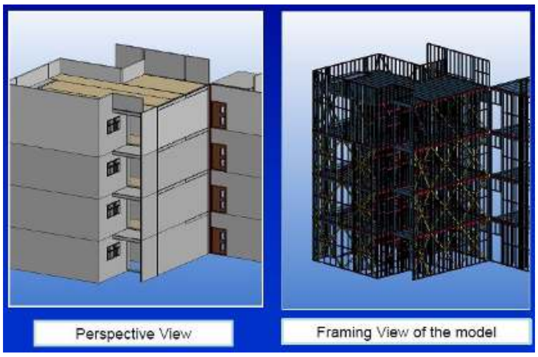


Fig.4 – A Typical working of a LGSFS

Frame is made of cold rolled high strength steel sections and EPS panels for walling. Internal walls covered with gypsum and cementitious board. Exterior wall Sprayed with cementitious material directly onto the studs. It gives Faster construction by prefabricated panels. All structural components are precisely pre-manufactured and simply assembled on site. Also it gets Enhanced Thermal & Acoustic insulation with Boarding/Expanded Polystyrene (EPS) /Rockwool/Vapor Barrier.

2.8.3. Precast Large Concrete Panel System

Precast Large Construction Panel (PLCP) system is a structural system comprising of various precast elements such as walls, beams, slabs, columns, staircase, landing and customized elements. There

Fig.5 – A Typical working of a Precast Large Concrete Panel System

are two types of precast concrete elements, namely precast reinforced concrete elements and precast pre-stressed concrete elements, prefabricated in a precast yard or site. The precast elements are installed on site and supported by temporary jacks. Shims are used to carefully align the elements and grouted after the final adjustments. A typical construction involves design, strategic yard planning, lifting, handling, transportation and assembly of precast elements.

The industrialized total open prefab construction technology is based on factory mass manufactured structural prefab components conforming to norms of IS standards and BIS Certification mark. In this Patented system, precast dense concrete hollow column shell of appropriate size are used in combination with precast dense concrete rectangular T Shape/ L shape beams and lightweight reinforced autoclaved cellular concretes labs for floors and roofs. The hollow columns are grouted with appropriate grade of in–situ concrete. All the connections and jointing of various structures are accomplished through in situ concreting along with secured embedded reinforcement of appropriate size, length and configuration to ensure monolithic continuous resilient ductile behavior.

2.8.4. SIP Panel - Building System using Steel Mesh, Polystyrene Core and Chipping Concrete (evaluated through PACS)

EMMEDUE Advanced Building System (patented) is based on factory made panels consisting of self-extinguishing expanded polystyrene core (generally corrugated) sandwiched between two-welded wire fabric mesh made of high strength galvanized wire. A galvanized steel truss wire is pierced completely through the core at an offset angle for superior strength and welded to each of outer layer welded wire fabric mesh.

Fig.6 – A Typical working of a SIP panels

The panels are finished at site using shotcrete of mix of cement and coarse aggregate of required thickness on both sides. The panels are used for load bearing walls and floors and suitable for 3 to 4 storey buildings.

2.8.5. Glass Fibre Reinforced Gypsum (GFRG) Panel System

Fig.7 – A Typical GFRG panels

GFRG is an integrated composite building system using factory made prefab load bearing cage panels and monolithic cast in-situ RC in filled for walling and floor/roof slabs, suitable for single storey to ten storey building. It is made of calcined gypsum plaster, reinforced with glass fibres and panels manufactured to a thickness of 124 mm under carefully controlled conditions to a length of 12 m and height of 3m, contains cavities. The panel are being produced at FRBL Kochi and RCF Mumbai and being promoted by IIT Madras.

Glass Fibre Reinforced Gypsum (GFRG)/ Rapid wall is a building panel product, made essentially of gypsum plaster, reinforced with glass fibers. Used since 1990 in Australia. 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 panels may be unfilled, partially filled or fully filled with reinforced concrete as per the structural requirement.

Chapter 3

Methodology

3.1 MODEL SELECTION AND PREPARATION

After comparing the above available construction techniques for the pros and cons, Glass Fibre Reinforced Gypsum (GFRG) Panel System was found most suitable for the desired outcome of the work. Hence, GFRG panels were shortlisted and chosen for the comparison from the prefabricated structures.

GFRG panels were initially designed for wall panels. However, because of the research work by Students and Faculties of IIT Madras, it was also found suitable for the flooring as well as staircase. It was observed that this system mimics the properties of a Load Bearing Structure, yet also due to the micro beams proposed within the panels it also inherits the properties of a RCC framed structure.

GFRG structures are a new kind of structural component to which conventional structural theories and design codes are not relevant. Glass fiber reinforced gypsum binder composites were created by using E-type glass fiber and newly developed water-resistant gypsum binder. The water resistant gypsum binder was formed by blending ground granulated slag, ordinary Portland cement and an organic retarder with claimed phosphogypsum in a ball mill to obtain a consistent product. The binder possesses good water resistance as it does not demonstrate leaching in water up to 28 days of immersion , while plain plaster displays leaching after 3 days of immersion, in water. For the reinforcing material in this program, chopped uncoated E-type glass fiber is used.

Rapid wall panel is world’s biggest load bearing lightweight panels. Each panel has 48 modular voids of 12 m x 3 m x 124 mm dimension. Reinforced concrete is one of the most broadly used modern building materials. Concrete is an “synthetic stone” acquired by mixing cement, sand and aggregates with water. Currently reinforced concrete buildings in many earthquake prone areas of the world are built according to design codes and yet several still suffer collapse during earthquakes. This may denote that there are insufficiencies in design. This occurrence cannot be avoided but, by appropriate planning and design we can avoid it to a notable extent and hence structural engineer's needs to design the structure taking into account every essential factor including the infill walls which plays a significant role during earthquakes.

Due to this fact, it could be used to replace both Load Bearing Structure as well as a moment resisting framed structure. Hence, for this work GFRG panel system is compared on various aspects with a load bearing structure and a RCC framed structure. A total of three models were decided to be formed and compared for a same building plan for a genuine comparison. Although, the Industrial giants for structure analysis and BIM like STAAD.PRO, ETABS, REVIT, etc. do not support GFRG as a building material. Also GFRG couldn't be found in their material libraries like concrete, steel, aluminum, glass, rebar, etc. for structure analysis, it was quite difficult for all three models to be analyzed to the desired precision get accurate data for the ground of comparison. After the long research and shear hard work, an attempt has been made here to impart the knowledge of the procedure for the structural analysis using CAD and BIM through software approach as a reference guide for anyone who tries to do a structure analysis of a building using GFRG panel system. All the three models were prepared with the help of Software approach for the structural stability and suitability for the initial comparison.

After the initial plan preparation, it was slightly modified to fit according to the wall sizes keeping the Super Built-Up area same for all the models, so a closer cost analysis could be done. Several plans were prepared to fit into all three requirements and the finalized plans are as in Fig 8 to Fig 10. After the finalization of plan, the main work started for preparation of the models in ETABS. The first model was prepared of the framed structure as can be seen in Fig 11.

The first step to modeling was to make the centerline diagram of the beam and column as in Fig 12. After that, the modeling was done using the centerline as in Fig 13. The after analysis resulted in Fig 14.

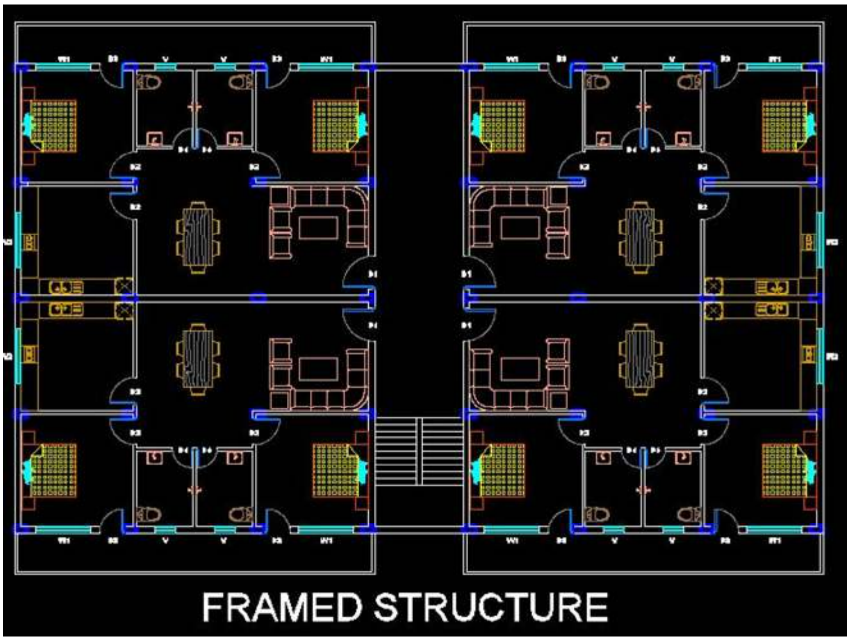


Fig.8 – A Typical working drawing of the building plan of the framed structure

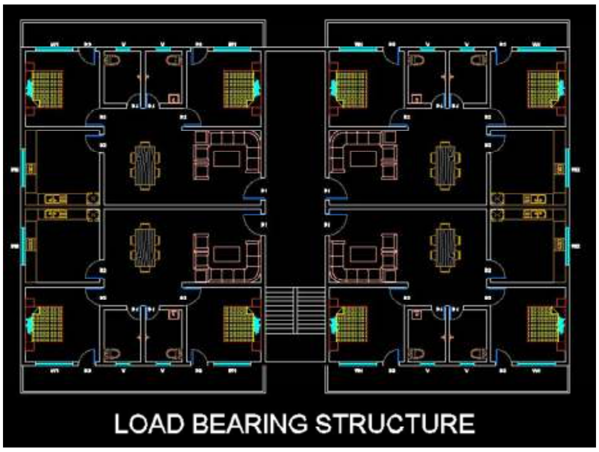


Fig.9– A Typical working drawing of the building plan of the Load Bearing structure

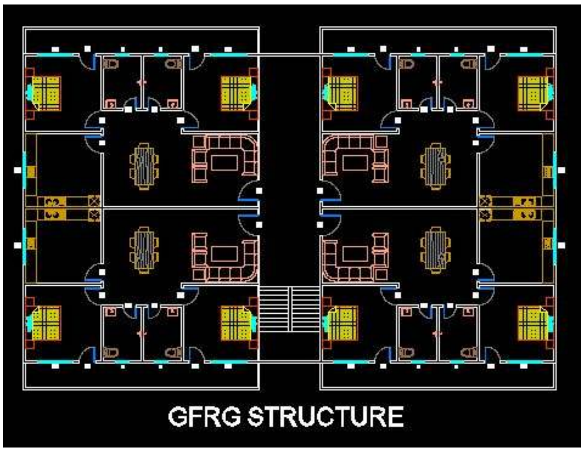
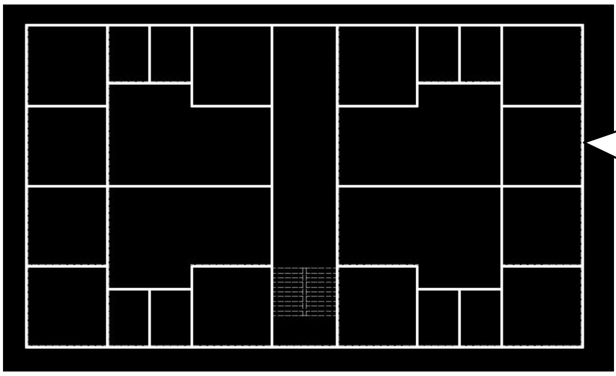


Fig.10– A Typical working drawing of the building plan of the GFRG structure

3.2 WHY GFRG

GFRG is of exceptional relevance to India, where there is a massive need for cost-effective mass-scale affordable housing.

- Most economic outcome.
- Eliminates lots of building material requirement.
- Reduced construction time and labour.
- GFRG panels had the thinnest wall space requirement, providing most usable space.
- In India, gypsum is available in plentiful amount as an industrial by-product waste.
- Environmental friendly and green, reduced carbon footprint.
- Resistant to damage by water and fire.
- Can be used as Shear wall, Partition wall, Slabs.
- Best for construction up to 10 storey.



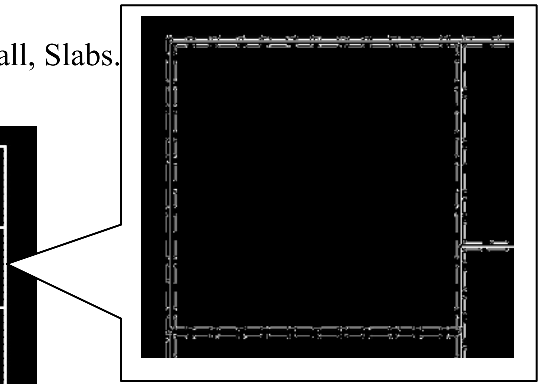


Fig.11– Centerline diagram of the beam and column of the building of the Framed Structure

Table 1 - Description of the typical plan

1	Type of building	Residential
2	Number of floors	G + 3
3	Storey height	3 m
4	Dwelling units	16
5	Total Height	12 m
6	Slab thickness	150 mm
7	Total covered Area per floor	2341.36 Sq mt
8	Wall thickness	230 mm for outer walls, 115mm for framed walls, 124mm for GFRG walls
9	Column Size	450 mm X 230mm
10	Beam size	300 mm X 230mm
11	Riser Height	150mm
12	Thread depth	250 mm
13	Seismic zone	V

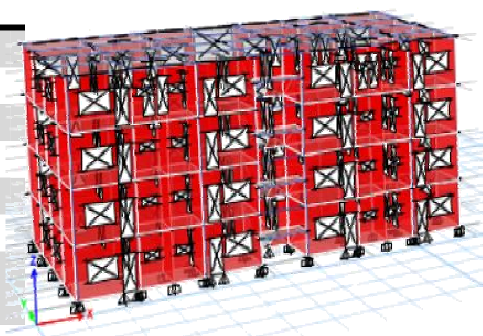


Fig.12– A 3D Model of the building plan of the Framed Structure

Table 2 - Material Properties of Unfilled GFRG Panels

1	Unit weight	0.433 kN/m^2
2	Modulus of elasticity	7500 N/mm^2
3	Ultimate shear strength	21.6 kN/m
4	Mohr hardness	1.6
5	Coefficient of thermal expansion	12×10^{-6} mm / mm / `C
6	Water absorption	1% : 1hr 3.85 % : 24hrs
7	Fire resistance	140 minutes
8	Sound transmission class (STC)	40dB
9	Uni axial compressive strength	160 kN/m
10	Out-of-plane moment capacity, Rib parallel to span	2.1 kNm / m
11	Out-of-plane moment capacity, Rib perpendicular to span	0.88 kNm / m
12	Out-of-plane flexural rigidity, Rib parallel to span	3.5 X 10^{11} Nmm^2 / m
13	Out-of-plane flexural rigidity, Rib perpendicular to span	1.7 X 10^{11} Nmm^2 / m

Property	**Nominal value**	**Remarks**
Uniaxial compressive strength, P_{uc} (Both ends fixed)	1310 kN/m	Obtained from longitudinal compression tests with ribs in the longitudinal direction
Uniaxial compressive strength, P_{uc} (One end fixed and other end hinged)	1360 kN/m	Obtained from longitudinal compression tests with ribs in the longitudinal direction
Ultimate shear strength, V_{uc}	61kN/m	Longitudinal cracks (parallel to the ribs)
Fire resistance	241 minutes	CSIRO, Australia

Table 3 – Compressive Strength of GFRG Panel

3.3. ASSUMPTIONS

While modeling, following assumptions are made-

1. Walls are modeled as shell elements with the equivalent composite properties as given in Table 4
2. Slabs are modeled as membrane elements.
3. Rigid diaphragm is assigned to all slab elements for lateral load analysis.
4. During modeling of GFRG structure, for convenience in design, the contribution of GFRG towards the flexural strength con be ignored and the GFRG is treated as lost formwork, both in walls and in slabs.

Materials	Modulus of Elasticity (MPa)	Area for 250mm length {one cell} mm^2
Concrete (M25)	25000 (E_C)	230 x 94 (=21620)
GFRG	7500 (E_G)	930
Infilled GFRG with concrete	19500	31000

Table 4 – Material Property of GFRG Panel

3.4. GENERAL LOAD CALCULATIONS

3.4.1. Dead load and super dead load–

- Self-weight is auto applied in ETABS.
- Floor finish- (Table 2, IS: 875 Part 1)
  - 1 cm mortar plaster on roof / ceiling of lower floor for finishing = 0.21kN/m^2.
  - 1 cm mortar plaster on floor for tiles = 0.21kN/m^2.
  - 20mm Clay tiles = 0.2kN/ m^2.
- Total Floor Finish load as per IS 875 Part 1 = 0.21+0.21+0.2 = 0.62kN/ m^2. (Table 2, IS: 875 Part 1)
- If one decides to not apply walls into the model and instead apply the load on the beams of the walls, the following calculations can be used.
  - Unit weight of the brick wall = 18.85 kN/ m^3.
  - 230 mm thick walls = (3-0.3) x 0.23 = 11.71 kN/m.
  - 115 mm thick walls = (3-0.3) x 0.115 = 5.85 kN/m.

3.4.2. Live Load –

- IS 875 Part 2 gives details of Live loads to be considered while designing.
- For rooms and kitchens – UDL of 2 kN/ m^2.
- For Toilets and Bathrooms – 2 kN/ m^2.
- Balconies – 3 kN/ m^2.
- Corridors/Passages – 3kN/ m^2.
- Staircase/ Storerooms – 3kN/ m^2.

3.4.3. Earthquake loads –

Since majority of India lies in Zone II and Zone III, we will be considering Zone III and the location is taken as Lucknow to ease the other calculations including cost comparison of material, Labour charges, feasibility and their factors, making the study more practical and realistic.

- Zone = III
- Zone Factor = 0.16
- Location = Lucknow

Importance factor – since the building considered is residential in nature, importance factor is taken as 1. (Table 6, IS: 1893:2002)

3.4.4. Response reduction factor –

We generally see the engineers taking response reduction factor as low as 5 or as high as 1 in their initial phases of designing to make cost efficient structure or earthquake proof structure respectively, which either makes the structure very unsafe or very uneconomical. Our motto as a Structural engineer is to make the structure earthquake resistant not earthquake proof making it economical keeping it safe. For the sake of safety under Indian conditions due to low quality of materials and workmanship IS 1893:2002 suggests in Table 7 to take response reduction factor as

- For OMRF = 3
- For Load bearing masonry wall structure = 1.5
- For GFRG = 3 for Low/Medium rise Buildings (According to GFRG Manual by IIT Madras and BMTPC)

3.4.5. Site Type –

According to Anbazhagan P. in his paper "Site Response Study of deep soil columns in Lucknow, India" Published in 2010, clearly states that the soil up to 6m fall under Type II ($15<N<30$) and below that N gradually increase up to $N > 90$, falling in Type I soil. Since our Building Height is quite less (=12m) then assuming foundation to be not more than 6m and taking soil Type II for analysis.

3.4.6. Wind Load –

IS 875 Part 3 is generally used for wind analysis, but in our case as the building height is < 15m, the need of wind analysis is eliminated (According to National Building Code). Also only one of the forces i.e. Earthquake or wind load are considered simultaneously, so it further removes the need of wind analysis for our building system.

3.5. DEFINING MATERIAL PROPERTIES

3.5.1. Concrete – The structure to be designed is designed using M20 concrete.

3.5.2. Rebars – HYSD 415 rebars were taken for designing

3.5.3. Masonry – Clay Brick masonry walls were used in the modeling of the structure having 18.85kN/m^3 weight density. walls in the RCC structure which were used were 230mm for outer walls, 115mm for inner walls; for load bearing structure, all walls were taken as 230mm walls; for the GFRG structure, Partially filled GFRG panels were used of thickness 124 mm whose property are defined in the 3.5.4.

3.5.4. GFRG – This property is defined for the wall panels used in the designing, taking material type as others, weight density as 3.464 kN/m^3,modulus of elasticity, E as 7500 MPa, Poisson's Ratio U as 0.2, coefficient of thermal expansion A as 0.000012/C`

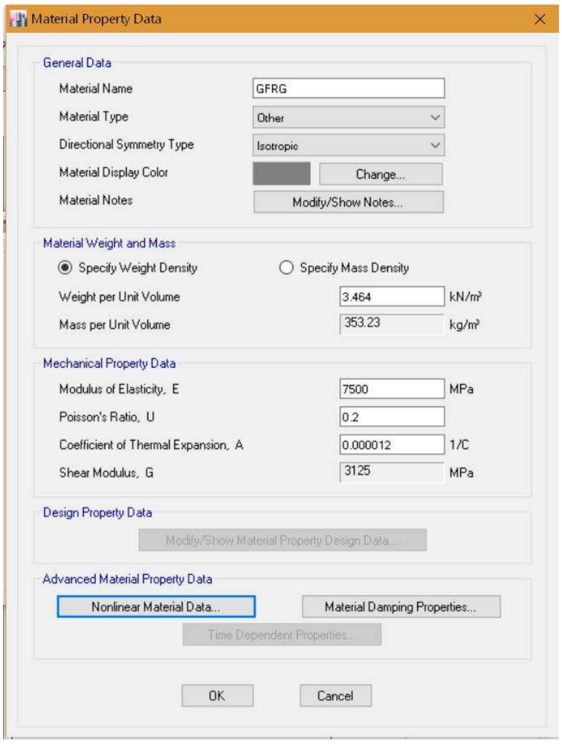


Fig 13 – Material Property Data of the GFRG

3.6. DEFINING FRAME PROPERTIES

3.6.1. RCC Beams – Concrete beams using M20 is taken for this purpose of dimensions 230mm width X 300mm depth. Under reinforcement tab, design type is kept as M3 design only, Longitudinal and confinement bars are taken as HYSD415 Bars, top and bottom covers are taken as 60mm each. Frame section properties are in table 3.5.1.

3.6.2. RCC Columns – Concrete columns using M20 is taken for this purpose of dimensions 230mm X 460 mm . Under reinforcement tab, design type is kept as M3 design only, Longitudinal and confinement bars are taken as HYSD415 Bars, and top and bottom covers are taken as 60mm each.

3.6.3. Micro-beams for GFRG Structure – Micro beams are to be placed inside the GFRG cavity 750 mm c/c (i.e. every 3rd cavity. Rectangular concrete beams of dimensions 230mm X 109 mm. For a residential building, using reinforcement of

0.876% (Table 3, SP – 16, Design Aids to IS: 456), try providing 2Y12 + 1Y10, and 6mm φ two legged mild stirrups @100 c/c.

3.6.4. Micro columns for GFRG structure – micro columns are to be placed inside the GFRG cavity 1000mm c/c (i.e. every 4th cavity). rectangular concrete columns of dimensions 230mm X 94 mm. For a residential building, using reinforcement of 0.28% take 1Y10 in each cavity.

3.7. DEFINING SLAB PROPERTIES

3.7.1. RCC slab – The slabs used in the RCC model and the load bearing structure models were taken as 150 mm thick RCC slabs. Concrete used in both the slabs is of M20 grade. During modeling, the type modeling type of the slabs are taken are membrane.

3.7.2. GFRG slab – The designing of the GFRG slabs are a bit different and complex than the normal RCC slab. GFRG-RC composite slab structure can be used proficiently in floor slabs and roof slabs. The ribs are to be oriented in the shorter span, resting on GFRG wall panels. For ease in design, the contribution of GFRG panels towards the flexure strength can be ignored and the GFRG panel can be treated as the lost framework. Reinforced concrete micro beams are to be provided by filling cavities at regular spacing (typically every third cavity) and provided with reinforcement duly designed, with the RC screed concrete as deck slab of depth not less than 50 mm. as shown in the Fig 15. One-way slab action may be assumed for strength and deflection check, considering T beam action of the embedded micro beams. In the screed concrete, appropriate welded wire fabric of necessary Gauge and spacing (typically 10 gauge welded mesh @100 mm c/c or 6mm bars at 150 mm spacing) shall be provided. The design of reinforcement in the micro beam shall conform to the requirements of IS 456: 2000. Such slabs can be suitably designed up to 5 m span.

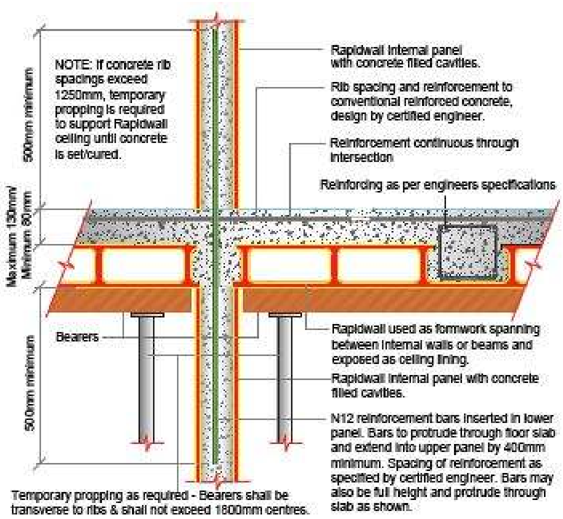


Fig 14 – Concrete filled Rapidwall and floor

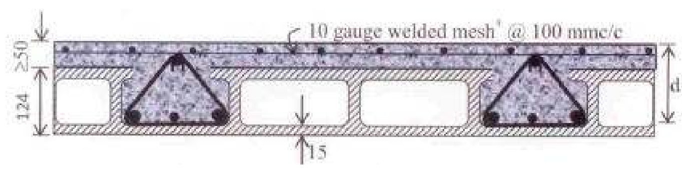


Fig 15 – Typical cross-section of panel with micro beams

Steps to be followed for slab placement:-

1. Formworks are erected.
2. Tie beams are erected all along the walls to present bond between roof slab and walls.
3. Panels are then placed in position.
4. Every third cavity is then cut out from the top and reinforcement cages are placed in for concrete micro beams.
5. Electrical conduits are then sited in position.
6. Welded wire mesh is then kept all over the panel.
7. Then concreting is done with thickness 50 mm.
8. Subsequently waterproofing of roof is to be done.

For more detailed structural joints refer to Annexure I

3.8. DEFINING WALL PROPERTIES

3.8.1. Wall 230 – A masonry wall structure with Thin-shell modeling type and thickness of 230 mm is defined for external walls of RCC framed structure and all the walls of the load bearing wall structure.

3.8.2. Wall 115 – A masonry wall structure with Thin-shell modeling type and thickness of 115mm is defined for internal walls of RCC framed structure.

3.8.3. GFRG wall – A GFRG wall structure with Thin-shell modeling type and thickness of 124 mm is defined for all the walls of GFRG structure.

3.9. DEFINING LOAD PATTERNS

3.9.1. Dead load – Type – Dead, Self weight Multiplier – 1, Auto Lateral Load – N/A

3.9.2. Live load – Type – Live, SW Multiplier – 0, Auto Lateral Load – N/A

3.9.3. Super Dead – Type – Super Dead, SW Multiplier – 0, Auto Lateral Load – N/A

3.9.4. EQ X+ load – Type – Seismic, Auto Lateral Load – IS 1893 2002

3.9.5. EQ Y+ load – Type – Seismic, Auto Lateral Load – IS 1893 2002

3.10. DEFINING LOAD COMBINATIONS

As we are following IS codes for this model, we will be adding Default design combos of concrete frame design and concrete slab design from the program conform to IS 1893 2002.

3.11. MODELING

After defining all the components described above we can move forward to modeling part. Since we are here dealing with three different types of construction technology, we have now two ways to model –

1) Making three different model files and working on them individually
2) Making all Three models in one file using Allow Multiple Tower.

Since, modeling all using multiple towers makes working complicated and file large to analyze, first option was chosen.

Even after careful planning and selection of position of columns and beams, during the process, the plan was required to be changed several times to achieve economy in the design. After the design was finalized in the final step, the following procedure was undertaken.

3.11.1. Model 1 RCC Structure – According to the plan, a G+3 RCC building was modeled. Columns and beams are placed according to the plan developed in the initial stages, which were constantly revised as per the situation. The alignments of columns were specifically taken care of, to avoid eccentricity in the columns and the frame. Slabs were placed according to the plan and after that, walls were applied after defining the wall sections with 230 mm walls and 115 mm walls placed as outer and inner walls respectively. Since ETABS apply the self-load automatically, we do not need to define it otherwise so we can directly move to super dead load and skip the self-wt. in the process. According to section 3.3 general load calculations, super dead load and live load were applied on the specific slabs as per the planning. Restraints were applied as fixed on all the column bases. Outcome of the model can be seen in Fig – 16.

3.11.2. Model 2 Load Bearing Structure – According to the plan, a G+3 load bearing building was modeled. Columns are absent in this type of structure, so brick masonry walls of 230 mm are placed according to the plan developed in the initial stages. Beams of specified dimensions were placed running all over the walls to support the slab, which would be casted monolithically during the erection process. Slabs were placed according to the plan. Since ETABS apply the self-load automatically, we do not need to define it otherwise so we can directly move to super dead load and skip the self-wt. in the process. According to section 3.3 general load calculations, super dead load and live load were applied on the specific slabs as per the planning. Outcome of the model can be seen in Fig – 18.

3.11.3. Model 3 GFRG Structure – According to the plan, a G+3 GFRG building structure was modeled. In this model, as specified in the GFRG building structural design manual developed by IIT Madras and BMTPC in accordance with IS Codes, wall panel act as load bearing structure with 'micro columns' running inside the panel generally in every fourth cavity for up to four storey. In the floor/roof slabs, as GFRG panels with ribs alignment in direction of bending hold flexural strength, such panels can be utilized as flexural slabs, whose strength can be significantly enhanced by embedding 'micro beams', filled with reinforced concrete. Unfilled GFRG panels can be used as pitched roofs. Since ETABS apply the self-load automatically, we do not need to define it otherwise so we can directly move to super dead load and skip the self-wt. in the process. According to section 3.3 general load calculations, super dead load and live load were applied on the specific slabs as per the planning. Restraints were applied as fixed on all the column bases. Outcome of the model can be seen in Fig – 20.

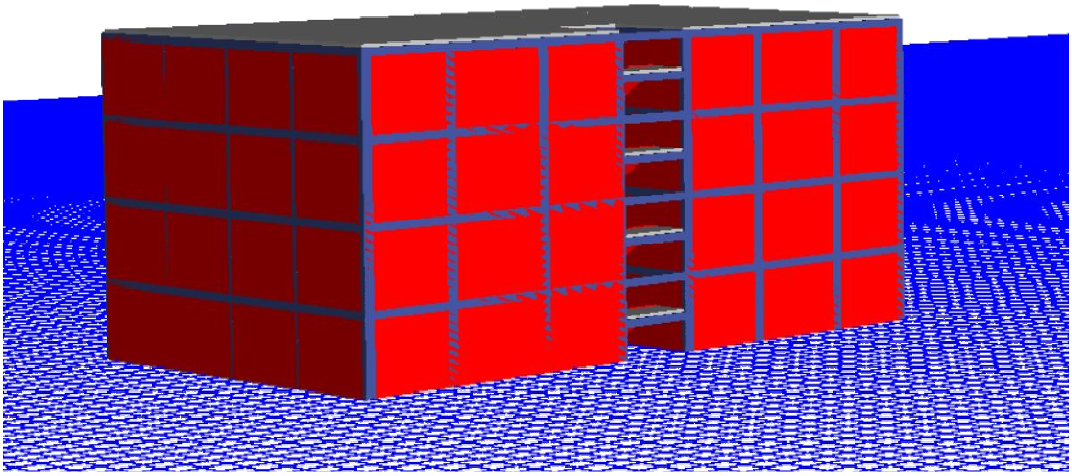


Fig.16– A 3D Model of the building of the Framed Structure in ETABS

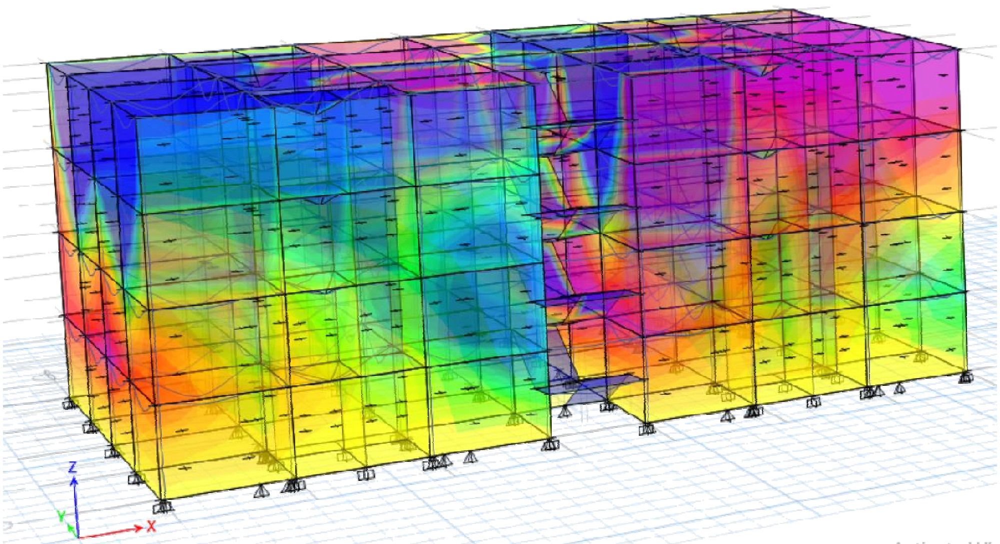


Fig.17- Analyzed result of the Building of the Framed Structure in ETABS

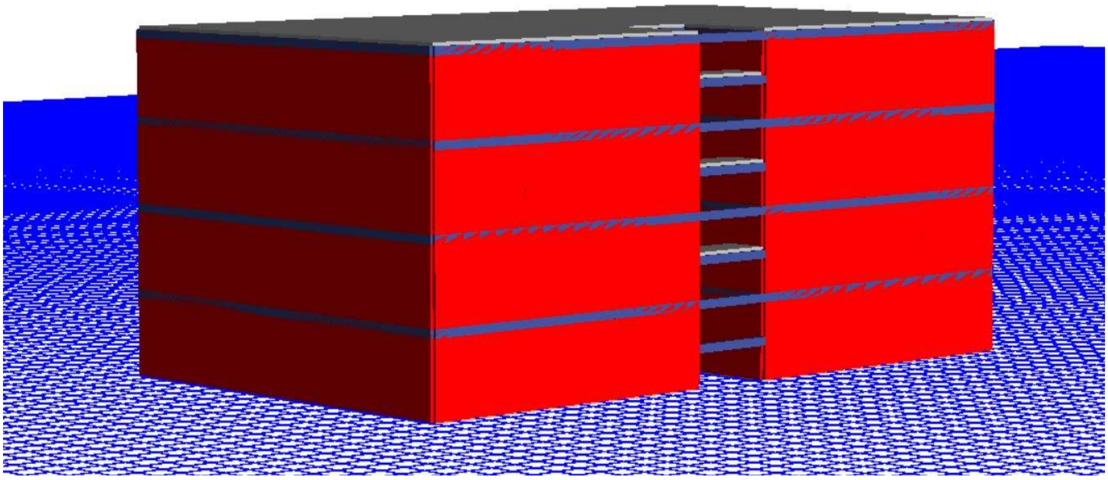


Fig.18– A 3D Model of the building of the load bearing Structure in ETABS

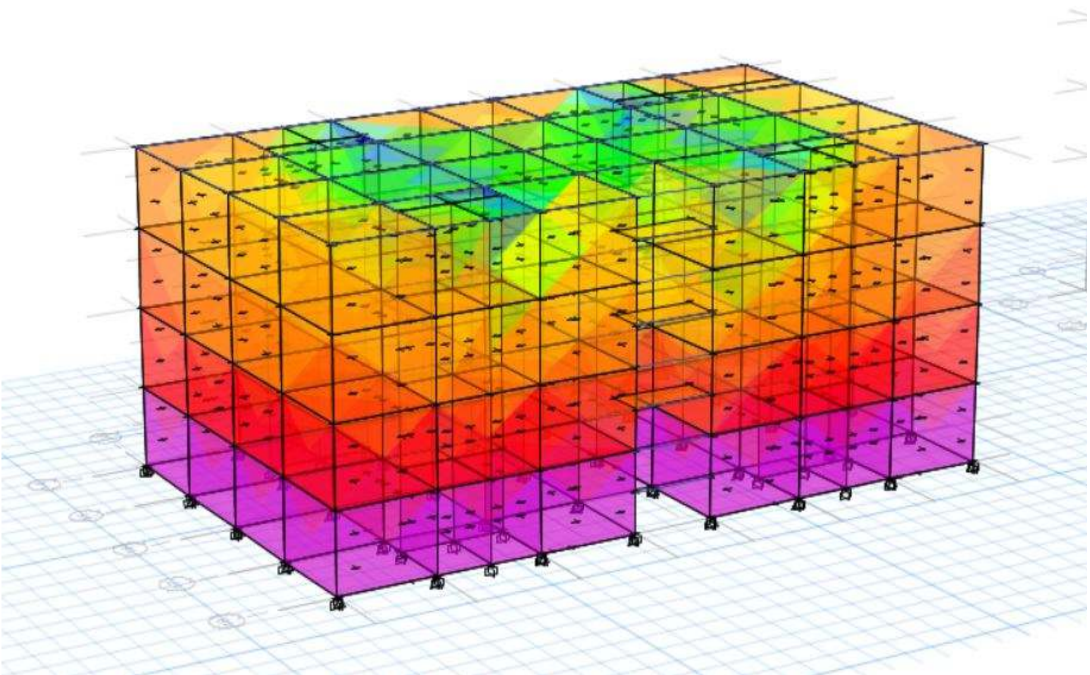


Fig.19- Analyzed result of the Building of the load bearing Structure in ETABS

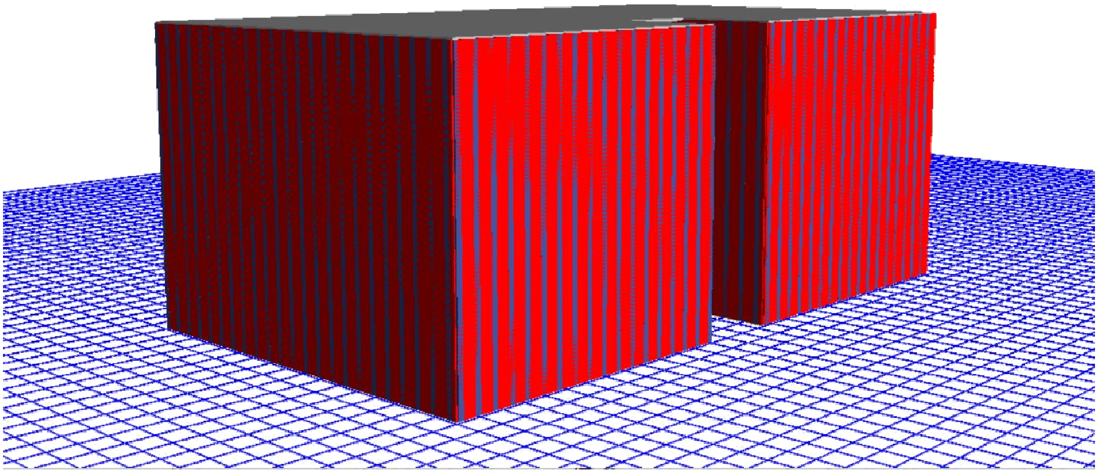


Fig. 20- A 3D Model of the building of the GFRG Structure in ETABS

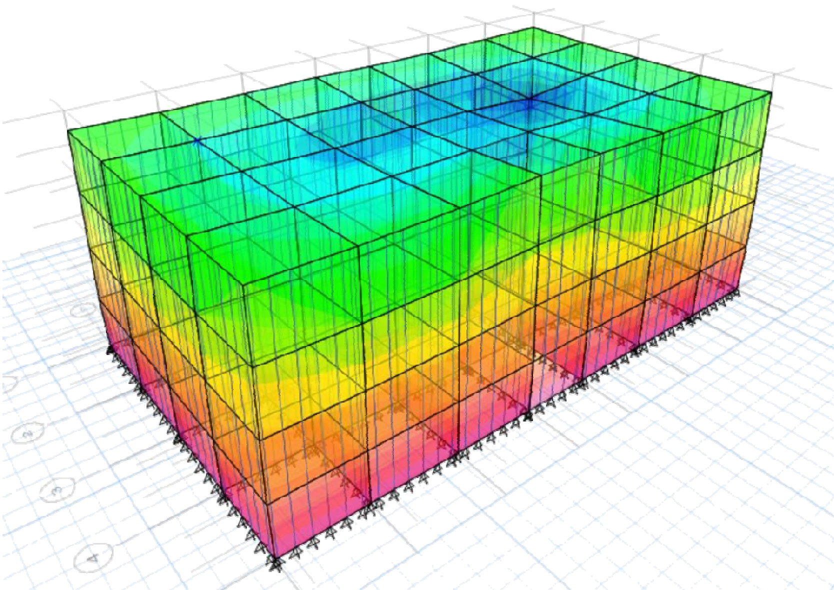


Fig. 21- Analyzed result of the Building of the GFRG Structure in ETABS

3.12. COST ANALYSIS

After the completion of model, the model was checked and found to be free from any warning and errors. It was then analyzed and the results were obtained which are discussed in Chapter 4 of this thesis. It was found that all the three structures are safe under the applied loads and all the deformations are under permissible limits, hence proving our structure is safe and now we can move to calculation of cost analysis.

Material	Rate
Mild Steel	Rs. 5500/ Qtl.
Cement	Rs. 450/ Bag
Coarse Sand	Rs. 1940.95 / m^3
Brick	Rs. 7/ Brick
GFRG Panels	Rs. 1120/ m^2
Stone Aggregate (20mm)	Rs. 3176.10 / m^3
Soil	Rs. 405.84 /m^3
Mason	Rs. 550 / day
Labour	Rs. 350 / day
Vitrified Tiles	Rs. 1027.58 / m^2
Shuttering	Rs. 550/ m^2

Table 5 – Rate List of Material

Being a civil engineer, it is our priority to provide cost effective solutions to our clients. With the escalating prices, the houses are becoming unaffordable with the current technology and hence we needed to explore another types of construction systems to reduce the cost of construction. This work is an attempt made to give an idea as to how can we reduce the construction cost as well as reduce the construction time using the prefabrication technology. This work compiles and retrospect the developments in the field of prefabricated building systems using GFRG construction technology also known as Rapidwall© construction technology in India. Glass fiber reinforced gypsum panels, manufactured in standardized parts are sections prepared for rapid erection of buildings, as they are ready-made gypsum structural panels with hollow cavities. This Rapidwall is employed in residential as well as commercial constructed establishments. GFRG walls can be used both for esthetical as well as structural component as walls and slabs, with no external columns and beams needed. It has currently found great utilization, even without exercising complicated codes of structural design, largely for the reason that they are environmental friendly. For the cost comparison, the fundamental materials considered were three types of building construction method such as low cost building using prefabrication technology as GFRG wall panel system and Conventional building construction systems like SMRF structure and Load bearing wall structure. Costs of these building materials were collected from contractors of the nearby areas. The focus in this part of work is comparative study on cost estimation between prefabricated system (GFRG) and conventional building systems.

In this new era of construction, several different building systems orientated for housing appeared in India. Most of these systems were introduced from first world countries and many were not able to fit into the Indian construction standards. This incursion of technology was originated after the announcement of the reconstruction plan for affected areas due to El Nino phenomena and Nazca earthquake. On the other hand, many of these systems were functional in countries lacking earthquake trouble and the majority of them employed foreign supplies. In this case of India, structural systems were supposed to be designed according with earthquake standard E-030 of the National Building Code. On the other hand, Indian researchers in the last 20 years developed different solutions for building systems using locally available materials and most of them were tested and had the approval and registration of BMTPC. The present work introduced five construction systems that are approved by BMTPC. The economic issues are also the main reason for these different building systems. So we have to select the most viable and low cost construction for avoid the financial problems.

The purpose of this part of works focuses on views of the construction industry about the difference of the two building methods such as GFRG (Glass

Fiber Reinforced Gypsum) wall panel system and conventional building construction system of SMRF structure and load bearing wall structure based on the estimation value and we have to generate some construction management results. We have to accumulate properties and cost details of the building materials. Comparing the methods, details were taken of cost and time duration for finishing each construction activity.

The major bulk of building construction work is small renovation, such as addition of a room, or renovation of a restroom. Often, the owner of the property work as the introspect, paymaster, and design team for the entire project. Although, all building construction projects consist of some elements in general – design, financial, estimation and legal considerations. Many projects of different sizes reach unwanted consequences, such as structural failure, cost overruns, and/or lawsuits. Due to such reasons, those with expertise in the field make comprehensive plans and keep cautious supervision throughout the project to ensure a positive result. Commercial building construction is procured privately or publicly utilizing various delivery methodologies, including cost estimating, hard bid, negotiated cost, conventional, organization contracting, construction management-at-risk, design & build and design-build bridging. Residential construction practices, technologies, and resources should match to the regulations of local building authority and codes of practice. Materials readily accessible in the region usually dictate the building materials used (e.g. brick vs. stone vs concrete). Cost of building construction can vary considerably based on site conditions, local policy, economy of scale (custom designed residences are often more costly to build) and the availability of trained workers and labors. As residential building construction (as well as all other types of construction) can produce a lot of waste, so careful planning again is required here.

Glass fiber reinforced gypsum, or GFRG (also known as Rapidwall in the trade) is the name of a new building panel, made of gypsum plaster, reinforced with glass fibers. GFRG is of exceptional relevance to India, where there is a massive need for cost-effective mass-scale affordable housing, and here gypsum is available in plentiful amount as an industrial by-product waste. The product not only proves to be environmental friendly or green, but also resistant to damage by water and fire. GFRG panels are currently manufactured in a panel size of length of 12m, a height of 3m and a thickness of 124 mm. Although its main function is in the construction of walls, it was found to be effective to be used in floor and roof slabs in combination with reinforced concrete. IIT Madras and BMTPC have been involved, since 2003, in the development of prefabricated building systems (especially with respect to use of GFRG panels as floor slabs and earthquake resistant design) for utilization in India. The panel contains cavities that can be filled with concrete and reinforced with steel bars to provide additional strength and ductility, if required. Experimental researches and studies have shown that GFRG panels, when properly filled with reinforced concrete, acquires significant strength to act not only as load-bearing elements, but also as shear walls, able of resisting lateral forces due to earthquake and wind. It is possible to design such buildings up to ten storeys in low seismic zones (and to smaller elevation in high seismic zones). However, such building needs to be suitably calculated by a qualified structural engineer for safety.

The major element of this work is estimating the total cost of the construction work for a residential house based on the Quotation gathered from five different zones for each part of work. The compilation of quotation contains Cost for each construction Material like Cement, Sand, Aggregate, bricks, etc and every activity like Excavation, Centering work, Flooring, Plastering, Labour charges, etc. The estimation work is carried out for both types of building system of wall panel system and conventional building system. The approximate time requirement and time difference for every work of Prefabrication system and conventional Building system was also taken into account to calculate the cost due to time elapsed as time also plays an important role in determining the cost of the construction. Any one of the following three methods can be employed to carry out the estimation of the building quantities:

- Centre line method
- Long wall – short wall method
- Partly centre line and short wall method

3.12.1. Centre line method

This technique is appropriate for walls of similar cross sections. Here, the total centre line length is multiplied by width and depth of the individual component to get the total quantity at an instance. When cross walls, partition walls, false walls, or verandah walls join with main wall, half of width at each joint reduces the centre line length. Such junction or joints are calculated cautiously while calculating total centre line length. The estimation prepared by this technique is most precise and quick.

3.12.2. Long wall-short wall method

In this method, the larger wall along the length of room is measured to be long wall whereas the shorter wall perpendicular to long wall is said to be short wall. To get the span of long wall or short wall, compute the centre line length of each wall first. After that, the length of long wall, (out to out) may be calculated by adding half width of the wall at each end to its centre line length i.e., long wall equals to centerline length plus the width of the wall. Similarly, the length of short wall is measured (in to in) and may be calculated by deducting half width from its centre line length at each end i.e., short wall equals to centerline length minus the width of the wall. The length of long wall typically decreases from earthwork to brick work in super structure whereas the short wall increases. These lengths are multiplied by width and depth to get quantities and then are used for estimated.

3.12.3. Partly centre line and partly cross wall method:

This technique is adopted when outer (i.e., around the building) wall is of one thickness and the internal walls having different thicknesses. In such cases, centre line method is applied to outer walls and long wall-short wall method is applied for internal walls. This technique suits for variable thicknesses of the walls and different levels of foundations. It is because of this reason; all Engineering departments prefer this technique for calculations purposes. The estimation for prefabricated system is carried out based on the Material, Labour and size of panels used for erection activity.

For the calculations, Excel sheet was prepared with the help of guidance gained during the project. The Excel sheet comprises of sections and columns for each material and percentage with formulae established during the work. Basically the calculations were done manually taking the Excel as an Aid to the complex calculations.

The cost analysis was done under strict guidance of few well known evaluators who have been working in the field for last decade. Even though all the components affecting the cost have been taken into account during calculations, the costs of few elements have been skipped intentionally as they bring no difference in the cost comparison of the structures. They are common in all the models like cost of Doors and windows, cost of painting, cost of plumbing and electrification, cost of interior decoration, cost of electrical appliances.

Even though our results show only the direct costs and ignoring the payback calculation, if those were also included in the thesis, the saving in gfrg would have been increased by approximately up to 35% due to early finishing and quicker returns in form of sale or rent, reducing the negative cash flow period.

Chapter 4

RESULTS

4.1. STRUCTURE ANALYSIS RESULTS

After the completion of model, the model was checked and found to be free from any warning and errors. It was then analyzed and the result were obtained. It was found that all the three structures are safe under the applied loads and all the deformations are under permissible limits, hence proving our structure is safe and now we can move to calculation of cost analysis

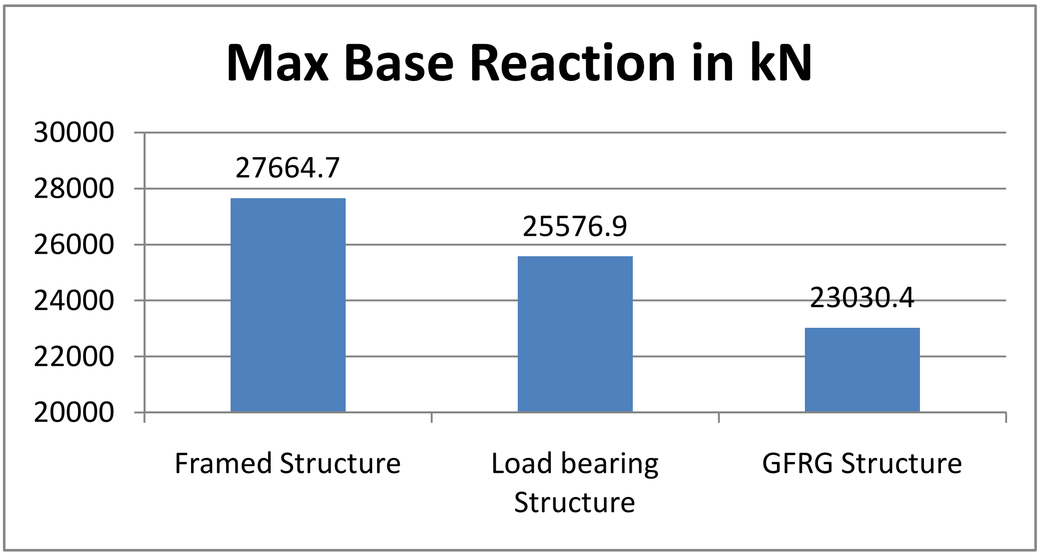


Table 6 – Max Base Reactions

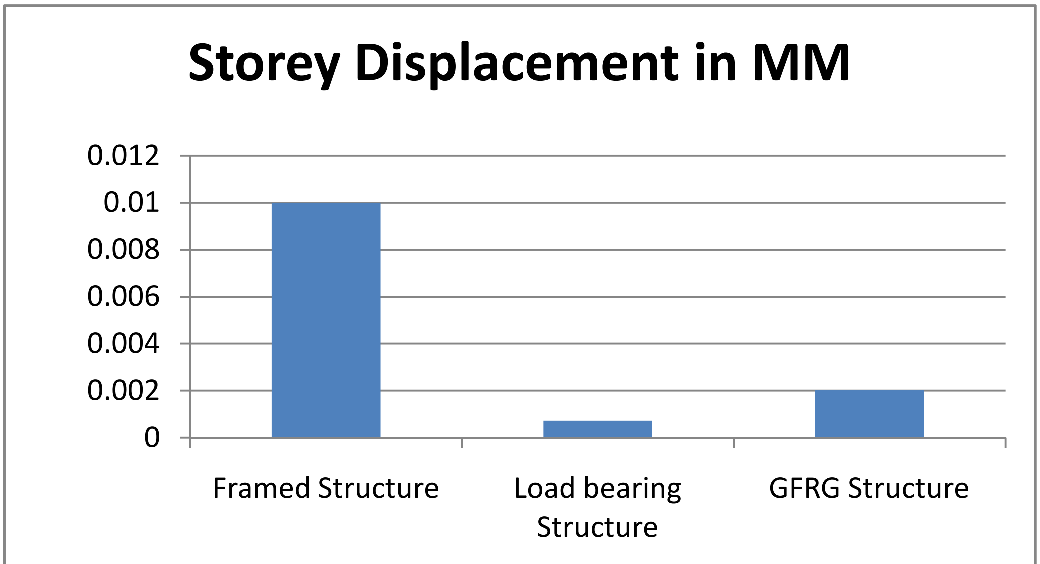


Table 7 – Storey Displacement

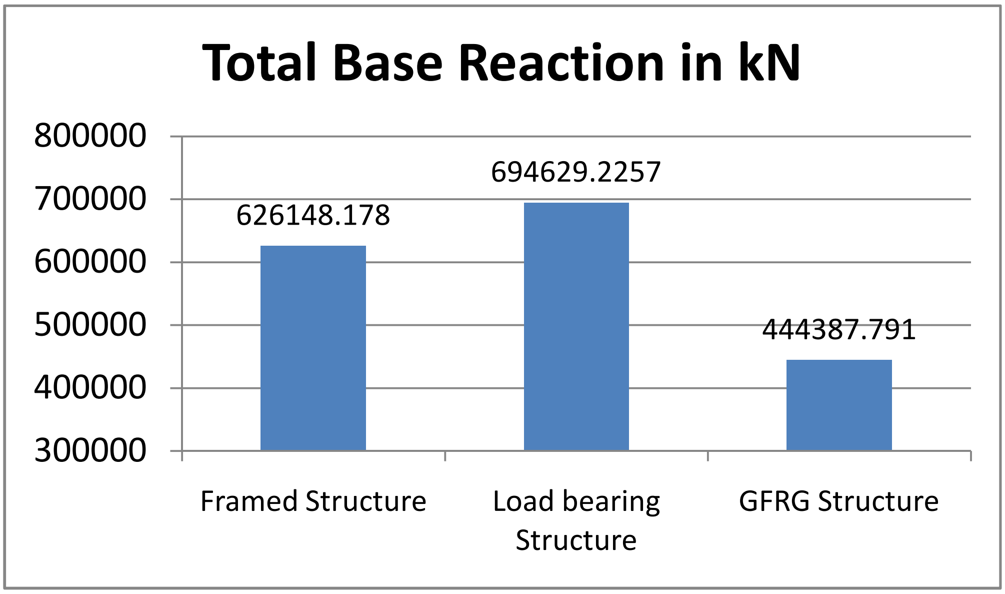


Table 8 – Total Base Reactions

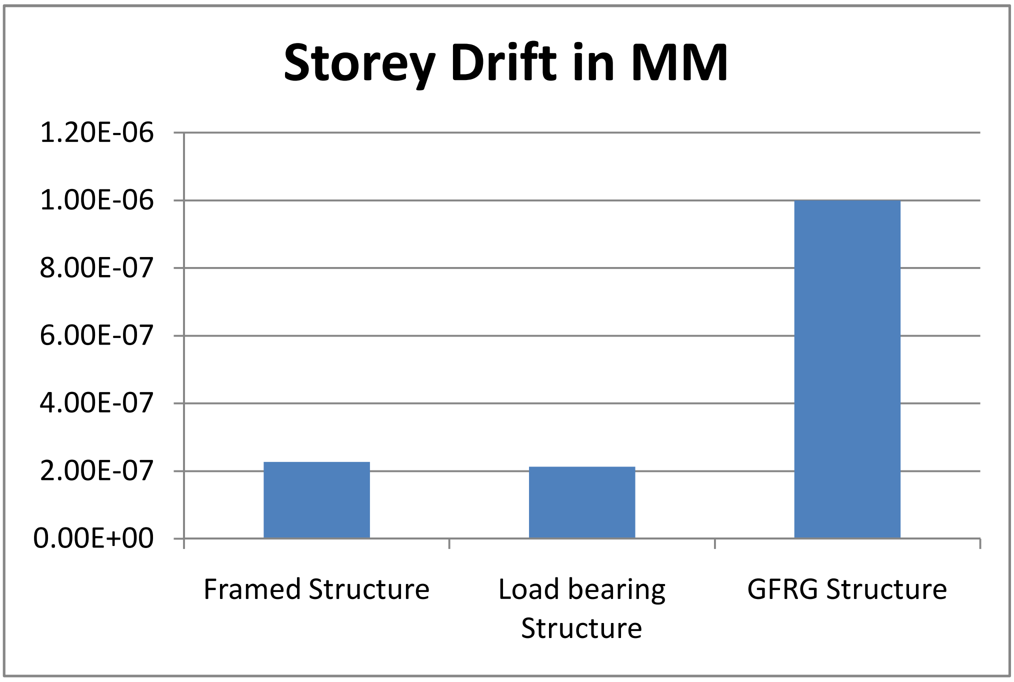


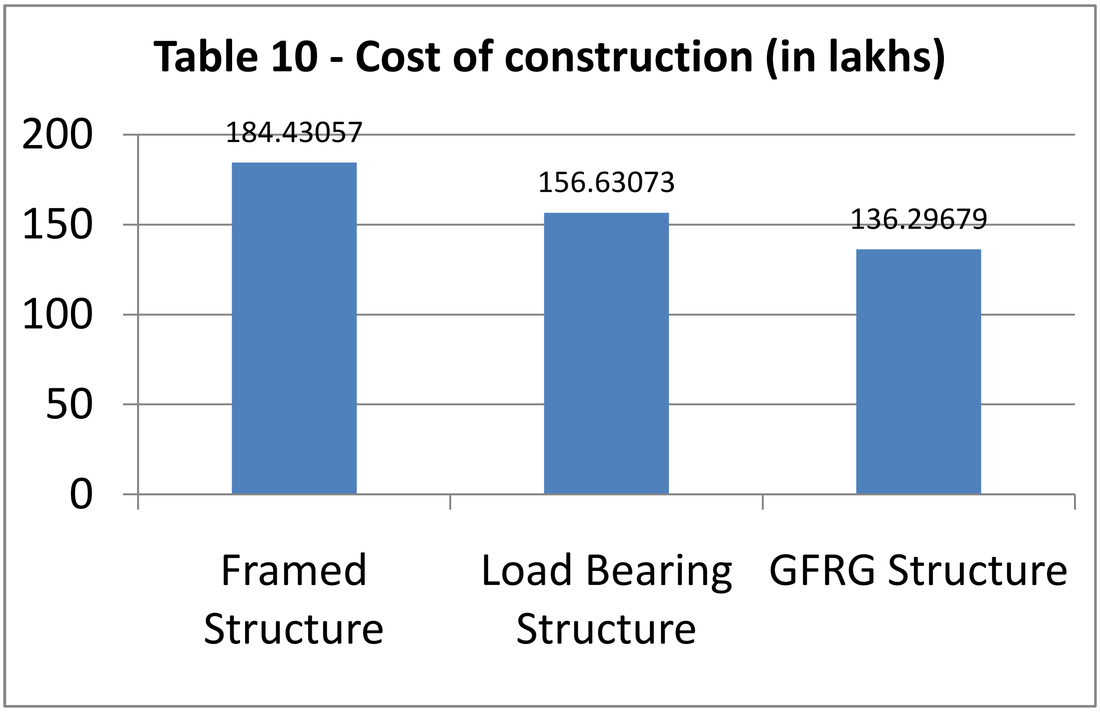
Table 9 – Storey Drift

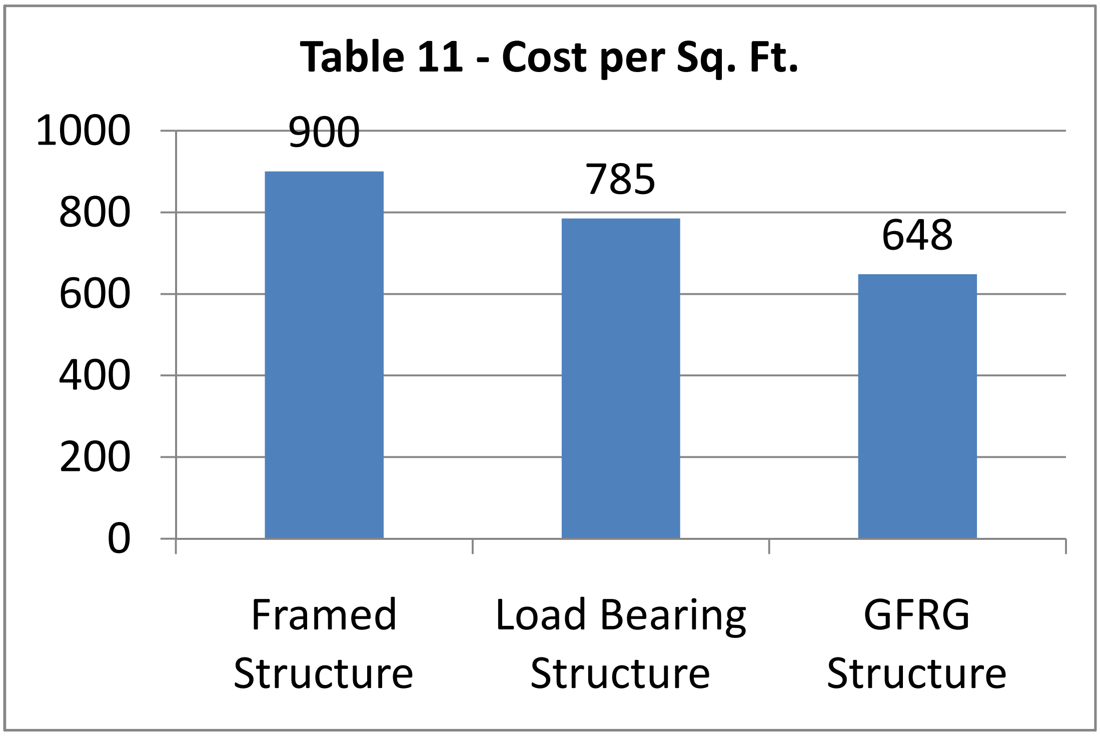
Smaller base reactions mean lesser load on the ground, on soil. That means smaller foundation work is required for that structure which will be a huge money saving in construction process also reducing the depth of foundation so less excavation will be required.

Max Storey displacement allowed – 0.004H = 0.004 X 12 = 0.048 m = 48 mm.

So we are under safe limit.

4.2. COST ANALYSIS RESULT





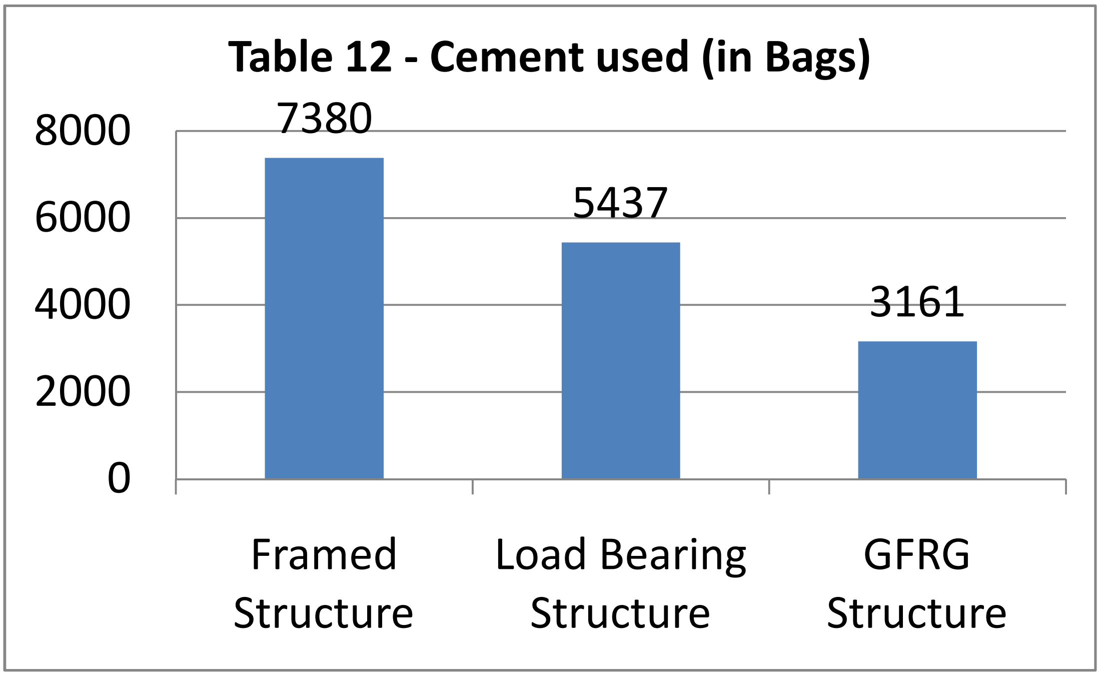


Table 12 - Cement used (in Bags)
8000
6000
4000
2000
0
7380
5437
3161
Framed Structure
Load Bearing Structure
GFRG Structure

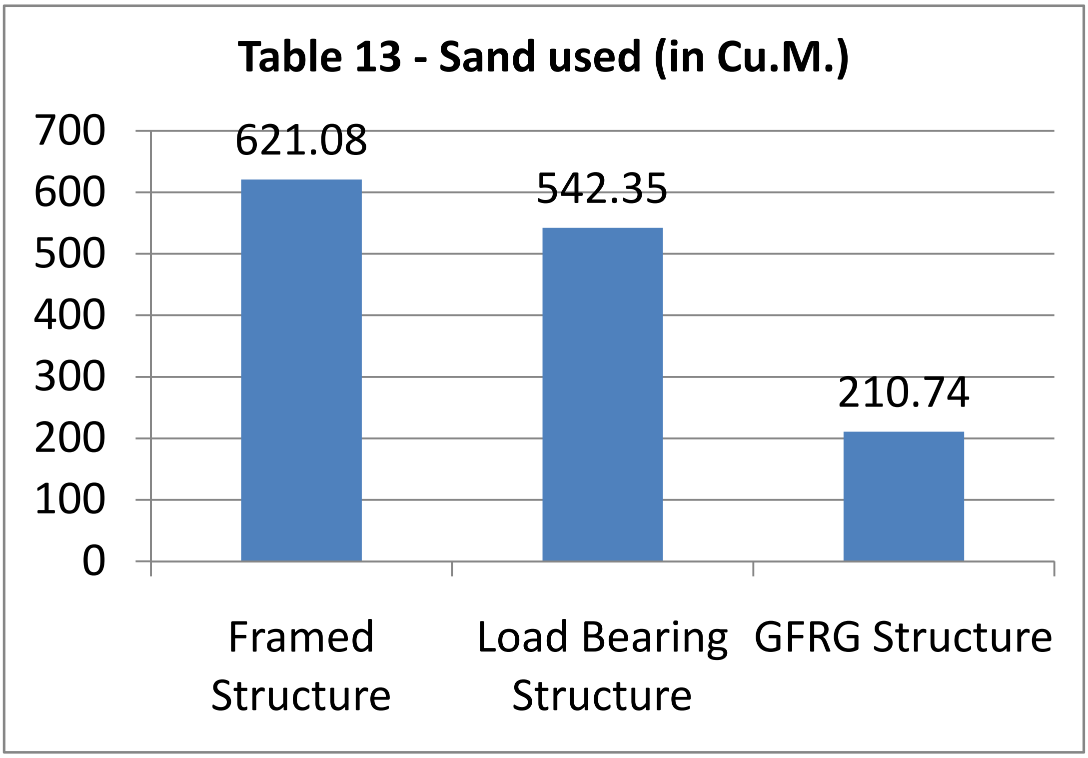


Table 13 - Sand used (in Cu.M.)
700
600
500
400
300
200
100
0
621.08
542.35
210.74
Framed Structure
Load Bearing Structure
GFRG Structure

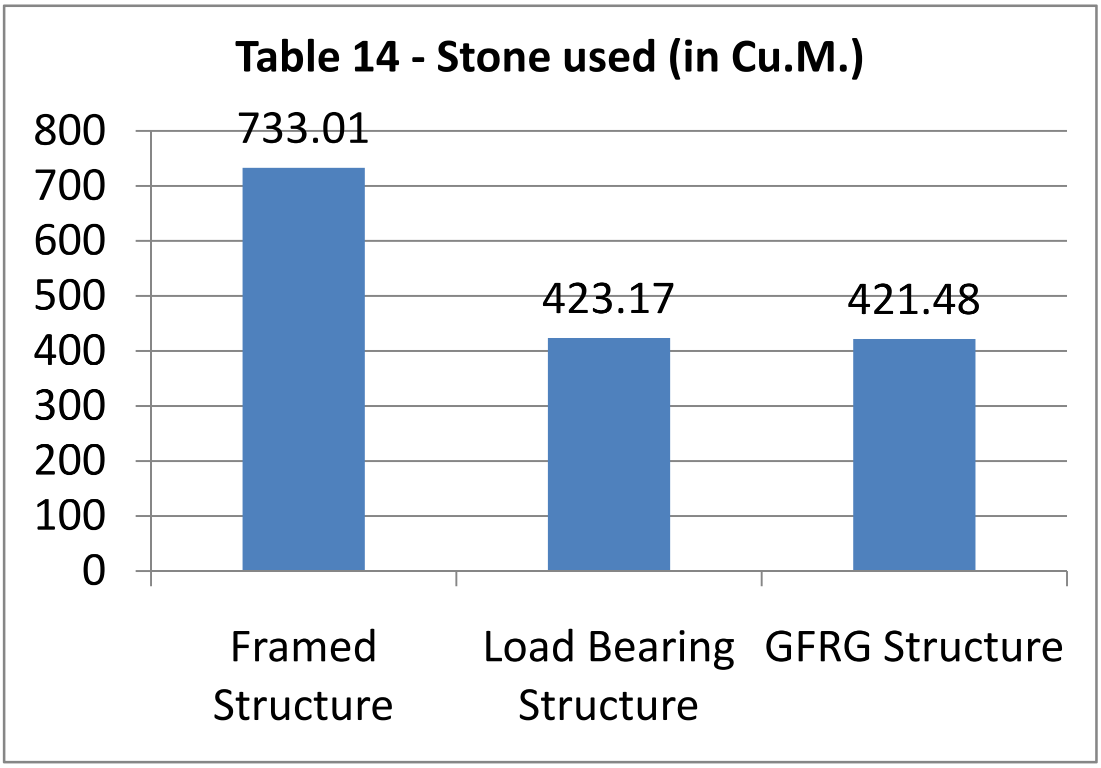


Table 14 - Stone used (in Cu.M.)
800
700
600
500
400
300
200
100
0
733.01
423.17
421.48
Framed Structure
Load Bearing Structure
GFRG Structure

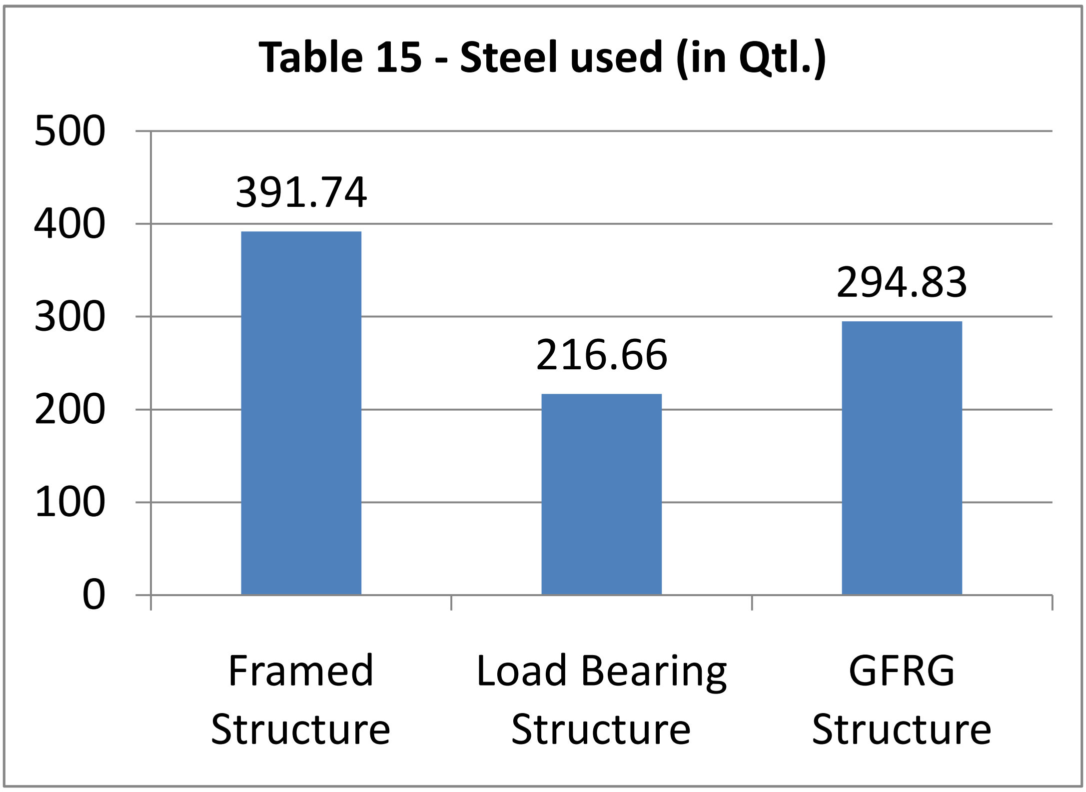


Table 15 - Steel used (in Qtl.)
500
400
300
200
100
0
391.74
216.66
294.83
Framed Structure
Load Bearing Structure
GFRG Structure

Description	Types of Building			Savings/Benefits in GFRG when compared to	
	GFRG building	Load bearing wall Str.	RCC Framed Str.	Load bearing wall Str.	RCC Framed Str.
Dwelling units	16	16	16	-	-
Carpet Area	122.19 SqM	116.02 SqM	119.02 SqM	5.32%	2.66%
Total Build up area	2341.36 sqm	2341.36 sqm	2341.36 sqm	-	-
Excavation	Rs. 74,560	Rs. 83,987	Rs. 95,025	11.22%	21.54%
Steel	Rs. 16,21,540	Rs. 11,91,679	Rs. 21,54,550	-36.07%	24.74%
Cement	Rs. 14,22,490	Rs. 24,46,373	Rs. 33,20,647	41.85%	57.16%
Bricks	-	Rs. 25,33,360	Rs. 15,45,745	-	-
Panels	Rs. 67,89,126	0	0	-	-
Course Aggregate	Rs. 13,47,046	Rs. 13,52,470	Rs. 23,42,706	0.40%	42.50%
Fine Aggregate	Rs. 4,09,045	Rs. 10,52,702	Rs 12,05,517	61.14%	66.07%
Shuttering cost	Rs. 0	Rs. 4,85,590	Rs 8,13,477	100%	100%
Labour	Rs.6,24,271	Rs. 27,71,050	Rs. 28,91,952	77.47%	78.41%
Sub Total	Rs. 1,22,88,078	Rs. 1,19,17,211	Rs. 1,42,74,596	-	-
Miscelaneous	Rs. 13,41,600	Rs. 37,45,862	Rs. 41,68,461		
Total	Rs. 1,36,29,679	Rs. 1,56,63,073	Rs. 1,84,43,057	12.98%	26.10%

Table 16 – Cost Calculation

foundtion			
type	raft foundation		
total area	587.84		
depth	0.45	0.61	
particular	rate/m2 or m3	quantity	cost
excavation charge	INR 265.00	358.5824	INR 95,024.34
PCC	INR 8,154.02	94.0544	INR 766,921.46
rcc raft charge with steel	INR 11,392.15	264.528	INR 2,899,331.37
super structure			
no of storeys	4		
column size	0.23x0.46		
no of columns	40		
height of column	2.7		
total volumn of conc	45.7056	INR 18,781.93	INR 858,439.52
beam size	.23x.3		
total running length of beam	280.71		
total vol of beam	77.47596	INR 11,777.45	INR 912,468.89
SLAB roof			
total area of slab per floor	585.34		
depth of slab	0.15		
total vol of conc req/ floor	87.801		
total vol of conc req	351.204	INR 12,308.81	INR 4,322,903.89
WALL			
BRICK WORK			
type	0.23	0.115	
length	147.51	113.68	
height	2.7	2.7	
vol of brick	91.60371	35.29764	
surface area of wall both side	796.554	613.872	
openings /floor	52.8	37.8	90.6
vol after opening	79.45971	30.95064	
surface area after opening	690.954	538.272	
total vol of 4 floors	317.83884	123.80256	441.6414
total SA of 4 floors	2763.816	2153.088	4916.904
cost of brickwork(class 1 brick + 1:	INR 1,933,938.10	INR 753,295.25	2687233.345
cost of 12 MM plaster both side	INR 564,233.04	INR 439,552.92	1003785.952
FLOORING-tiles + 20mm cement mortar			
floor area/ floor	585.34		
total floor area	2341.36	INR 3,220,306.54	
			INR 16,766,415.30

	quantity	cement		sand	stone	steel			labour	shuttering	total
		m3	bags			@	m3	qt	rs		
pcc foundation	94.0544	20.69197	620.75904	41.383936	82.767872	0.00%	0	0	142727.552	0	
		rs	INR 279,341.57	INR 80,326.22	INR 264,526.12			INR 0.00	INR 142,727.55	0	INR 766,921.46
raft foundation	264.528	58.19616	1745.8848	116.39232	232.78464	0.65%	1.719432	134.975412	401421.24	0	
		rs	INR 785,648.16	INR 225,917.49	INR 743,979.71			INR 742,364.77	INR 401,421.24	0	INR 2,899,331.37
column	45.7056	10.05523	301.65696	20.110464	40.220928	0.80%	0.3656448	28.7031168	69358.248	rate 550/m2	
		rs	INR 135,745.63	INR 39,034.41	INR 128,546.09			INR 157,867.14	INR 69,358.25	INR 327,888.00	INR 858,439.52
beam	77.47596	17.04471	511.341336	34.0894224	68.1788448	0.35%	0.27116586	21.28652001	117569.7693	rate 550/m2	
		rs	INR 230,103.60	INR 66,167.57	INR 217,899.59			INR 117,075.86	INR 117,569.77	INR 163,652.50	INR 912,468.89
slab	351.204	77.26488	2317.9464	154.52976	309.05952	0.75%	2.63403	206.771355	532952.07	rate 550/m2	
		rs	INR 1,043,075.88	INR 299,942.26	INR 987,754.23			INR 1,137,242.45	INR 532,952.07	INR 321,937.00	INR 4,322,903.89
wall	441.6414										
brick	220820.7	19.87386	596.21589	119.243178	0	0.00%	0	0	647004.651	rate 550/m2	
	INR 1,545,744.90	rs	INR 268,297.15	INR 231,451.01	INR -			INR 0.00	INR 647,004.65	INR -	INR 2,692,497.71
plaster	4916.904	14.75071	442.52136	88.504272	0	0.00%	0	0	636739.068	rate 550/m2	
		rs	INR 199,134.61	INR 171,786.79	INR -			INR 0.00	INR 636,739.07	INR -	INR 1,007,660.47
flooring	2341.36	28.09632	842.8896	46.8272	0	0.00%	0	0	344179.92	rate 550/m2	
tiles	INR 2,405,934.71	rs	INR 379,300.32	INR 90,891.60	INR -			INR 0.00	INR 344,179.92	INR -	INR 3,220,306.54
total			7379.215386	621.0805524	733.0118048			391.7364038			
			INR 3,320,646.92	INR 1,205,517.35	INR 2,342,705.73			INR 2,154,550.22	INR 2,891,952.52	INR 813,477.50	INR 16,680,529.85

Table 17 – Cost Calculation of Framed Structure

foundation	width	depth/height	area	volume	rate	cost
excavation	Total area	0.5	562.7182	281.3591	265	74560.1615
rcc step 1	Total area	0.15	562.7182	84.40773		
rcc step 2	1.3 M	0.2	308.0348	61.60696		
rcc step 3	0.2M	0.15	52.668	7.9002		
lintel beam	0.15 M	0.15	52.668	7.9002	16500	INR 2,339,452.99
length of panel	1072.4	3				
	for 4 floors					
area of concrete per meter run of wall			0.028571429	0.085714286		
area of steel per mt run in wall			0.000415171	0.001245514		
slab						
surface		0.05	2883.41			
microbeam	0.23	0.16	volume per floor	19.07		
			76.23			
opening	90.6	43.14285714				
vol of beam /m2	0.03765	2250.8728	flooring	2962703.775		
cost of panels	INR 6,789,126.00					
						INR 15,353,320.88
wall	2.7	60.0392	162.10584	565.07136		INR 4,452,657.57
beam	0.15	60.0392	9.00588	36.02352		INR 511,825.04
slab	0.15	585.34	87.801	351.204		INR 4,322,903.89
opening	0.23	90.6	20.838	83.352		
flooring	0.02	585.34		2341.36		INR 3,220,306.54
						INR 14,323,143.44

	quantity	cement		sand	stone	steel			labour	shuttering	total
		m3	bags			@	m3	qt	rs		
pcc foundation	93.6544	20.603968	618.11904	41.207936	82.415872	0.00%	0	0	142120.552	0	
		rs	INR 278,153.57	INR 79,984.60	INR 263,401.13			INR 0.00	INR 142,120.55	0	INR 763,659.85
raft foundation	0	0	0	0	0	0.65%	0	0	0	0	
		rs	INR -	INR -	INR -			INR 0.00	INR -	0	INR -
column	0	0	0	0	0	0.80%	0	0	0	rate 550/m2	
		rs	INR -	INR -	INR -			INR 0.00	INR -	INR -	INR -
beam	36.02352	7.9251744	237.755232	15.8503488	31.7006976	0.35%	0.12608232	9.89746212	54665.6916	rate 550/m2	
		rs	INR 106,989.85	INR 30,765.53	INR 101,315.43			INR 54,436.04	INR 54,665.69	INR 163,652.50	INR 511,825.04
slab	351.204	77.26488	2317.9464	154.52976	309.05952	0.75%	2.63403	206.771355	532952.07	rate 550/m2	
		rs	INR 1,043,075.88	INR 299,942.26	INR 987,754.23			INR 1,137,242.45	INR 532,952.07	INR 321,937.00	INR 4,322,903.89
wall	0										
brick	0	0	0	0	0	0.00%	0	0	0	rate 550/m2	
	INR -	rs	INR -	INR -	INR -			INR 0.00	INR -	INR -	INR -
plaster	0	0	0	0	0	0.00%	0	0	0	rate 550/m2	
		rs	INR -	INR -	INR -			INR 0.00	INR -	INR -	INR -
flooring	2341.36	28.09632	842.8896	46.8272	0	0.00%	0	0	344179.92	rate 550/m2	
tiles	INR 2,405,934.71	rs	INR 379,300.32	INR 90,891.60	INR -			INR 0.00	INR 344,179.92	INR -	INR 3,220,306.54
total			5436.384528	542.350096	423.1760896	0.0255	2.76011232	216.6688171	2771049.148		0
			INR 2,446,373.04	INR 1,052,701.54	INR 1,352,470.78	INR -	INR -	INR 1,191,678.49	INR 2,771,049.15	INR 485,589.50	INR 14,239,156.57
foundation calculation											
step 1	70.7712										
brick	35385.6	3.184704	95.54112	19.108224	0	0.00%	0	0	103679.808	rate 550/m2	
	INR 247,699.20	rs	INR 42,993.50	INR 37,089.06	INR -			INR 0.00	INR 103,679.81	INR -	INR 431,461.57
plaster	0	0	0	0	0	0.00%	0	0	0	rate 550/m2	
		rs	INR -	INR -	INR -			INR 0.00	INR -	INR -	INR -
step 2	53.1552										
brick	26577.6	2.391984	71.75952	14.351904	0	0.00%	0	0	77872.368	rate 550/m2	
	INR 186,043.20	rs	INR 32,291.78	INR 27,857.05	INR -			INR 0.00	INR 77,872.37	INR -	INR 324,064.40
plaster	0	0	0	0	0	0.00%	0	0	0	rate 550/m2	
		rs	INR -	INR -	INR -			INR 0.00	INR -	INR -	INR -
step 3	34.8192										
brick	17409.6	1.566864	47.00592	9.401184	0	0.00%	0	0	51010.128	rate 550/m2	
	INR 121,867.20	rs	INR 21,152.66	INR 18,247.70	INR -			INR 0.00	INR 51,010.13	INR -	INR 212,277.69
plaster	0	0	0	0	0	0.00%	0	0	0	rate 550/m2	
		rs	INR -	INR -	INR -			INR 0.00	INR -	INR -	INR -
wall	565.07136										
brick	282535.68	25.4282112	762.846336	152.5692672	0	0.00%	0	0	827829.5424	rate 550/m2	
	INR 1,977,749.76	rs	INR 343,280.85	INR 296,136.95	INR -			INR 0.00	INR 827,829.54	INR -	INR 3,444,997.10
plaster	4916.904	14.750712	442.52136	88.504272	0	0.00%	0	0	636739.068	rate 550/m2	
		rs	INR 199,134.61	INR 171,786.79	INR -			INR 0.00	INR 636,739.07	INR -	INR 1,007,660.47

Table 18 – Cost Calculation of Load Bearing Structure

foundation	width	depth/height	area	volume	rate	cost
excavation	Total area	0.5	562.7182	281.3591	265	74560.1615
rcc step 1	Total area	0.15	562.7182	84.40773		
rcc step 2	1.3 M	0.2	308.0348	61.60696		
rcc step 3	0.2M	0.15	52.668	7.9002		
lintel beam	0.15 M	0.15	52.668	7.9002	16500	INR 2,339,452.99
length of panel	1072.4	3				
	for 4 floors					
area of concrete per meter run of wall			0.028571429	0.085714286		
area of steel per mt run in wall			0.000415171	0.001245514		
slab						
surface		0.05	2883.41			
microbeam	0.23	0.16	volume per floor	19.07		
			76.23			
opening	90.6	43.14285714				
vol of beam/m2	0.03765	2250.8728	flooring	2962703.775		
cost of panels	INR 6,789,126.00					
						INR 15,353,320.88

	quantity	cement		sand	stone	steel			labour	shuttering	total
		m3	bags			@	m3	qt	rs		
rcc foundation	161.81509	35.5993198	1067.979594	71.1986396	142.3972792	1.46%	2.362500314	185.4562746	245554.3991	rate 550/m2	
		rs	INR 480,590.82	INR 138,196.56	INR 455,101.70			INR 1,020,009.51	INR 245,554.40	INR -	INR 2,339,452.99
conc in wall	88.22204082	19.40884898	582.2654694	38.81769796	77.63539592	0.75%	0.661665306	51.94072653	133876.9469	rate 0/m2	
		rs	INR 262,019.46	INR 75,345.15	INR 248,122.73			INR 285,674.00	INR 133,876.95	INR -	INR 1,005,038.28
conc in slab beam	84.74536092	18.6439794	559.3193821	37.2879588	74.57591761	0.51%	0.428811526	33.66170481	128601.0852	rate 0/m2	
		rs	INR 251,693.72	INR 72,375.93	INR 238,344.63			INR 185,139.38	INR 128,601.09	INR -	INR 876,154.74
			INR 994,304.00	INR 285,917.64	INR 941,569.06			INR 1,490,822.88	INR 508,032.43	INR -	
conc in slab	144.1705	31.71751	951.5253	63.43502	126.87004	0.21%	0.30275805	23.76650693	218778.7338	rate 0/m2	
		rs	INR 428,186.39	INR 123,127.37	INR 405,476.65			INR 130,715.79	INR 218,778.73	INR -	INR 1,306,284.93
			INR 1,422,490.39	INR 409,045.01	INR 1,347,045.71			INR 1,621,538.67	INR 726,811.16		INR 5,526,930.94

Table 19 – Cost Calculation of GFRG Structure

Chapter 5

CONCLUSION

5.1. CONCLUDING REMARKS

Prefabricated structure is the need of the hour due to high demand. It is Suitable to Indian climatic and hazard conditions. These emerging technologies are cost effective in relation to conventional construction system (RCC and masonry construction). Prefab helps to reduce the dependency on cement, aggregates and water in constructions, in particular, the fine aggregate (sand) and water. Prefabrication can help to standardize the construction process on manufacturing line to improve the quality of construction due to the shortage of skilled labor. It increases Speed of construction and quality.

In addition, traditional construction cannot be green buildings normally. But green buildings are the order of the day, in view of energy scarcity and, fast depletion of precious natural materials. There are several alternative building techniques present in the construction industry backed by BMTPC, suitable of Indian Subcontinent. GFRG is compatible and adherence of the system to established standards and IS codes.

Panel systems are structurally strong and stable. The panels also have good life span compared to conventional materials also help us save the environment by reducing our carbon footprints. GFRG Structure is much more cost effective and the time saving. Most of the people and engineers, suffer from lack of awareness about this type of building practices for residential buildings.

All the three models were found safe in earthquake Zone V with response reduction factor = 3 (Table 7, IS 1893:2002), (GFRG Manual). All the Deformations are under acceptable limits under all load combinations. The cost of construction of prefabricated GFRG structure is less then both the building types. GFRG is one of the best alternative construction technologies for the Indian Subcontinent due to large availability of Gypsum as by product of fertilizers. GFRG helps us greatly reduce our dependency on the natural materials like sand water stone and great reduction in use of cement further reducing the carbon footprints.

Our finding tells that we can save up to 13% and 26% in direct costs in comparison to Load bearing Structure and RCC Framed Structure respectively. If one opts to go little further to undergo payback cost analysis these results may approximately reach as high as 35% and 50% respectively as the time period of negative cash flow is very small in comparison to other two structures. GFRG starts to payoff in less than half the time just in construction.

5.2. ADVANCED OBJECTIVE

Advanced objective for this thesis includes the some points where the structure could be made lighter and stronger by adding or replacing few items and materials. Our current findings are when we keep all the loads and materials same with same type of building materials. This percentage of savings, the quality of building, living conditions, etc. could be improved by replacing few items such as –

- Replacing wooden doors, windows and ventilators and frames with Fiber or WPC or Aluminum work, which are quite cheaper than wooden frames and panels.
- Using recycled Fibers and plastics can help to reduce plastic waste in the environment.
- Using composite Bamboo as reinforcement and as a replacement of Steel, as theoretically, bamboo fiber with organic resins formed reinforced rebars are stronger than carbon fibers and 100 times cheaper from carbon fiber. In addition, it will help to reduce the Dead load of the structure as its four times lighter than steel for similar strength.
- Glass sheets and glass rods can also replace steel rebars.
- Using Earth Friendly Concrete (made from Blast Furnace Slag and Fly Ash) can potentially bring down the consumption of Cement to zero in concrete as in production of cement, each Kg of cement is responsible of 1Kg of carbon Di Oxide and other harmful gases, i.e., cement production causes equivalent amount of gases.
- Also using EFC, our dependency on Natural sand will reduce.
- Synthetic Sand made using plastic and glass grains can also replace natural sand.
- Using spray form in the cavities can help to increase the sound and heat insulation properties of GFRG wall panels.

All the above points can be used to further reduce the weight of structure, increase strength and quality of structure, reduce our dependency on natural resources and reducing the carbon footprints of the construction on the world.

Through the use of GFRG panels the workability of the construction process may increase and would help in upgrading the workmanship of the labors. It will generate the skilled labour forces that could manage and build the structure without heavy supervision.

Although special precautions would be needed in calculation of loads and installation of panels for the first few times, as this technology would be a new hand experience for the labors and they may cause damage to self and the building due to inproficiency.

References

1. Arifullah P. Sherfudeen, Radhakrishna G. Pillai in Indian Concrete Journal · May 2016 **“Promoting precast concrete for affordable housing - An overview on promotional policies worldwide and challenges and possibilities in India.”**
2. Bindurani.P, A. Meher Prasad, Amlan K. Sengupta in IJIRSET Volume 2, Special Issue 1, December 2013 **“Analysis of precast multistoried building – a case study” -**
3. Bhavin H. Zaveri, Jasmin A. Gadhiya, Hitesh K. Dhameliya Vol. 5, Issue 1, Januray 2016 **“A Review on the Comparative Study of Steel, RCC and Composite Building**”-
4. U. D. Dabhade, N.A.Hedaoo, Dr. L. M. Gupta and Dr. G. N. Ronghe in 26th International Symposium on Automation and Robotics in Construction (ISARC 2009) **“Time and Cost Evaluation of Construction of Steel Framed Composite Floor with Precast Concrete Floor Structure.”**
5. Krish R. Villaitramani, Dhruv P. Hirani International Journal of Innovative Research in Advanced Engineering (IJIRAE) Volume 1 Issue 9 (October 2014) **“Prefabricated construction for mass housing in Mumbai”**
6. A.R. Santhakumar in International Symposia on Low Cost Housing Problems 1970 **“Low cost housing projects in India.” –**
7. Prasad Bhamare, Sagar Bhosale, Akshay Ghanwat, Shubham Gore, Sheetal Jadhv,Sachin Patil in 7th international conference on recent trends in engineering, science and management, April 2017 **“Compare parameters of rcc and prestressed structures**.”
8. A. K. Jain, M. C. Paliwal in World Academy of Science, Engineering and Technology, International Journal of Economics and Management Engineering, Vol:6, No:3, 2012 **“Adoption of Appropriate and Cost EffectiveTechnologies in Housing: Indian Experience.”**
9. A.Sattainathan Sharma, G.R.Iyappan, J.Harish in Journal of Chemical and Pharmaceutical Sciences Volume 8 issue 4, 2015 **“Comparative study of cost and time evaluation in RCC, steel & Composite high rise building.”**

10. R. Anjughap Priya, R. Thirugnanam, A. Sattainathan Sharma and P. Rathna Priya. In Indian Journal of Science and Technology, Vol 9(2), January 2016 **"Comparative Study on Multi-storey Structure of R.C.C and Composite Material."-**
11. N.Dineshkumar, P.Kathirvel. In International Journal of Innovative Science, Engineering & Technology, Vol. 2 Issue 4, April 2015. **"Comparative Study on Prefabrication Construction with Cast In-Situ Construction of Residential Buildings."**
12. Md Azree Othuman Mydin,Mohd Nasrun Mohd Nawi, Nangkula Utaberta and Mohd Yazid Mohd Yunos in Australian Journal of Basic and Applied Sciences · January 2015 **- "Modern Prefab Modular System in Malaysia: Critical Matters and Obstacle."**
13. Fred Edmond Boafo , Jin-Hee Kim and Jun-Tae Kim in Sustainability 2016, 8, 558 - **"Performance of Modular Prefabricated Architecture:Case Study-Based Review and Future Pathways."**
14. Ryan E. Smith, Shilpa Narayanamurthy in his book Without A Hitch: New Directions In Prefabricated Architecture **- "Prefabrication in Developing Countries: a case study of India."**
15. Xudong Zhao and Saffa Riffat. International Journal of Low Carbon Technologies 2/1, April 2018 **- "Prefabrication in house constructions."**

Annexure I

This annexure deals with the designing of the GFRG according to the manual and describes the placement of structural components during the construction of structure to be followed. It also displays the placement of columns and services and describes the placement of joints.

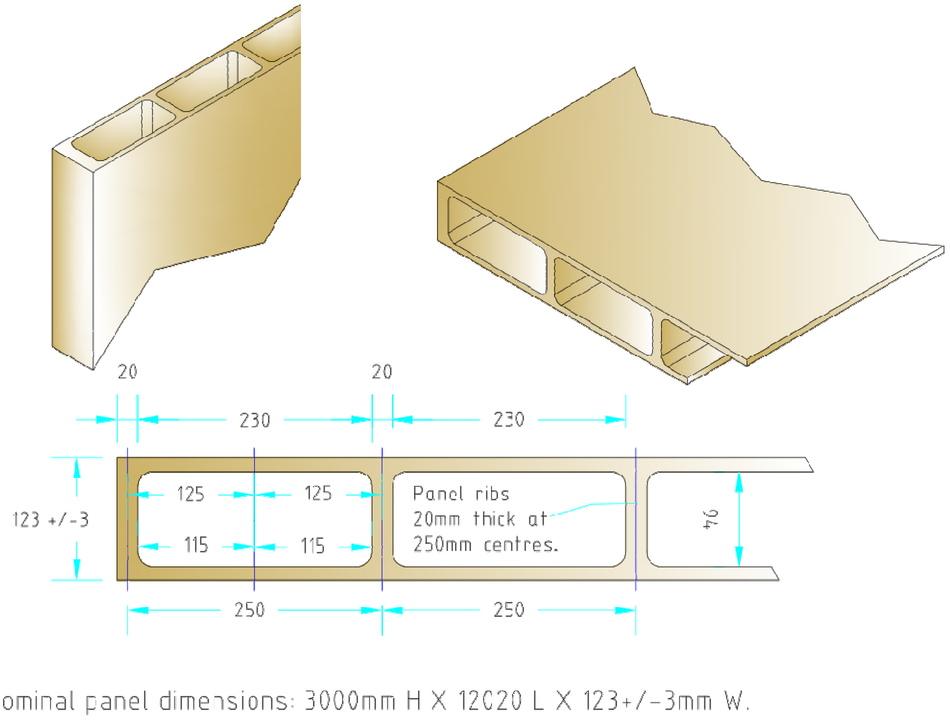


Fig A-1 Sectional View

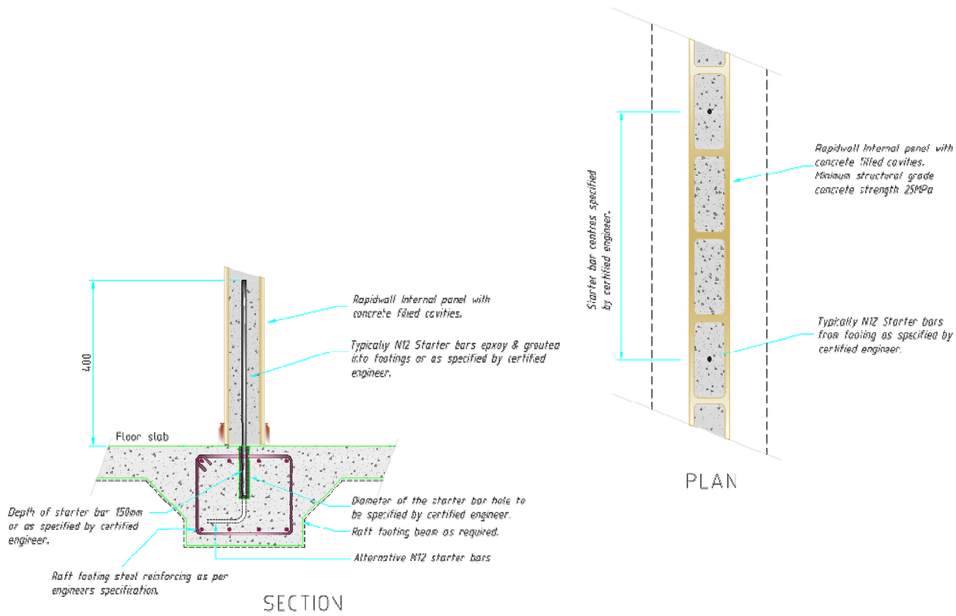


Fig A-2 Concrete filled internal Rapidwall

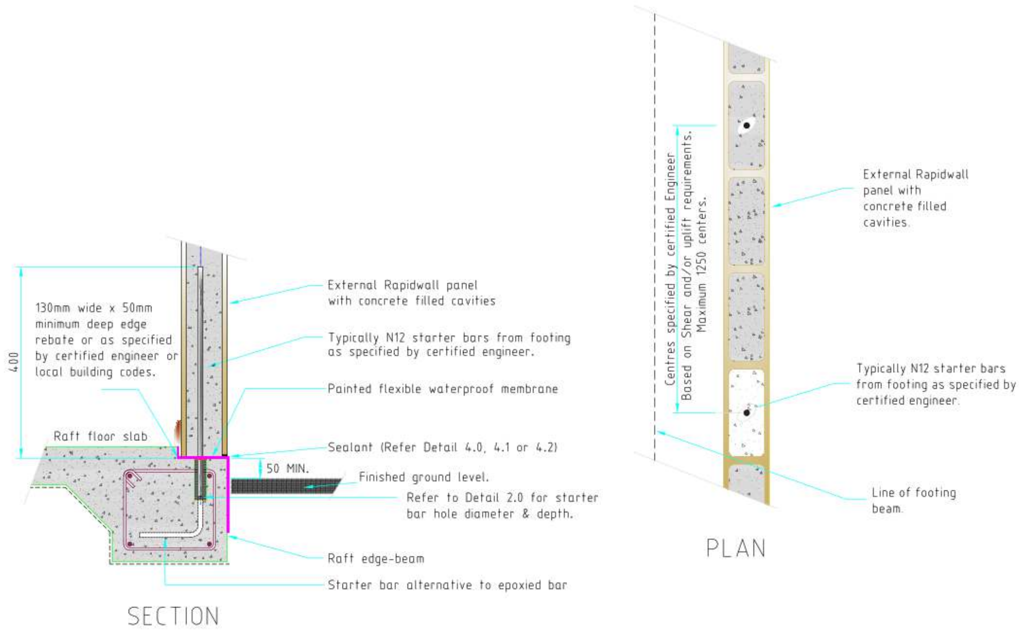


Fig A-3 Concrete filled external Rapidwall

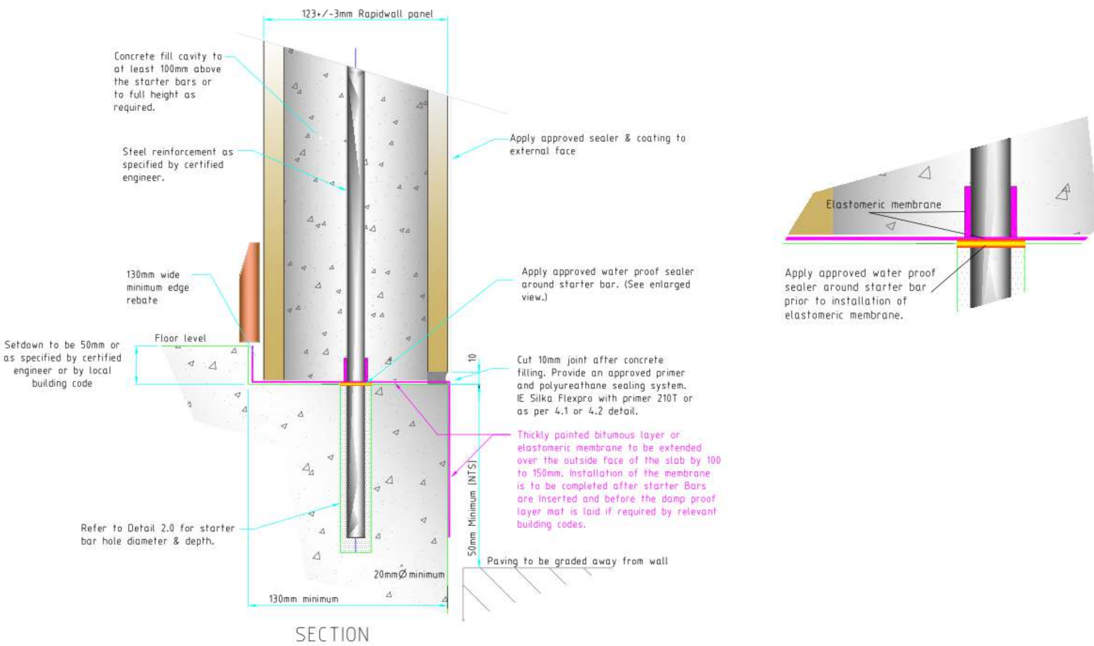


Fig A-4.1 Concrete filled Rapidwall External wall to footing connection option 1 of 3

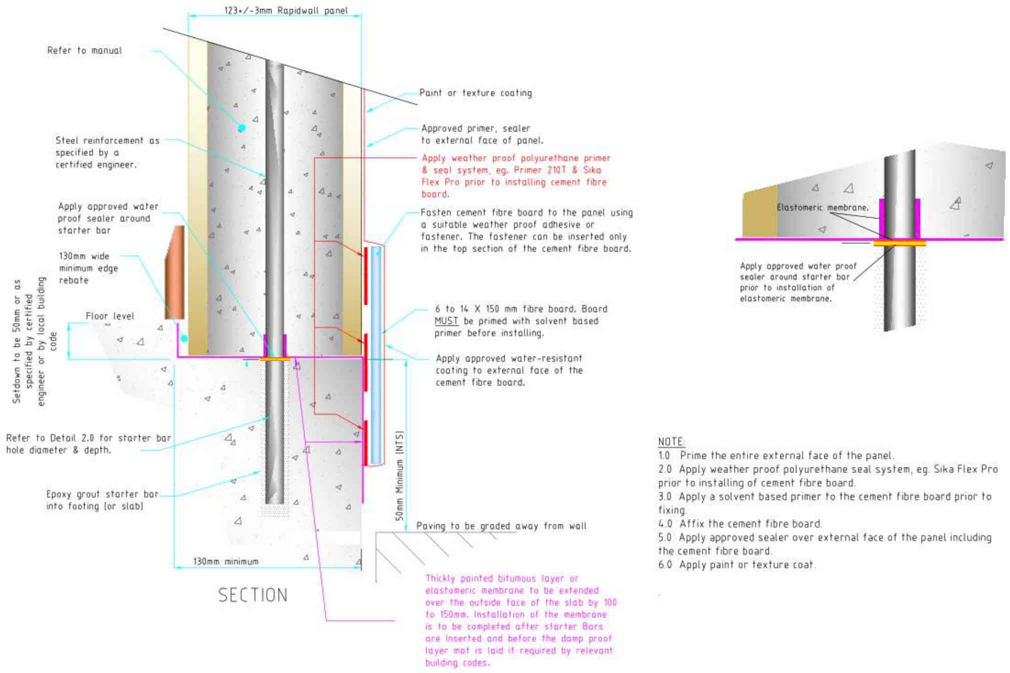


Fig A-4.2 Concrete filled Rapidwall External wall to footing connection option 2 of 3

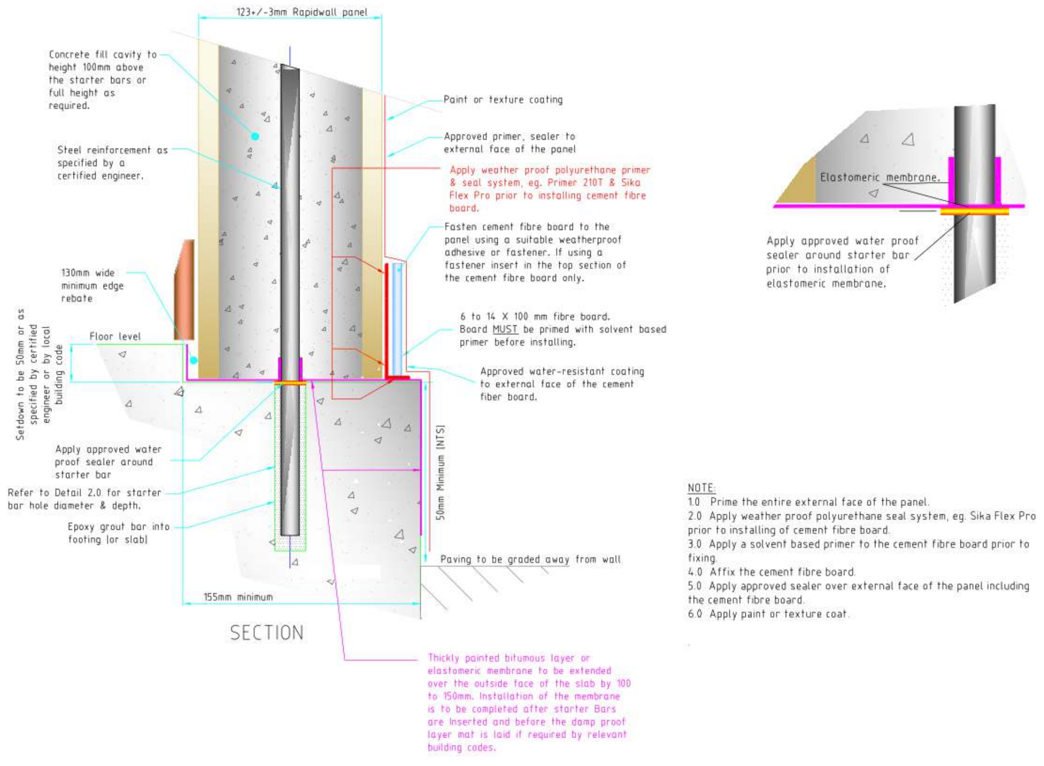


Fig A-4.3 Concrete filled Rapidwall External wall to footing connection option 3 of 3

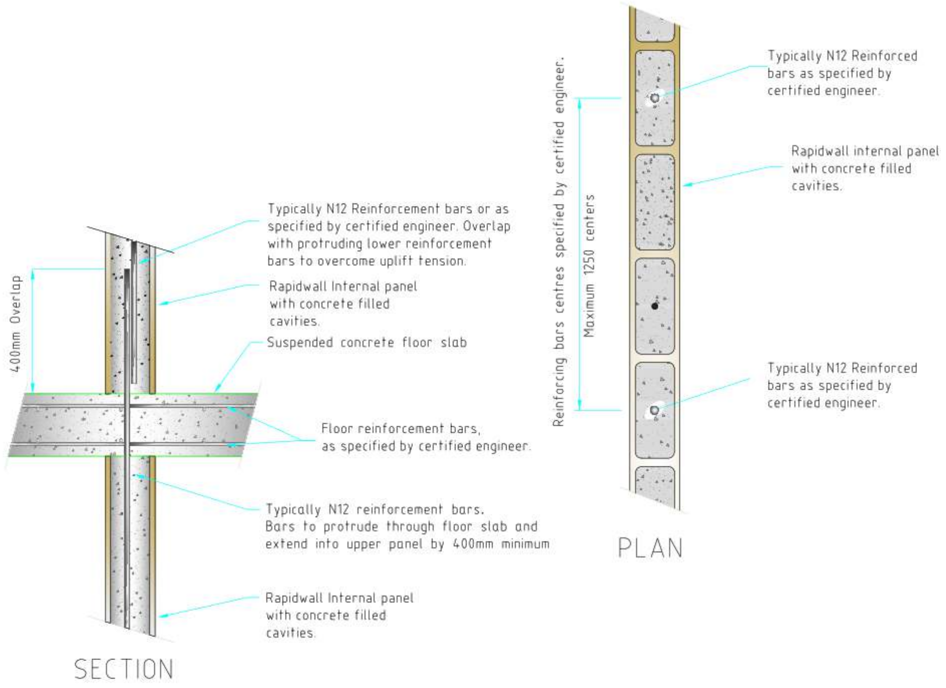


Fig A-5 Concrete filled Rapidwall Internal wall to suspended floor continuously reinforced

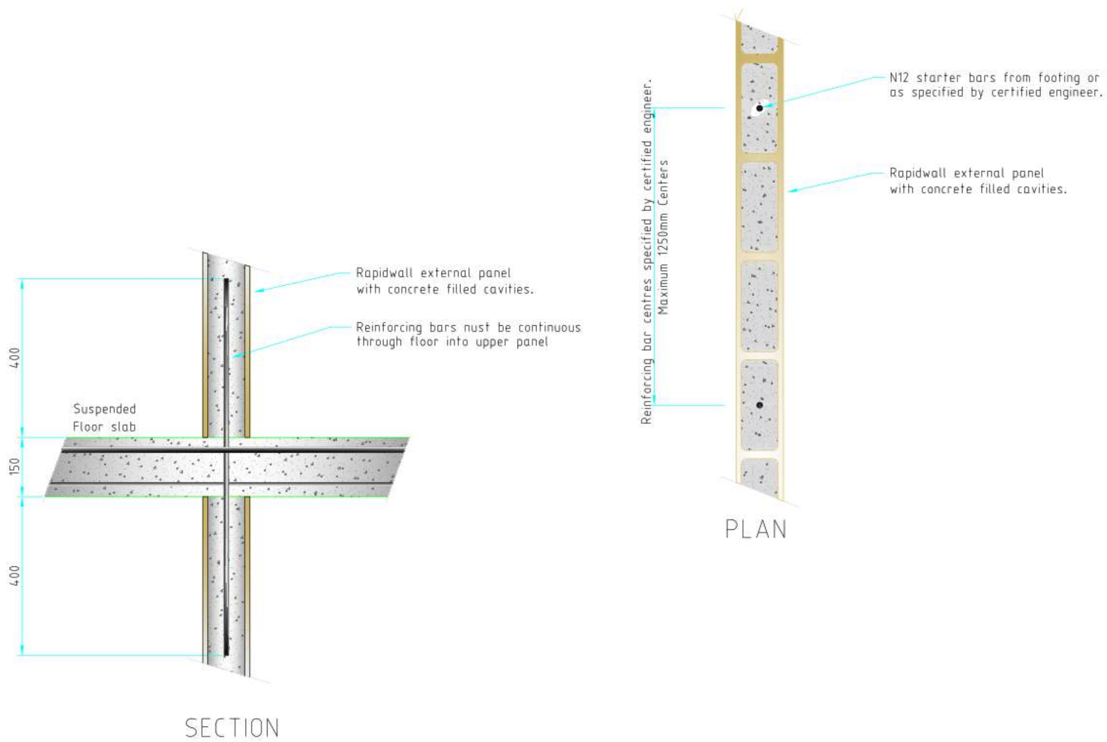


Fig A-6 Concrete filled Rapidwall Internal wall to suspended floor Non-continuous reinforced

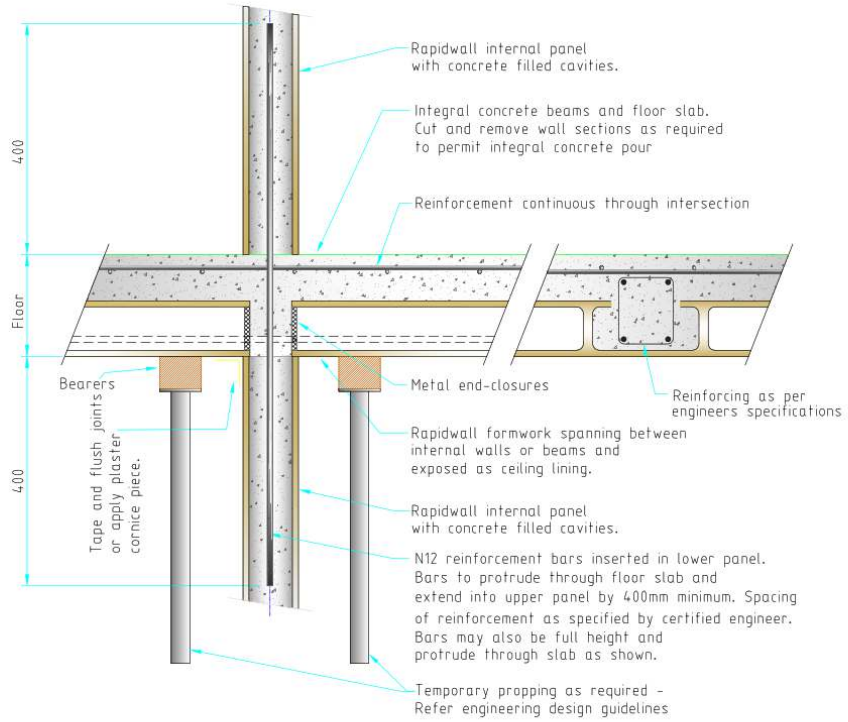
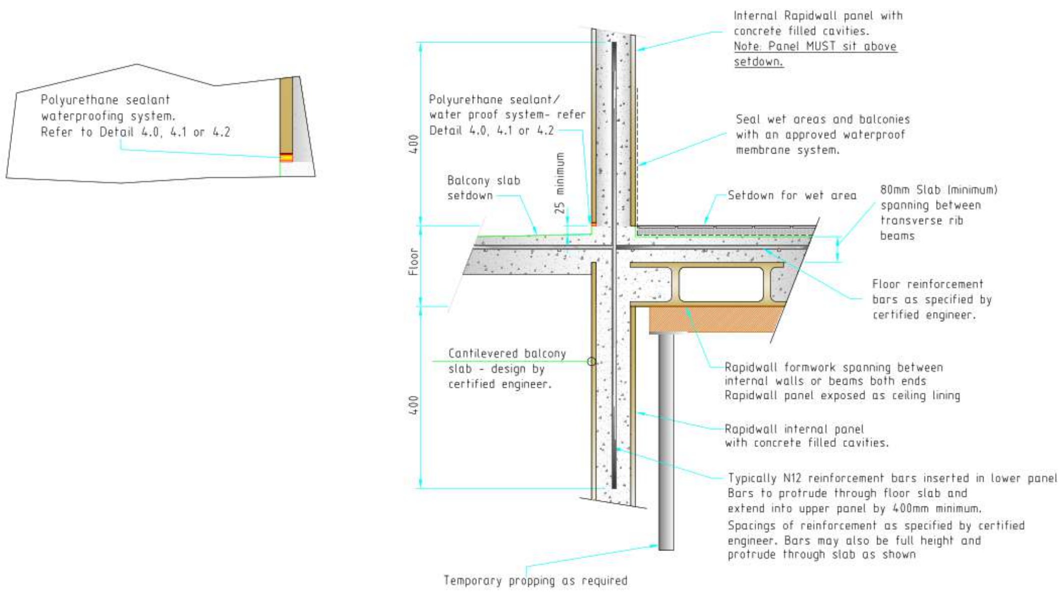


Fig A-7 Concrete filled Rapidwall with Rapidwall slab formwork / ceiling internal wall to suspended slab



SECTION

Fig A-8 Concrete filled Rapidwall with Rapidwall slab formwork / ceiling balcony and set down details

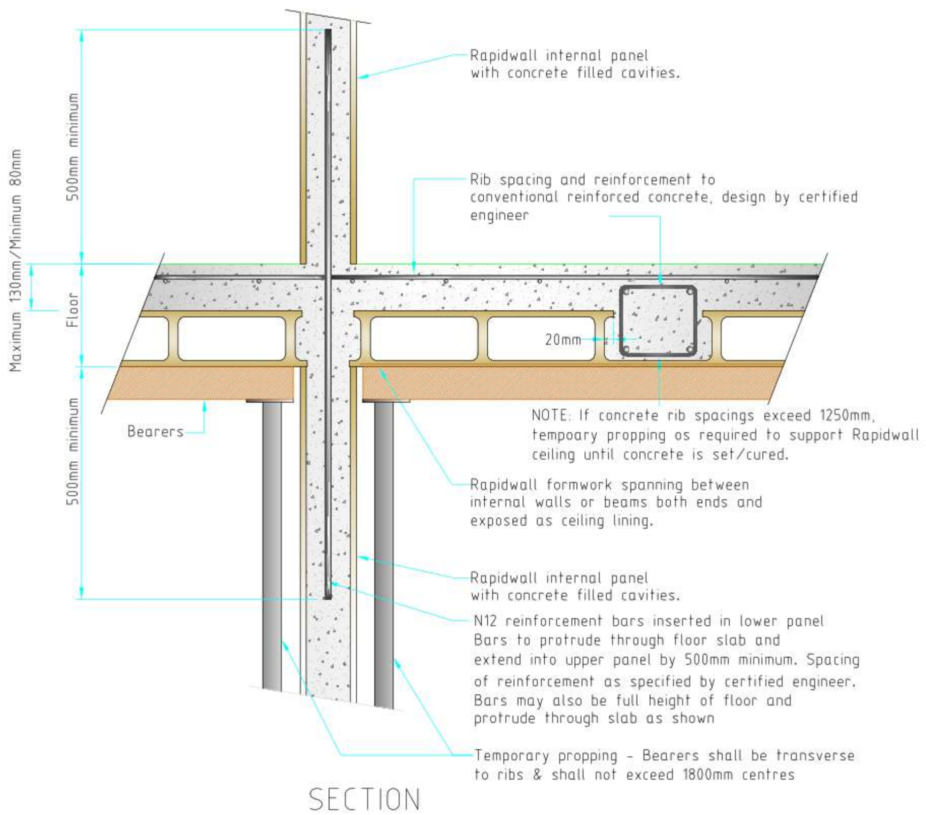


Fig A-9 Concrete filled Rapidwall with Rapidwall slab formwork / ceiling internal wall to suspended slab

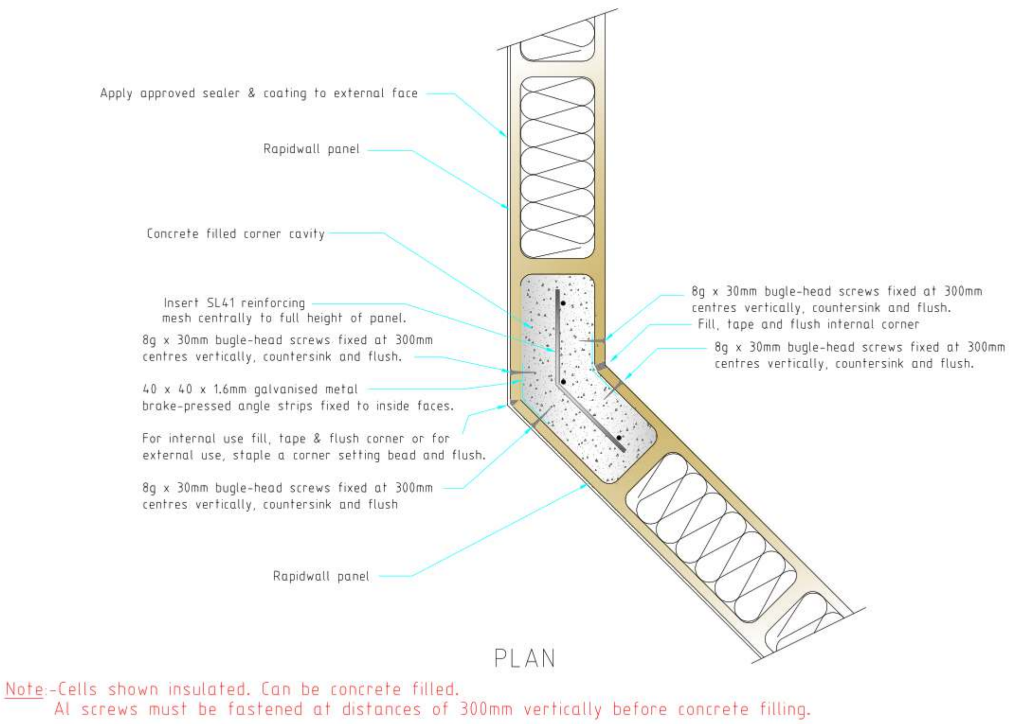


Fig A-10 External 45` corner concrete filled or insulated

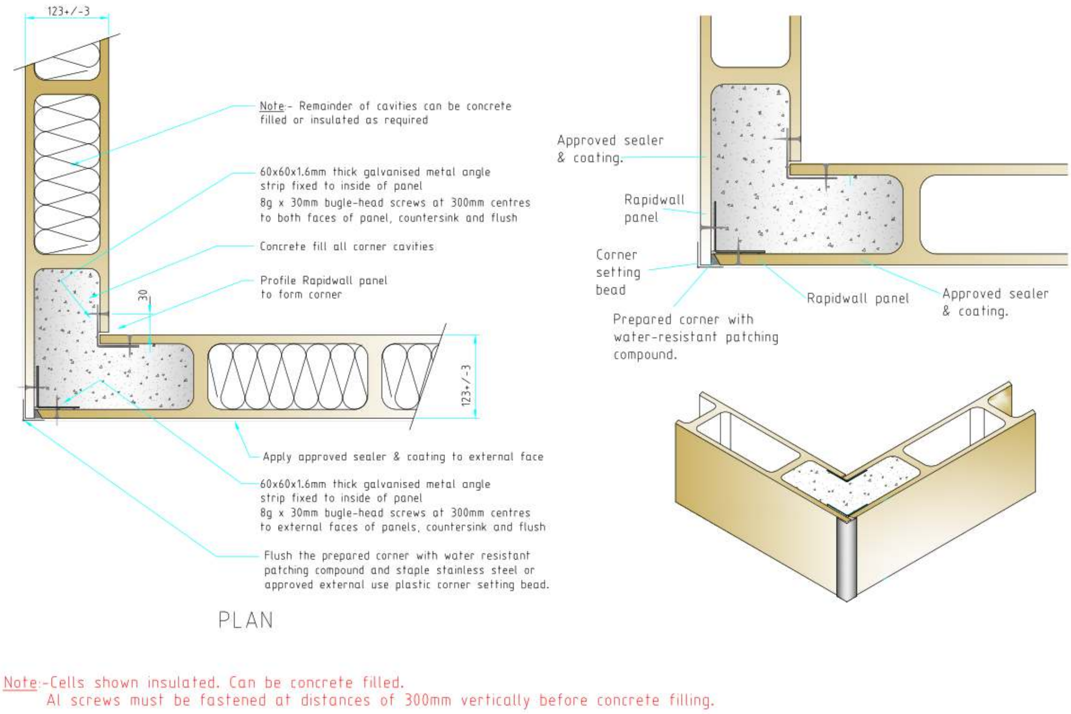


Fig A-11 External Corner Alternative Concrete filled or insulated

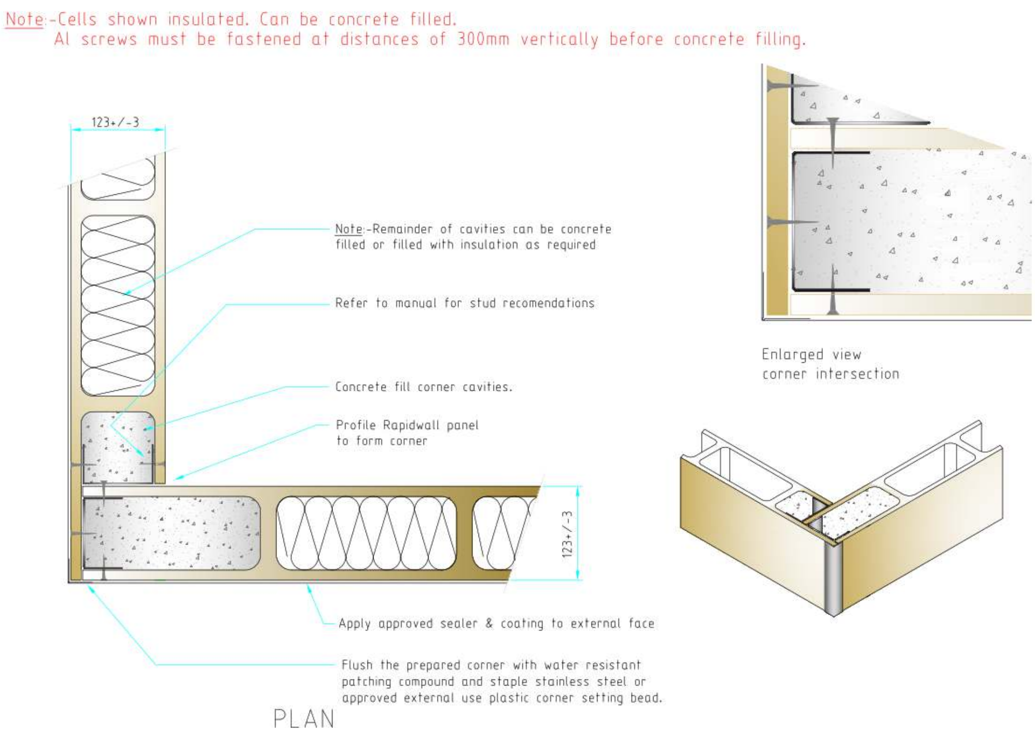


Fig A-12 External Corner Alternative Concrete filled or insulated

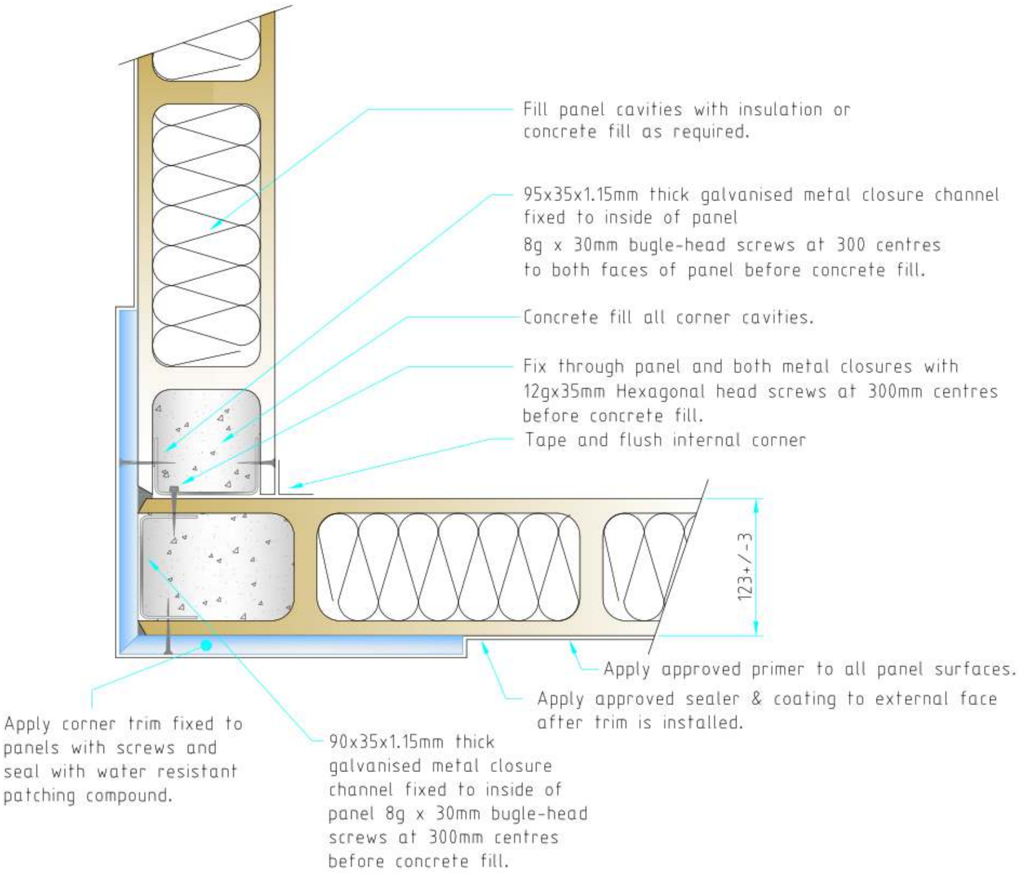


Fig A-13 External Corner Alternative Concrete filled or insulated

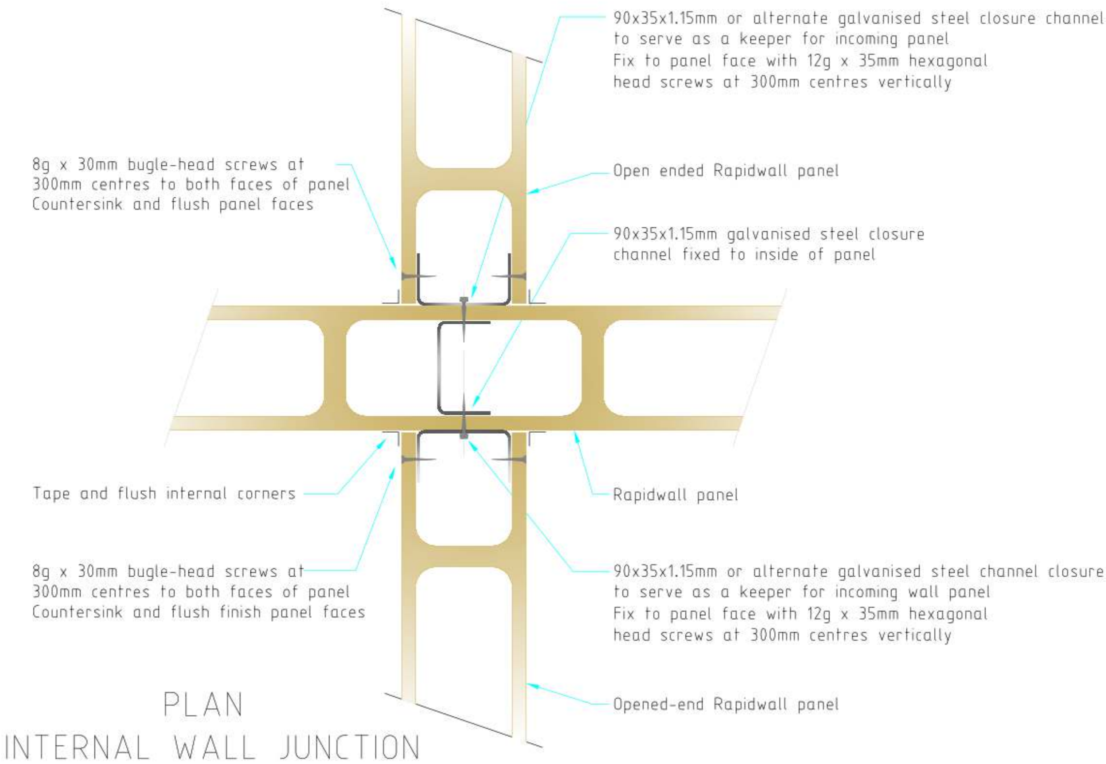


Fig A-14 Internal Intersecting walls concrete filled or Insulated

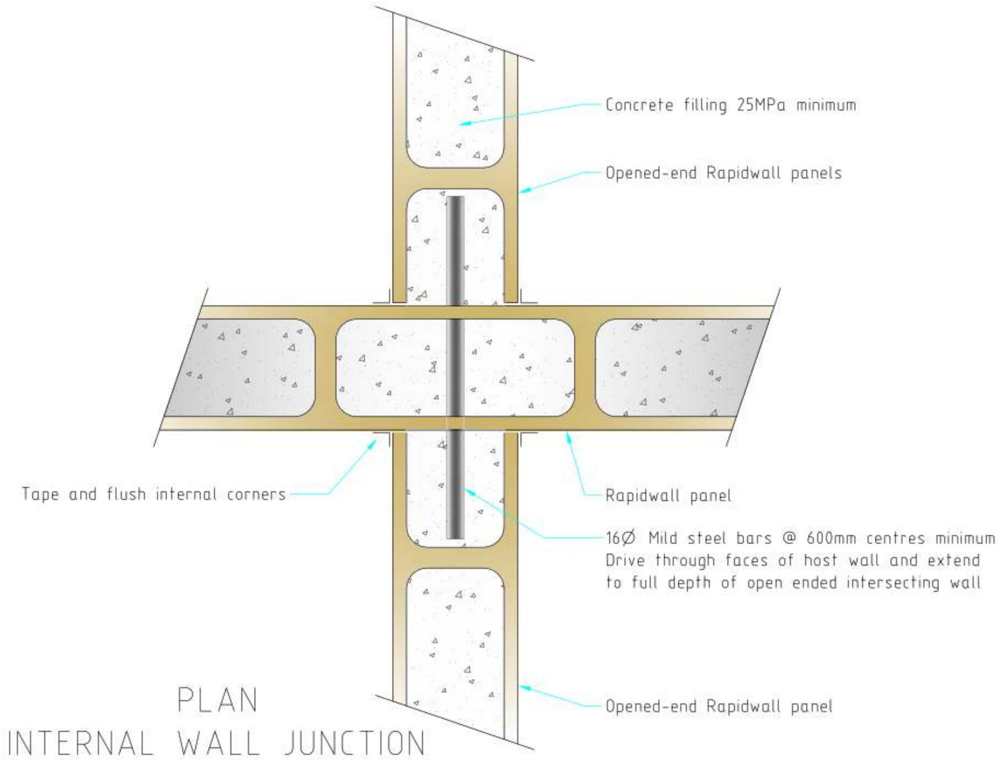


Fig A-15 Internal Intersecting walls concrete filled or Insulated

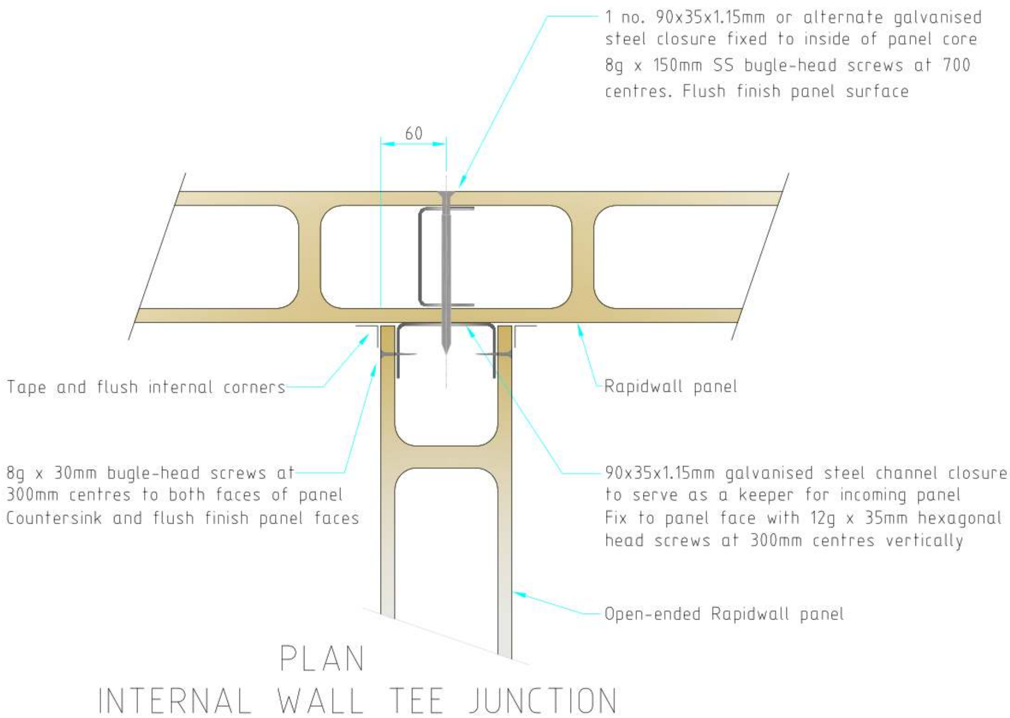


Fig A-16 Internal walls 'T' Junction concrete filled or Insulated

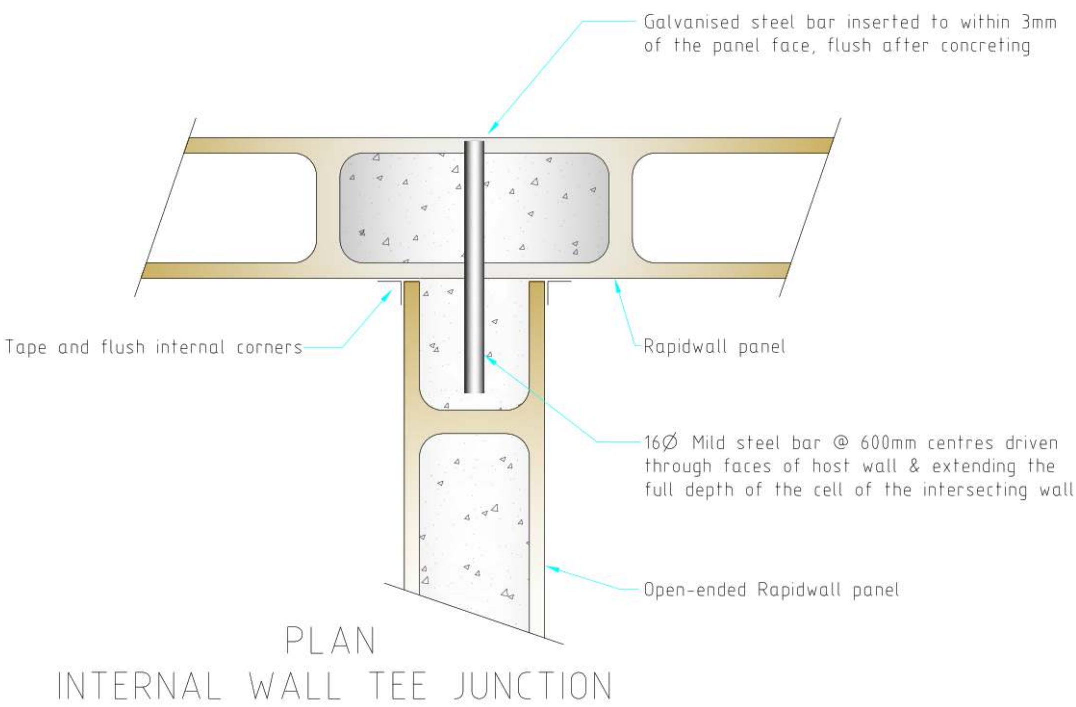


Fig A-17 Internal walls 'T' Junction concrete filled

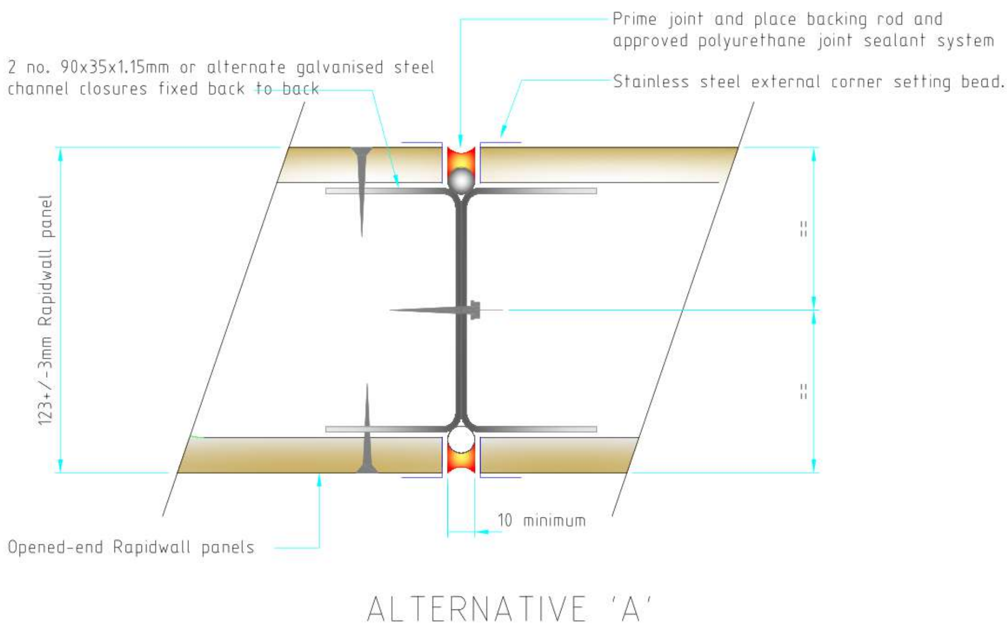


Fig A-18.1 Control Joints – wall length Alternative A

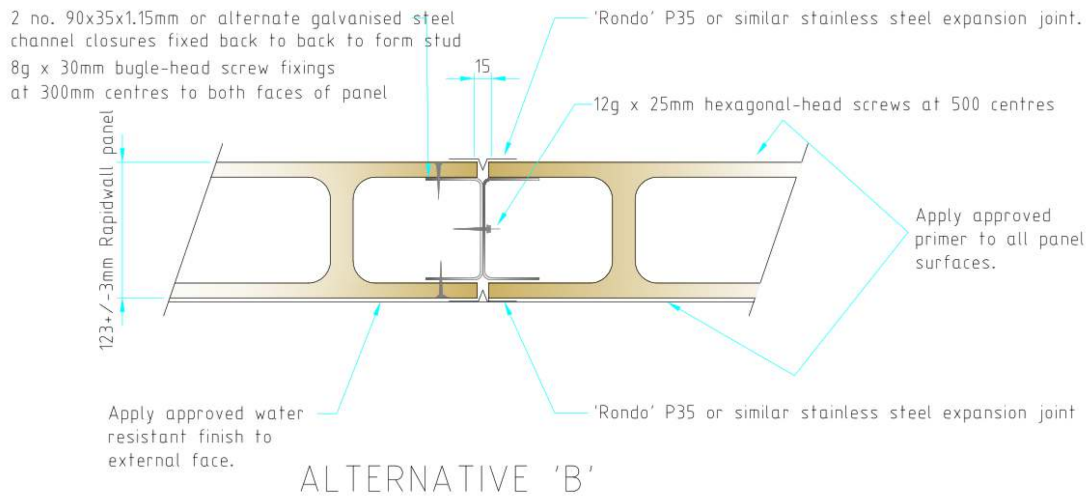


Fig A-18.2 Control Joints – wall length Alternative B

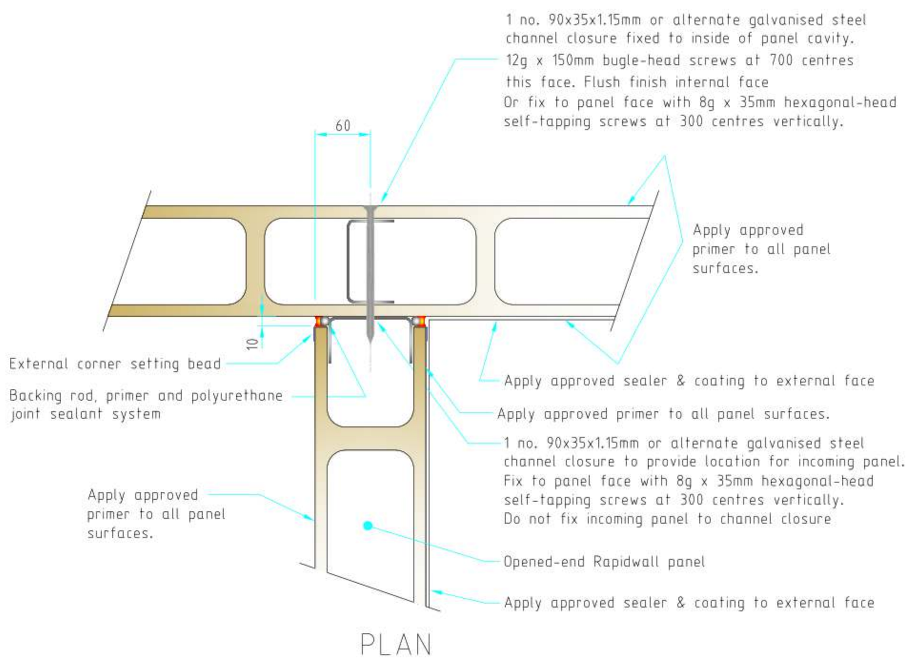


Fig A-19 Control Joints T inter section

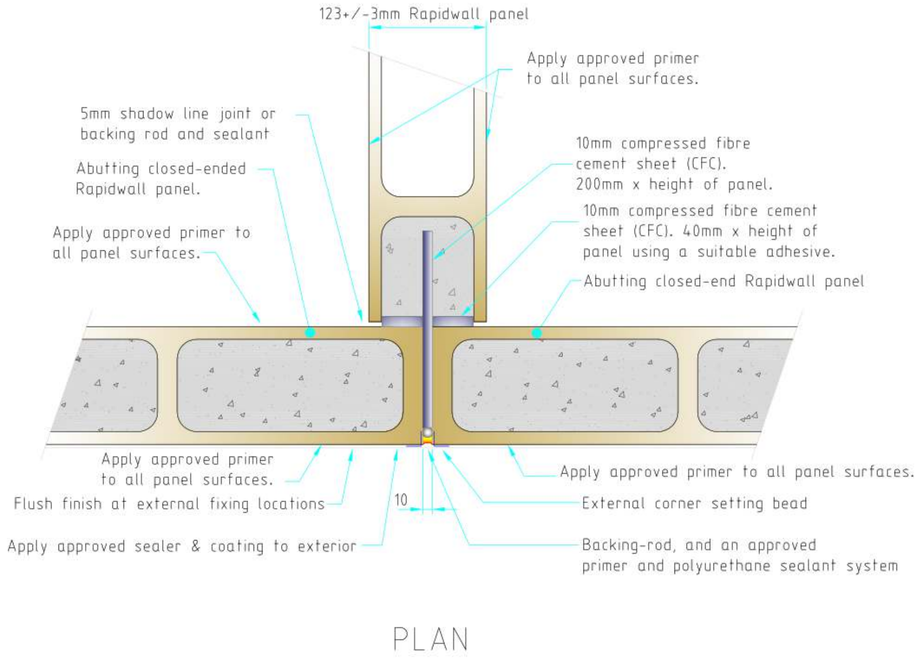


Fig A-20 Blind Control Joints T inter section Concrete filled panels

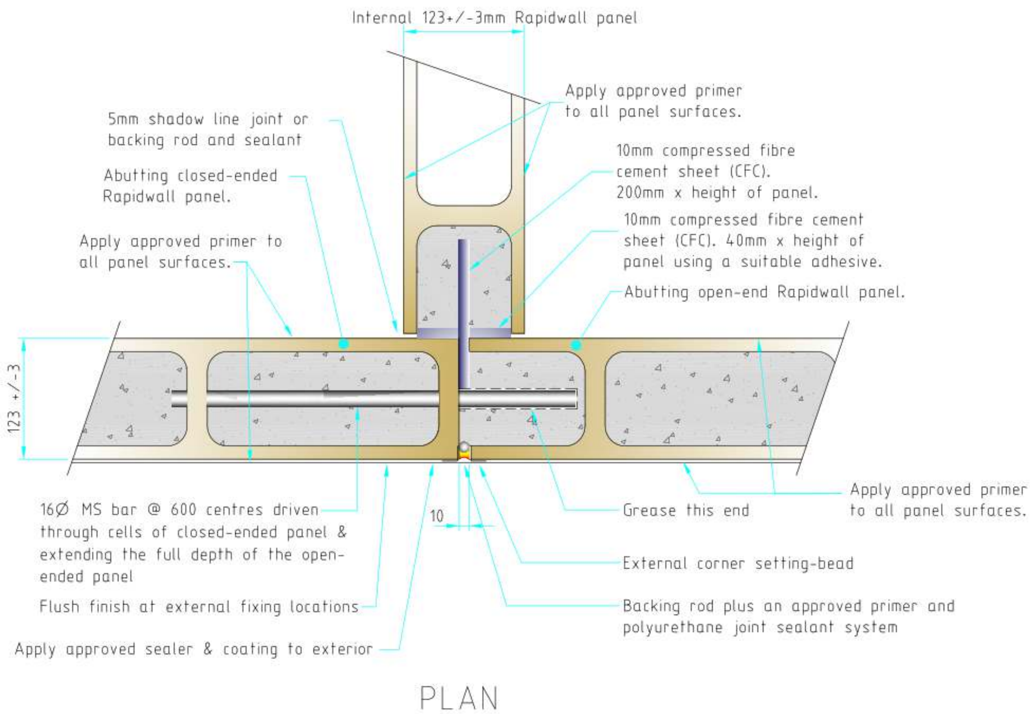


Fig A-21 Blind Control Joints T inter section Concrete filled panels

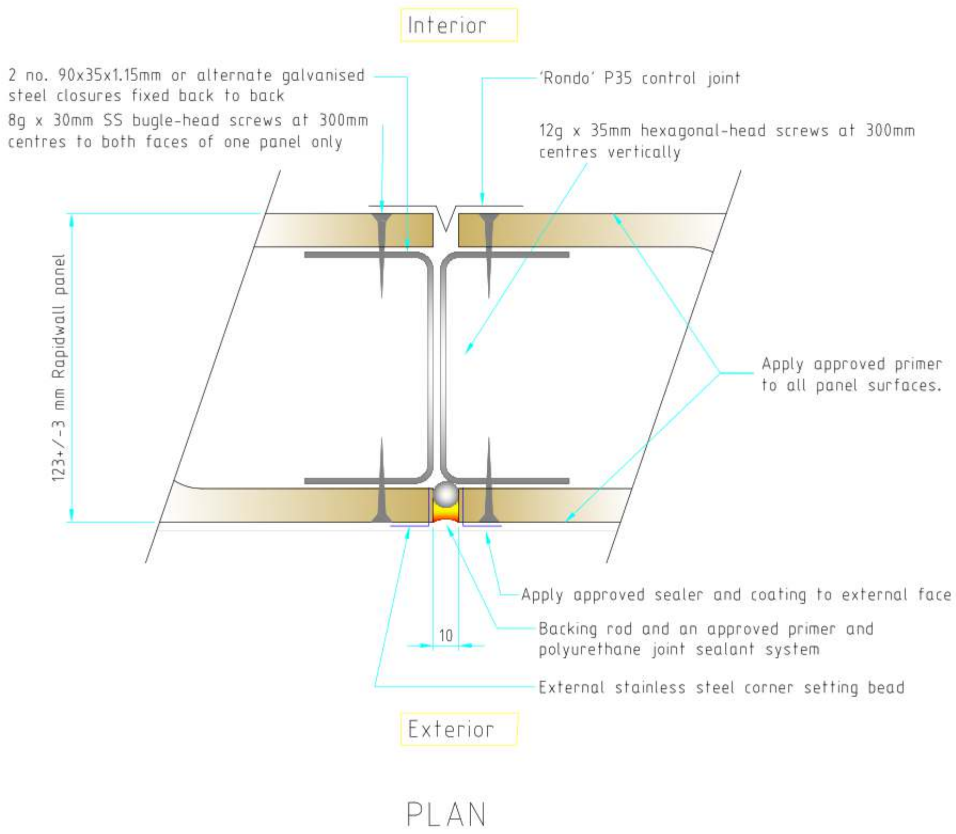


Fig A-22 Typical Control Joint External concrete filled or insulated

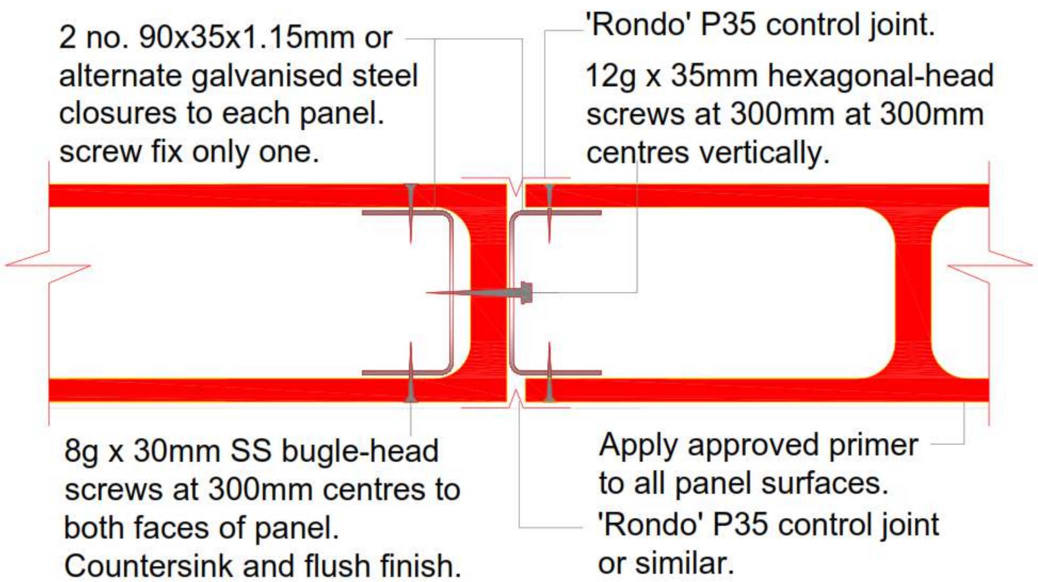


Fig A-23 Typical Control Joint

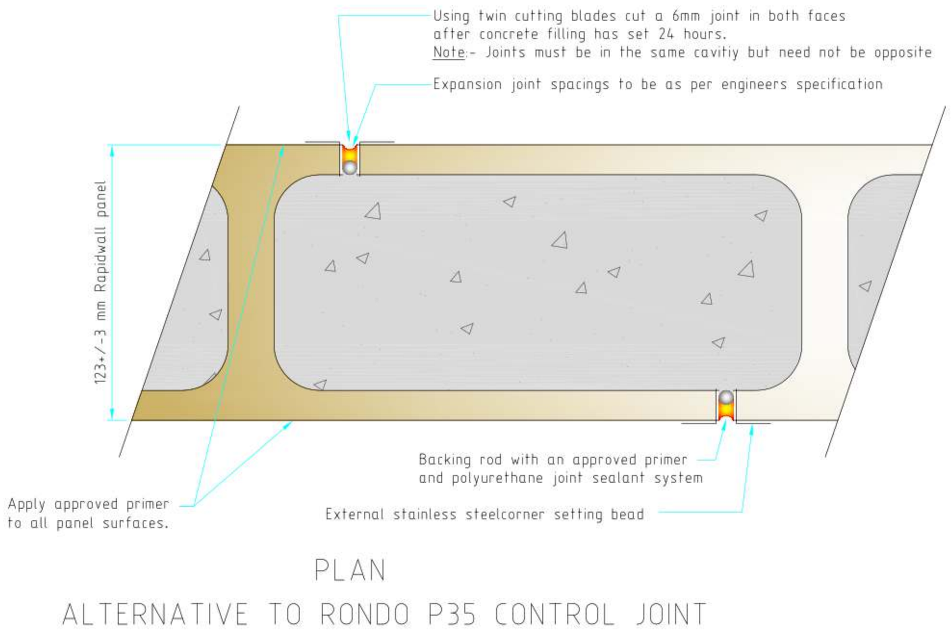


Fig A-24 Typical Control Joint External concrete filled

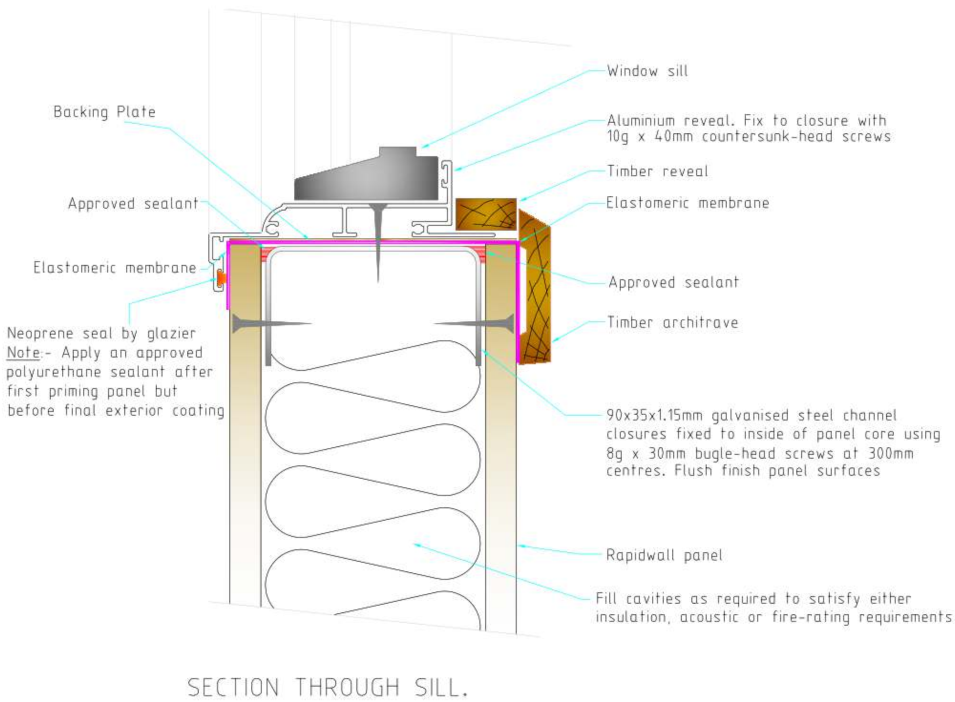


Fig A-25 Window Frame Inserts typical detail with architraves

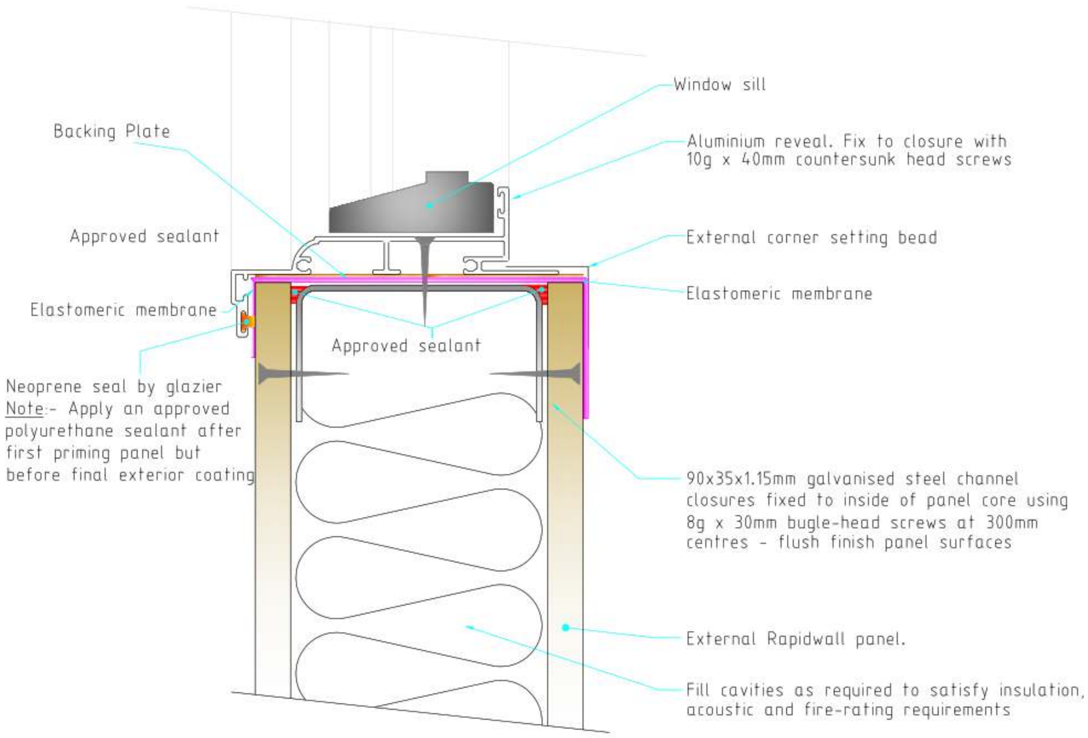


Fig A-26 Window Frame Inserts typical detail with Square set

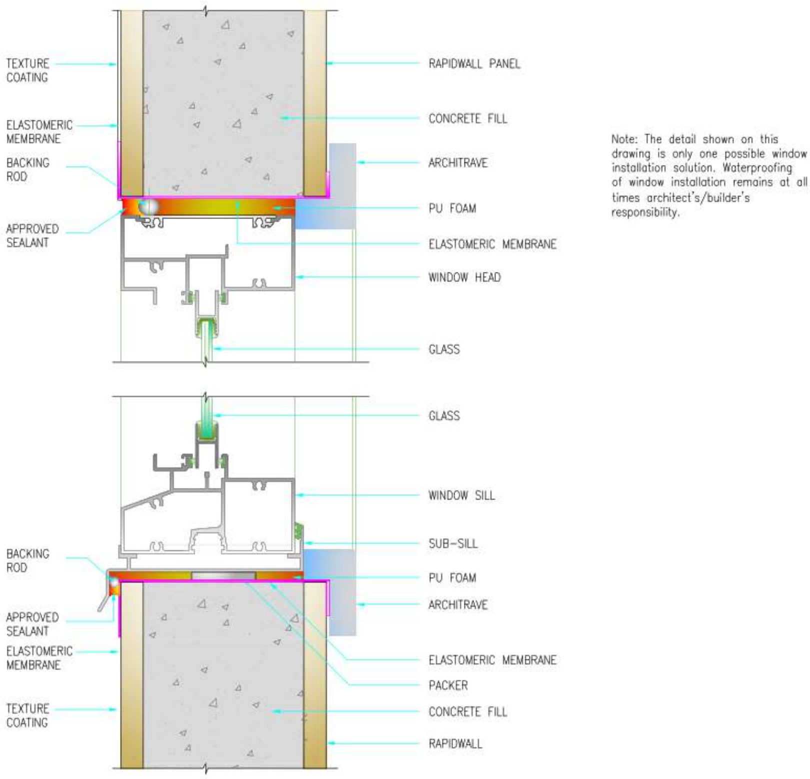


Fig A-26.1 Window Sealing details commercial window

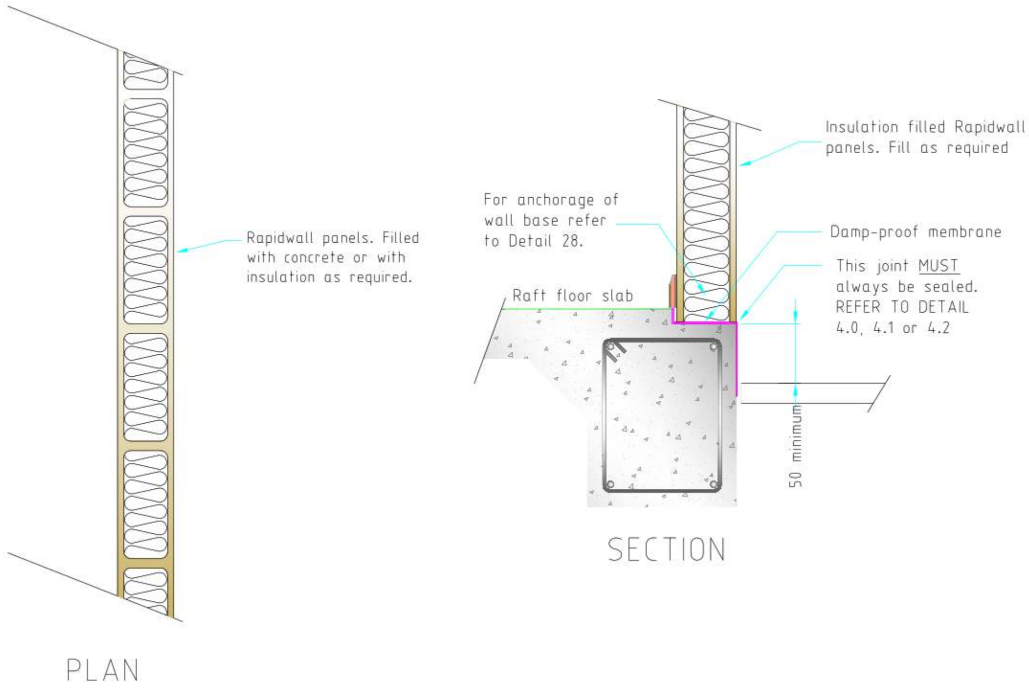


Fig A-27 Typically insulated Rapidwall

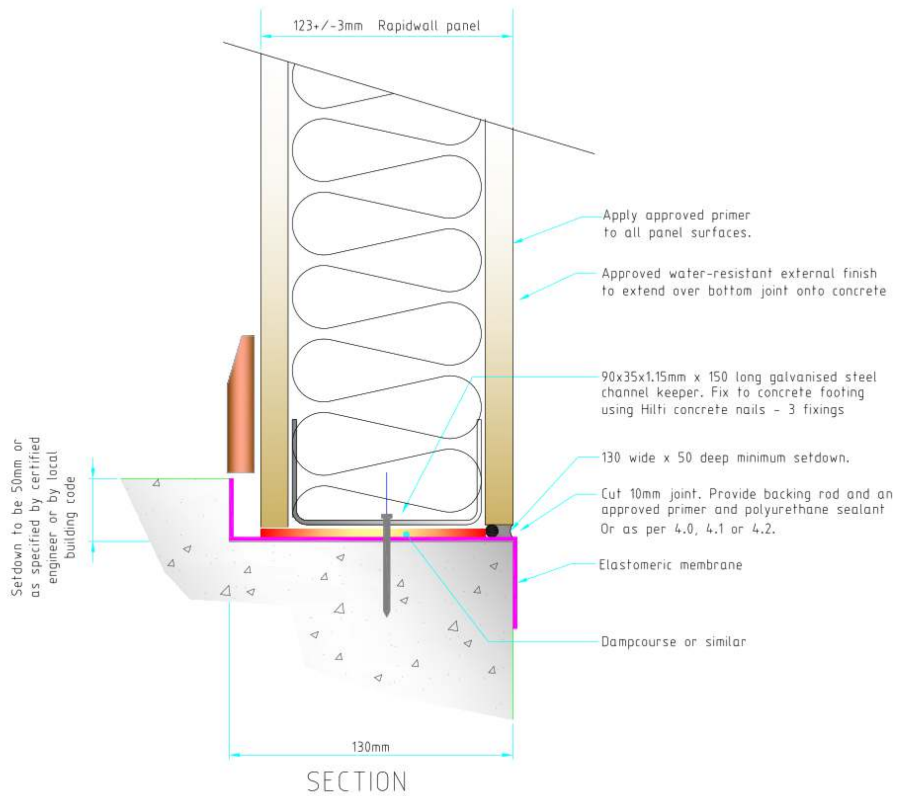


Fig A-28 Typical Slab Edge detail insulated Rapidwall

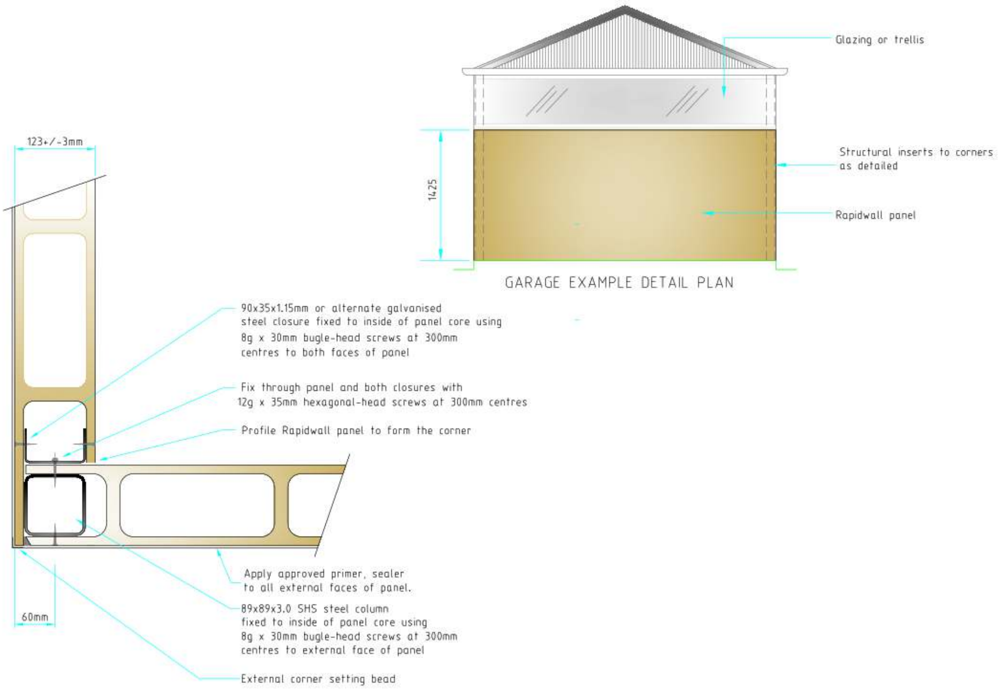


Fig A-29 Structural Inserts garage example

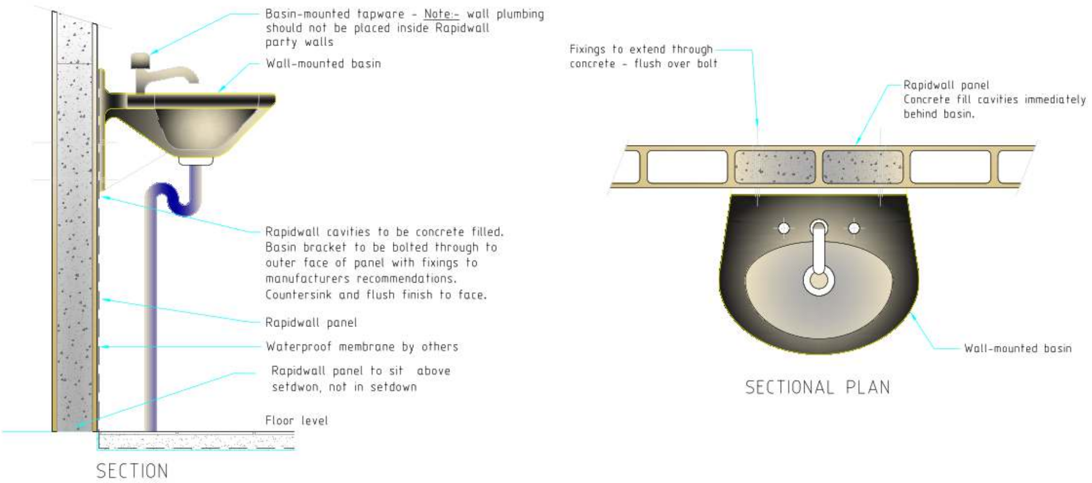


Fig A-30 Wall Mounting Basin

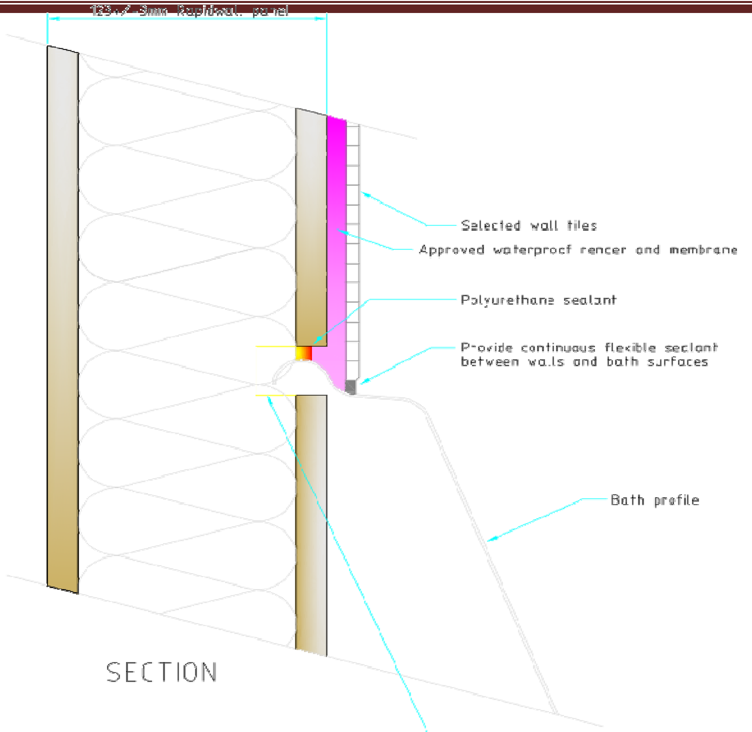


Fig A-31 Bath Housing

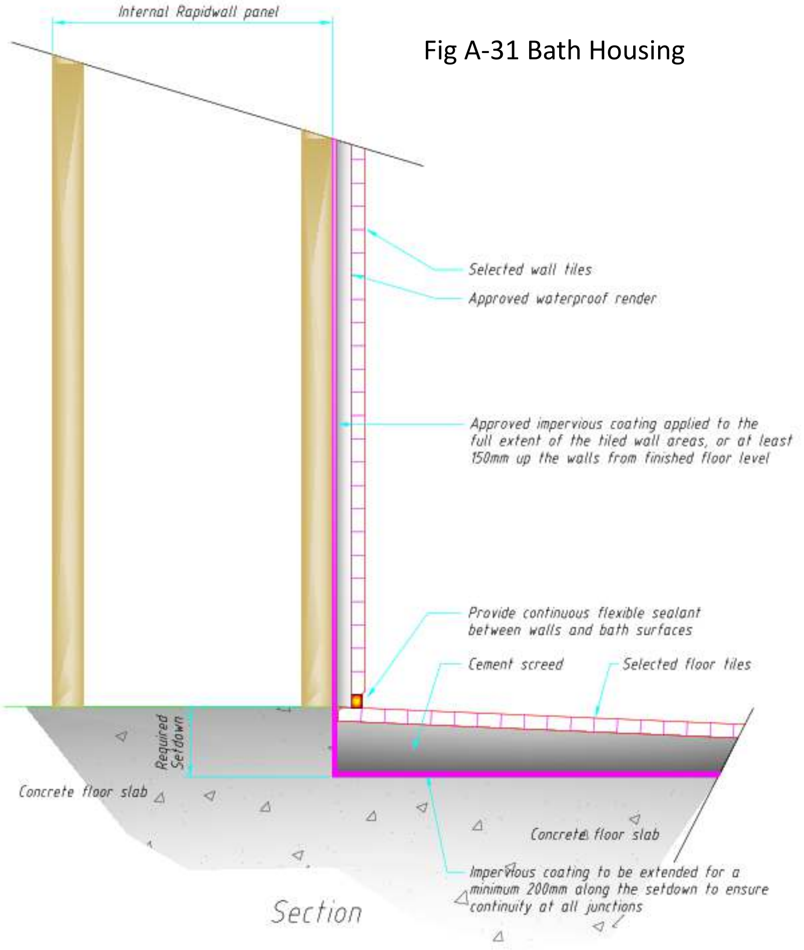


Fig A-32 Balcony and wet area set down Architectural plumbing details

e-ISSN: 2395-0056 p-ISSN: 2395-0072

International Research Journal of Engineering and Technology (IRJET)

(An ISO 9001 : 2008 Certified Journal)

Is hereby awarding this certificate to

Siddhant Singhal

In recognition the publication of the manuscript entitled

Comparative Study between RCC Structures and Prefabricated Structures

published in our Journal Volume 6 Issue 4 April 2019

Editor in Chief

E-mail : editor@irjet.net

Impact Factor : 7.211

www.irjet.net

International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 06 Issue: 02 | Feb 2019 www.irjet.net p-ISSN: 2395-0072

Comparative Study between RCC Structures and Prefabricated Structures

Siddhant Singhal[1], Bilal Siddiqui[2]

[1] M.Tech. Student, Dept. Of Civil Engineering, Babu Banarasi Das University, Uttar Pradesh, India
[2] Assistant Professor, Dept. Of Civil Engineering, Babu Banarasi Das University, Uttar Pradesh, India

---***---

Abstract - *Building cost in India is increasing at around 50% over the average inflation levels. It have registered amplification of up to 15 % every year, mostly due to cost of basic building materials such as steel, cement, bricks, timber and other inputs as well as cost of labor. Consequently, the cost of construction using conventional building materials and construction is becoming further away than the affordable limits particularly for low-income groups of population as well as a large division of the middle – income groups. Hence, there is an urgent need to adopt cost-effective construction methods either by up-gradation of traditional technologies using local resources or applying modern construction materials and techniques with efficient inputs leading to cost-effective solutions. This has become the most relevant aspect in the context of the large volume of housing needed in both rural and urban areas and the consideration of limitations in the availability of resources such as building materials and finance. Each state in India is currently investigating the developments in the prefabricated system and its potential to overcome the shortages of housing accommodation in this country. The Indian government, involved through its agency, the Building Materials and technology promotion council (BMTPC) and National Urban Housing and Habitat Policy (NUHHP) has been persistently pushing the construction industry to utilize the prefab method of construction since the year 2016. It is a part of an incorporated venture to further improving the aptitude, potential, efficiency and competitiveness of the industry as well as to diminish the industry's dependence on natural resources and unskilled labor. It is an attempt by the Indian construction industry to encourage positive inroads in matters related to construction-site safety concerning a working environment that is cleaner, more convenient and more organized. This paper makes an overview of the housing status in India and adoption of suitable and cost effective technologies in the country.*

***Key Words*: Prefabrication; Rapidwall; GFRG; monolithic; LGSFS; Precast; SIP panels; Building; Gypsum; Glass Fibres; Prefabrication; Construction; Wall Panels; New Building System;**

1. INTRODUCTION

The Architects, engineers, contractors and planers are still unable to switch from conventional construction systems even after such a heavy and urgent demand. Its due to lack of awareness, support from authorities and distrust on the new technological advancement because of unavailability of sufficient and proper design guides and provision in IS codes and structural analysis software giants like STAAD.PRO, ETABS, Autodesk Revit, etc.

Although the Building Materials & Technology Promotion Council (BMTPC), Ministry of Housing & Urban Poverty Alleviation, Government of India has taken an initiative in this direction to provide support to Architects and engineers to adopt new building technologies. BMTPC took an initiative to study/select emerging technologies suitable to Indian geo-climatic conditions.

The conventional construction systems are primarily cast in-situ slow pace construction systems and cannot meet the present requirement of housing shortage. Therefore, it is call of the day to adopt new construction systems, which are fast track and at the same time meet functional and structural requirements, which includes Constituted Technology Advisory Group for identification, evaluation and selection of the suitable technologies/ systems, comprising of eminent experts from Government, CSIR, academic and private agencies.

It is envisaged to construct 20 million houses by 2022 in urban area and about 10 million houses in next 3 years in rural areas (urban : 2.5 million houses a year, 7000 houses per day). Such a heavy requirement puts a very massive load on the natural resources and conventional building materials, so that brings us to consider alternative new technologies for mass housing, keeping in mind Speed, Quality, Safety, Life Cycle cost, Thermal, acoustics, Fire, etc. In addition, the need of the hour suggests use of renewable resources for building materials, use of raw materials resources based on waste products, efficient use of existing conventional materials by producing factory made (pre-cast) building components, affordability and sustainability, Industrialization of housing sector.

2. OBJECTIVE

The purpose of this paper focuses on the literature review of the prefabricated system of construction methodology. The author tries to bring out the merits and demerits of prefabricated construction to its readers. For this purpose, this paper presents the five major prefabrication system approved and promoted by BMTPC for the fast track construction in India. Aim of this paper also is to project building materials and technologies, which are less dependent on natural resources and labor and require less time in construction without compromising with the quality and esthetic value of the building.

3. NEED OF PREFABRICATED SYSTEM

Conventional building materials use bricks, cement, steel, stone, timber, glass, plastic, ceramics and other metals that exploit a huge amount of natural resources and leave a large carbon footprint on the planet. These materials have a finite resource base and the huge demand of material have its consequences. Due to larger demand and limited availability causes escalation in the cost leading to increased cost of shelter and rapid & irrationally managed utilization of finite natural resources. This causes Environmental degradation; depletion of fertile topsoil, Deforestation, Lime-quarrying, Surface working in stone belts. The factory made products like cement, steel etc. calls for high-energy inputs also liable to enhanced cost because of transportation.

There is too much of dependency on cement, aggregates and water in these conventional construction practices. In particular, the fine aggregate (sand) and water to-day are quite scarce. After the restriction from government over sand mining, the cost escalated even higher. It is also seen that, because of lack of skilled labor, these construction nowadays, in general, are not up to the mark in terms of quality. In addition, traditional buildings cannot be green buildings normally. However, green buildings are the order of the day, in view of energy scarcity and, fast depletion of precious natural materials.

Prefabrication seems to be the immediate solution for these problem as they are more manageable and quality controlled hence reducing the waste significantly reducing the environmental impact. Most of the prefabrication technologies also reduce the requirement of building material in general further reducing the impact.

It is need of the hour to use raw materials resources based on waste and other by products, which may eventually end up in landfills. This may help us to achieve affordability and sustainability.

4. TYPES OF PREFABRICATED SYSTEMS

BMTPC took an initiative to study/select promising technologies appropriate to Indian geo-climatic conditions, through Global Expression of Interest (EOI). BMTPC composed technology advisory group for identification and evaluation of the suitable technologies based on following parameters-

1. Safety of the structure against anticipated live loads and safety and stability with respect to the prevailing wind loads and with respect to the possible earthquake loads and other loads such as snow, cyclone etc.
2. Performance of the structure during its life span
    a. Thermal efficiency of the construction during summer and winter
    b. Acoustics efficiency, Damp proof-ness of the construction during rains
    c. Efficiency of the joinery systems, Fire resistance characteristics of the structure
3. Durability of the structure
    a. Deterioration of components with age
    b. Deterioration of components due to atmospheric pollutions
    c. Deterioration of foundation system due to polluted/chemically adverse soil media
    d. Life expectancy (*Our normal housing constructions are designed for a life of 60 years and above*).

The following are the recommended prefabrication technologies by BMTPC according to the Indian geographical conditions.

1. Monolithic Concrete Construction Technology-

The conventional mode of construction is RCC framed structure with infill masonry walls whereas in this system, all walls, floors/slabs, stairs together with door & window openings are cast in-situ monolithically using specifically custom designed modular formwork made up of aluminum/plastics/steel/ composite.

Fig.1 – A Typical working of a Monolithic Concrete Construction Technology

The appropriate grade of concrete and reinforcement is used as per design and the entire casting of a modular unit is done in a single pour. Being modular predesigned formwork system, it acts as an assembly line production and enables rapid construction of multiple/mass scale of units of repetitive type.

In the Monolithic concrete construction with aluminum/plastic/steel/composite forms system, Concrete walls and slabs are cast monolithically at one pour. The system allows reduction in thickness of concrete members below the minimum value than the conventional construction, thus reducing the consumption of natural resources.

A Typical plan is of a Single floor with built up area of about 300 SQ.M. can be completed in two days using the aluminum formwork system. The technology reduces the cost of repair and maintenance compared to conventional system. Walls and slabs are cast in one operation in specially designed lightweight form/ moulds in concrete. Concrete is poured in the forms & forms are removed after the setting of concrete takes place, resulting in box like cubical structure of required architectural design. The pre-designed formwork also acts some sort of assembly line production and enables rapid construction of multiple units of repetitive type.

2. Light Gauge Steel Framed Structure (LGSFS)

Light Gauge Steel is cold form steel which has an advantage over hot rolled steel as it is lighter in weight and on thin sections of any form can be manufactured. Normally, LGSFS is factory made galvanized light gauge steel components assembled as panels at site and suitable for 3 to 4 storey structures. The infill walls can be of any material ranging from precast boards, blocks, EPS panels or an external layer of insulation material and outer leaf of CP Board or dry mix shotcrete. The floor/roof can be RCC/ Steel truss /Steel deck on joists as per the requirement.

Fig.2 – A Typical working of a LGSFS

Frame is made of cold rolled high strength steel sections and EPS panels for walling. Internal walls covered with gypsum and cementitious board. Exterior wall Sprayed with cementitious material directly onto the studs. It gives faster construction by prefabricated panels. All structural components are precisely pre-manufactured and simply assembled on site. In addition, it gets Enhanced Thermal & Acoustic insulation with Boarding/Expanded Polystyrene (EPS) /Rockwool/Vapor Barrier.

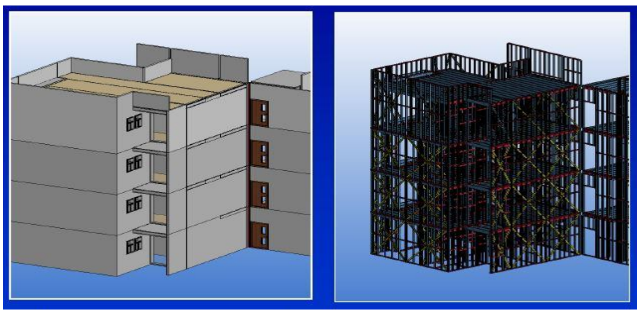


Fig.3 – A Perspective View and Framing View

3. Precast Large Concrete Panel System

Precast Large Construction Panel (PLCP) system is a structural system comprising of various precast elements such as walls, beams, slabs, columns, staircase, landing and customized elements. There are two types of precast concrete elements, namely precast reinforced concrete elements and precast pre-stressed concrete elements, prefabricated in a precast yard or site. The precast elements are installed on site and supported by temporary jacks. Shims are used to carefully align the elements and grouted after the final adjustments. A typical construction involves design, strategic yard planning, lifting, handling, transportation and assembly of precast elements.

Fig.4 – A Typical working of a Precast Large Concrete Panel System

The industrialized total open prefabricated construction technology is based on factory mass manufactured structural prefab components conforming to norms of IS standards and BIS Certification mark. In this Patented system, precast dense concrete hollow column shell of appropriate size are used in combination with precast dense concrete rectangular T Shape/ L shape beams and lightweight reinforced autoclaved cellular concretes labs for floors and roofs. The hollow columns are grouted with appropriate grade of in–situ concrete. All the connections and jointing of various structures are accomplished through in situ concreting along with secured embedded reinforcement of appropriate size, length and configuration to ensure monolithic continuous resilient ductile behavior.

4. SIP Panel - Building System using Steel Mesh, Polystyrene Core and Chipping Concrete (evaluated through PACS)

EMMEDUE Advanced Building System (patented) is based on factory made panels consisting of self-extinguishing expanded polystyrene core (generally corrugated) sandwiched between two-welded wire fabric mesh made of high strength galvanized wire. A galvanized steel truss wire is pierced completely through the core at an offset angle for superior strength and welded to each of outer layer welded wire fabric mesh.

The panels are finished at site using shotcrete of mix of cement and coarse aggregate of required thickness on both sides. The panels are used for load bearing walls and floors and suitable for 3 to 4 storey buildings.

Fig.5 – A Typical working of a SIP panels

5. Glass Fiber Reinforced Gypsum (GFRG) Panel System

GFRG is an integrated composite building system-using factory made prefabricated load bearing cage panels and monolithic cast in-situ RC in filled for walling and floor/roof slabs, suitable for single storey to ten-storey building. It is made of calcined gypsum plaster, reinforced with glass fibers and panels manufactured to a thickness of 124 mm under carefully controlled conditions to a length of 12 m and height of 3m, contains cavities. The panels are being produced at FRBL Kochi and RCF Mumbai and being promoted by IIT Madras.

Fig.6 – A Typical GFRG panels

Glass Fiber Reinforced Gypsum (GFRG)/ Rapid wall is a building panel product, made essentially of gypsum plaster, reinforced with glass fibers. Used since 1990 in Australia. 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 panels may be unfilled, partially filled or fully filled with reinforced concrete as per the structural requirement.

5. RESULT AND CONCLUSION

After comparing the above available construction techniques for the pros and cons, author finds Glass Fiber Reinforced Gypsum (GFRG) Panel System most suitable for the desired outcome of the work. The reason being, from all the types of construction technologies, GFRG prove to be giving most economic outcome by saving lots of building material, time and labor. In addition, GFRG panels had the thinnest wall space requirement, providing most usable space. Hence, GFRG panels were shortlisted and chosen for the comparison from the prefabricated structures.

GFRG is of exceptional relevance to India, where there is a massive need for cost-effective mass-scale affordable housing, and here gypsum is available in plentiful amount as an industrial by-product waste. The product not only proves to be environmental friendly or green, but also resistant to damage by water and fire. GFRG panels are currently manufactured in a panel size of length of 12m, a height of 3m and a thickness of 124 mm. Although its main function is in the construction of walls, it was found to be effective to be used in floor and roof slabs in combination with reinforced concrete. IIT Madras and BMTPC have been involved, since 2003, in the development of prefabricated building systems (especially with respect to use of GFRG panels as floor slabs and earthquake resistant design) for utilization in India.

The panel contains cavities that can be filled with concrete and reinforced with steel bars to provide additional strength and ductility, if required. Experimental researches and studies have shown that GFRG panels, when properly filled with reinforced concrete, acquires significant strength to act not only as load-bearing elements, but also as shear walls, able of resisting lateral forces due to earthquake and wind. It is possible to design such buildings up to ten storeys in low seismic zones (and to smaller elevation in high seismic zones). However, such building needs to be suitably calculated by a qualified structural engineer for safety.

ACKNOWLEDGEMENT

First, I would like to express my heartily thanks to Mr. Bilal Siddiqui for being a great guide and helping me during this work. In addition, I would like to express my sincere gratitude towards all the scholars whose articles were referred to and a remarkable help was obtained while working on this paper. I am also thankful to BMTPC and government of India to take initiative in promoting Prefabrication technology in India by adding guidelines in 2016.

REFERENCES

1. “Prefabricated construction for mass housing in Mumbai” - Krish R. Villaitramani, Dhruv P. Hirani

2. “Low cost housing projects in India.” – A.R. Santhakumar

3. "Comparative Study on Prefabrication Construction with Cast In-Situ Construction of Residential Buildings."- N.Dineshkumar, P.Kathirvel.

4. "Modern Prefab Modular System in Malaysia: Critical Matters and Obstacle."- Md Azree Othuman Mydin,Mohd Nasrun Mohd Nawi, Nangkula Utaberta and Mohd Yazid Mohd Yunos.

5. "Performance of Modular Prefabricated Architecture:Case Study-Based Review and Future Pathways." - Fred Edmond Boafo , Jin-Hee Kim and Jun-Tae Kim.

6. "Prefabrication in Developing Countries: a case study of India."- Ryan E. Smith, Shilpa Narayanamurthy.

7. "Prefabrication in house constructions." - Xudong Zhao and Saffa Riffat.

8. "Using Prefabrication Systems in Building Construction."- Alireza Baghchesaraei, Meltem Vatan Kaptan, Omid Reza Baghchesaraei.

9. Devdas Menon, Maganti Janardhana, and A. Meher Prasad(2003) " Studies on the Behavior of Glass Fiber Reinforced Gypsum Wall Panels"

10. Huiqing Ying and Zhengyong Liu "Elastic Lateral Features of a New Glass Fiber Reinforced Gypsum Wall" International Journal of science Index Vol:4 2010-03-29

11. IIT Madras, Department of Civil Engineering(2003) "Constuction Manual for Glass Fibre Reinforced Gypsum Based Building Panels"

BIOGRAPHIES

Mr. Siddhant Singhal was born in 1995 in Varanasi, (U.P.). He received his Bachelor Degree in Civil Engineering from AKTU, Lucknow in 2017. He is currently pursuing his Masters Degree in Structural Engineering from Babu Banarasi Das University, Lucknow.

Mr. Bilal Siddiqui was born in 1992 in Barabanki, (U.P.). He received his Bachelor Degree in Civil Engineering from AKTU, Lucknow in 2014. He received his Masters Degree in Structural Engineering from Integral university, Lucknow in 2016. He is currently working as Assistant Professor in Civil Engineering Department in Babu Banarasi Das University, Lucknow.

e-ISSN: 2395-0056 p-ISSN: 2395-0072

International Research Journal of Engineering and Technology (IRJET)

(An ISO 9001 : 2008 Certified Journal)

Is hereby awarding this certificate to

Siddhant Singhal

In recognition the publication of the manuscript entitled

Comparative Study on Cost Estimation of GFRG Wall Panel System with Conventional Building

published in our Journal Volume 6 Issue 4 April 2019

Editor in Chief

E-mail : editor@irjet.net

Impact Factor : 7.211

www.irjet.net

Comparative Study on Cost Estimation of GFRG Wall Panel System with Conventional Building

Siddhant Singhal[1], Bilal Siddiqui[2]

[1] *M.Tech. Student, Dept. Of Civil Engineering, Babu Banarasi Das University, Uttar Pradesh, India*
[2] *Assistant Professor, Dept. Of Civil Engineering, Babu Banarasi Das University, Uttar Pradesh, India*

---***---

Abstract - *Being a civil engineer it is our priority to provide cost effective solutions to our clients. With the escalating prices, the houses are becoming unaffordable with the current technology and hence we needed to explore another types of construction systems to reduce the cost of construction. This paper is an attempt made to give an idea as to how can we reduce the construction cost as well as reduce the construction time using the prefabrication technology. This review paper compiles and retrospect the developments in the field of prefabricated building systems using GFRG construction technology also known as Rapidwall© construction technology in India. Glass fiber reinforced gypsum panels, manufactured in standardized parts are sections prepared for rapid erection of buildings, as they are ready-made gypsum structural panels with hollow cavities. This Rapidwall is employed in residential as well as commercial constructed establishments. GFRG walls can be used both for esthetical as well as structural component as walls and slabs, with no external columns and beams needed. It has currently found great utilization, even without exercising complicated codes of structural design, largely for the reason that they are environmental friendly. For the cost comparison, the fundamental materials considered were three types of building construction method such as low cost building using prefabrication technology as GFRG wall panel system and Conventional building construction systems like SMRF structure and Load bearing wall structure. Costs of these building materials were collected from contractors of the nearby areas. The focus in this paper is comparative study on cost estimation between prefab system (GFRG) and conventional building systems.*

***Key Words*: Cost Comparison, GFRG, Prefabrication, Construction, Wall panels, Rapidwall, New building system, etc...**

1. INTRODUCTION

In this new era of construction, several different building systems orientated for housing appeared in India. Most of these systems were introduced from first world countries and many were not able to fit into the Indian construction standards. This incursion of technology was originated after the announcement of the reconstruction plan for affected areas due to El Nino phenomena and Nazca earthquake. On the other hand, many of these systems were functional in countries lacking earthquake trouble and the majority of them employed foreign supplies. In this case of India, structural systems were supposed to be designed according with earthquake standard E-030 of the National Building Code. On the other hand, Indian researchers in the last 20 years developed different solutions for building systems using locally available materials and most of them were tested and had the approval and registration of BMTPC.

The present work introduced five construction systems that are approved by BMTPC. The economic issues are also the main reason for these different building systems. So we have to select the most viable and low cost construction for avoid the financial problems.

2. OBJECTIVE

The purpose of this paper focuses on views of the construction industry about the difference of the two building methods such as GFRG (Glass Fiber Reinforced Gypsum) wall panel system and conventional building construction system of SMRF structure and load bearing wall structure based on the estimation value and we have to generate some construction management results. We have to accumulate properties and cost details of the building materials. Comparing the methods, details were taken of cost and time duration for finishing each construction activity.

3. CONVENTIONAL BUILDING WORK

The major bulk of building construction work is small renovation, such as addition of a room, or renovation of a restroom. Often, the owner of the property work as the introspect, paymaster, and design team for the entire project. Although, all building construction projects consist of some elements in general – design, financial, estimation and legal considerations. Many projects of different sizes reach unwanted consequences, such as structural failure, cost overruns, and/or lawsuits. Due to such reasons, those with expertise in the field make comprehensive plans and keep cautious supervision throughout the project to ensure a positive result.

Commercial building construction is procured privately or publicly utilizing various delivery methodologies, including cost estimating, hard bid, negotiated cost, conventional, organization contracting, construction management-at-risk, design & build and design-build bridging.

Residential construction practices, technologies, and resources should match to the regulations of local building authority and codes of practice. Materials readily accessible in the region usually dictate the building materials used (e.g. brick vs stone vs concrete). Cost of building construction can vary considerably based on site conditions, local policy, economy of scale (custom designed residences are often more costly to build) and the availability of trained workers and labours. As residential building construction (as well as all other types of construction) can produce a lot of waste, so careful planning again is required here.

4. OVERVIEW OF (GFRG) WALL PANEL SYSTEM

Glass fiber reinforced gypsum, or GFRG (also known as Rapidwall in the trade) is the name of a new building panel, made of gypsum plaster, reinforced with glass fibers. GFRG is of exceptional relevance to India, where there is a massive need for cost-effective mass-scale affordable housing, and here gypsum is available in plentiful amount as an industrial by-product waste. The product not only proves to be environmental friendly or green, but also resistant to damage by water and fire. GFRG panels are currently manufactured in a panel size of length of 12m, a height of 3m and a thickness of 124 mm. Although its main function is in the construction of walls, it was found to be effective to be used in floor and roof slabs in combination with reinforced concrete. IIT Madras and BMTPC have been involved, since 2003, in the development of prefabricated building systems (especially with respect to use of GFRG panels as floor slabs and earthquake resistant design) for utilization in India.

The panel contains cavities that can be filled with concrete and reinforced with steel bars to provide additional strength and ductility, if required. Experimental researches and studies have shown that GFRG panels, when properly filled with reinforced concrete, acquires significant strength to act not only as load-bearing elements, but also as shear walls, able of resisting lateral forces due to earthquake and wind. It is possible to design such buildings up to ten storeys in low seismic zones (and to smaller elevation in high seismic zones). However, such building needs to be suitably calculated by a qualified structural engineer for safety.

5. METHODOLOGY

The major element of this work is estimating the total cost of the construction work for a residential house based on the Quotation gathered from five different zones for each part of work. The compilation of quotation contains Cost for each construction Material like Cement, Sand, Aggregate, bricks, etc and every activity like Excavation, Centering work, Flooring, Plastering, Labour charges, etc. The estimation work is carried out for both types of building system of wall panel system and conventional building system.

The approximate time requirement and time difference for every work of Prefabrication system and conventional Building system was also taken into account to calculate the cost due to time elapsed as time also plays an important role in determining the cost of the construction.

Any one of the following three methods can be employed to carry out the estimation of the building quantities:

- Centre line method
- Long wall – short wall method
- Partly centre line and short wall method

5.1. Centre line method

This technique is appropriate for walls of similar cross sections. Here, the total centre line length is multiplied by width and depth of the individual component to get the total quantity at an instance. When cross walls or partition walls or false walls or verandah walls join with main wall, the centre line length is reduced by half of width at each joint. Such junction or joints are calculated cautiously while calculating total centre line length. The estimation prepared by this technique is most precise and quick.

5.2. Long wall-short wall method

In this method, the larger wall along the length of room is measured to be long wall whereas the shorter wall perpendicular to long wall is said to be short wall. To get the span of long wall or short wall, compute the centre line length of each wall first. After that, the length of long wall, (out to out) may be calculated by adding half width of the wall at each end to its centre line length i.e., long wall equals to centerline length plus the width of the wall. Similarly, the length of short wall is measured (in to in) and may be calculated by deducting half width from its centre line length at each end i.e., short wall equals to centerline length minus the width of the wall.

The length of long wall typically decreases from earth work to brick work in super structure whereas the short wall increases. These lengths are multiplied by width and depth to get quantities and then are used for estimated.

5.3. Partly centre line and partly cross wall method:

This technique is adopted when outer (i.e., around the building) wall is of one thickness and the internal walls having different thicknesses. In such cases, centre line method is applied to outer walls and long wall-short wall method is applied for internal walls. This technique suits for variable thicknesses of the walls and different levels of foundations. It is because of this reason; all Engineering departments prefer this technique for calculations purposes.

The estimation for prefabricated system is carried out based on the Material, Labour and size of panels used for erection activity.

From the Comparative study on estimation of prefabrication system and conventional building system, we can evaluate the cost difference for different working methodology.

The central focus of this paper is to spread awareness among engineers, contractors and public about the new and innovative construction materials available at affordable cost with good life span.

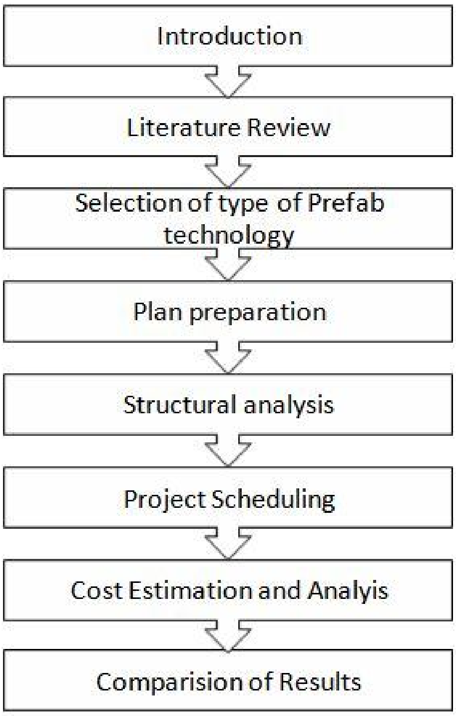


Fig 1 : Flow Chart of work

6. COST ESTIMATION AND ANALYSIS

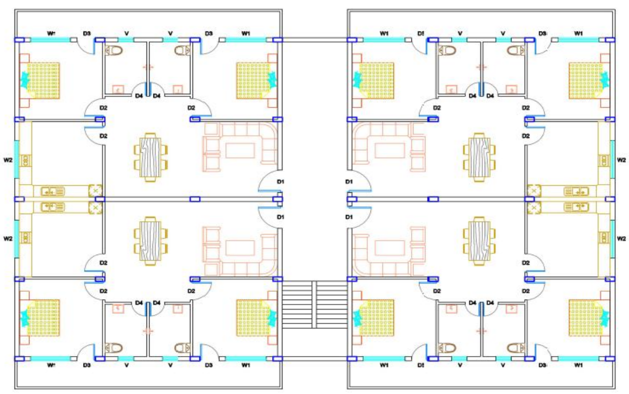


Fig -2 : Typical floor Plan

Standard size of the panel = 12m x 3m x 0.124 m
Rate of GFRG panels (per square meter) = Rs. 1120
Quantity of panels required for G+3 building-
In slab = 2883.41 Sq. Mt.
In walls = 3217.80 Sq. Mt.
In parapet = 265.55 Sq. Mt.
In stairs = 26.24 Sq. Mt.
In openings =341.28 Sq. Mt
Total = 6061.72 Sq. Mt.
Total cost of panels = Rs. 67.89 Lakhs

Table -1: Cost Comparison of GFRG Building with Load Bearing Wall Structure and Framed Structure

Description	Types of Building			Savings/Benefits in GFRG when compared to	
	GFRG building	Load bearing wall Str.	RCC Framed Str.	Load bearing wall Str.	RCC Framed Str.
Dwelling units	16	16	16	-	-
Carpet Area	122.19 SqM	116.02 SqM	119.02 SqM	5.32%	2.66%
Total Build up area	2341.36 sqm	2341.36 sqm	2341.36 sqm	-	-
Excavation	Rs. 74,560	Rs. 83,987	Rs. 95,025	11.22%	21.54%
Steel	Rs. 16,21,540	Rs. 11,91,679	Rs. 21,54,550	-36.07%	24.74%
Cement	Rs. 14,22,490	Rs. 24,46,373	Rs. 33,20,647	41.85%	57.16%
Bricks	-	Rs. 25,33,360	Rs. 15,45,745	-	-
Panels	Rs. 67,89,126	0	0	-	-
Course Aggregate	Rs. 13,47,046	Rs. 13,52,470	Rs. 23,42,706	0.40%	42.50%
Fine Aggregate	Rs. 4,09,045	Rs. 10,52,702	Rs 12,05,517	61.14%	66.07%
Shuttering cost	Rs. 0	Rs. 4,85,590	Rs 8,13,477	100%	100%
Labour	Rs.6,24,271	Rs. 27,71,050	Rs. 28,91,952	77.47%	78.41%
Sub Total	Rs. 1,22,88,078	Rs. 1,19,17,211	Rs. 1,42,74,596	-	-
Miscelaneous	Rs. 13,41,600	Rs. 37,45,862	Rs. 41,68,461	-	-
Total	Rs. 1,36,29,679	Rs. 1,56,63,073	Rs. 1,84,43,057	12.98%	26.10%

7. RESULT AND DISCUSSION

The miscellaneous expenses include charges of Water supply, site-cleaning cost, transportation cost, etc.
On the extensive comparison between the three models taken into account results in huge savings in GFRG structure when compared to Load bearing structure and Framed structure of 12.98 % and 26.10 % respectively.

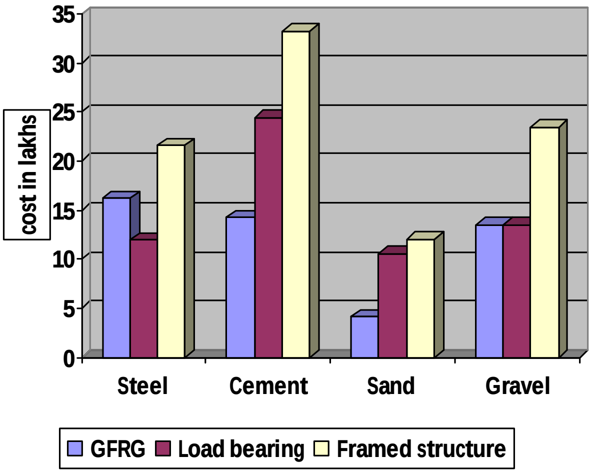


Chart -1: Cost comparison of materials required

In the above calculated cost, cost of finishing work like painting, wall putty, plumbing, electrification, sanitary fitting, installation of doors and windows, etc are not calculated as they are common in all three models and would not cause variation in prices for the comparison.

It is also important to note, the money saved due to early completion of the work and the gains in form of early selling or rent from the customers of the duration saved in construction time is additional to the comparative cost, which would further increase the benefits of the GFRG construction. We also see the carpet area increases in GFRG construction by 5.32% and 2.66% in comparison to other methods reducing the per SQ. Mt. cost of construction even further.

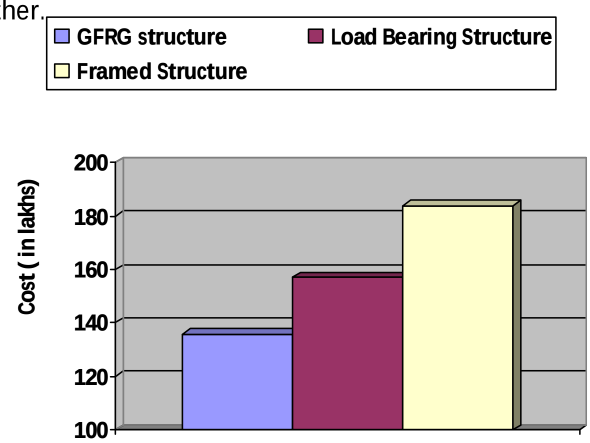


Chart -2: Total cost of construction

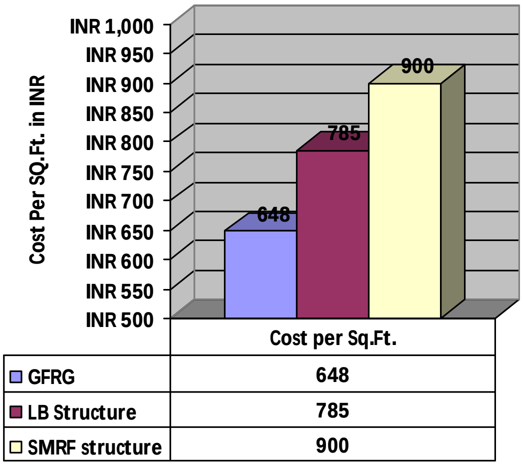


Chart -3: Cost per Sq. Ft.

8. CONCLUSIONS

With the above cost analysis, we return to the conclusion that opting for the GFRG Structure is much cost effective and also the time saving properties of this construction method is need of the hour under the increasing demand of the houses.

The panels also have good life span compared to conventional materials also help us save the environment by reducing our carbon foot prints. Nowadays, the use of panels in building advance gradually. Still, most of the people and engineers, suffer from lack of awareness about this type of building practices for residential buildings.

From this paper, we attempt to create some awareness about the construction of GFRG panel systems and about the costing, time management, resource allocation, etc.

9 FUTURE SCOPE

1. Analyze the cost of building in different seismic zones and with different materials with respect to local rates.
2. Analyze the cost of other types of prefabricated systems approved by BMTPC.
3. Analyze the reduction in carbon foot prints in construction, moving towards more sustainable development, by use of new construction technologies.

ACKNOWLEDGEMENT

First, I would like to express my heartily thanks to Mr. Bilal Siddiqui for being a great guide and helping me during this work. Also I would like to express my sincere gratitude towards all the scholars whose articles were referred to and a remarkable help was obtained while working on this project. I would like to extend my regards to all the evaluators and contractors, who selflessly helped me in obtaining the data correctly and paved the way to the results.

REFERENCES

1. Devdas Menon, Maganti Janardhana, and A. Meher Prasad(2003) " Studies on the Behavior of Glass Fiber Reinforced Gypsum Wall Panels"

2. Huiqing Ying and Zhengyong Liu "Elastic Lateral Features of a New Glass Fiber Reinforced Gypsum Wall" International Journal of science Index Vol:4 2010-03-29

3. Hegazy and Ayed (1998), Gunaydin and Dogan (2004), and M. – Y. Cheng Et Al. (2009) "Method of Estimation Using Neural Network"

4. IIT Madras, Department of Civil Engineering(2003) "Constuction Manual for Glass Fibre Reinforced Gypsum Based Building Panels"

5. Kang Liu, Xin-Liang Jliang and Yu-Fei WuShear(2008) "Strength of Concrete Filled Glass Fiber Reinforced Gypsum Walls" Materials and Structures Vol 41:649–662

6. Karshenas (1984), Trost and Oberlender (2003), Sonmez (2004), Lowe Et Al. (2006) "Method of Estimation Using Regression Model"

7. Kim Et Al. G - H (2004), Dogan Et Al. (2006), Wang Et Al. (2008) "Method of Estimation Using Case Based Reasoning Model"

8. Yu-Fei Wu (2004) "The Effect of Longitudinal Reinforcement on the Cyclic Shear Behavior of Glass Fiber Reinforced Gypsum Wall Panels: Tests"

9. Yu-Fei Wu (2009) "The Structural Behavior and Design Methodology for a New Building System Consisting of Glass Fiber Reinforced Gypsum Panels"

10. Glass Fibre Reinforced Gypsum Load Bearing Panels for Affordable Housing In Fast Track & Environmental Protection

11. Estimating and costing in civil engineering by B.N.Dutta.

12. Wu YF, Dare MP (2004) Axial and shear behavior of glass fiber reinforced gypsum wall panels: test. J Compos Constr ASCE8(6):569–678

13. Maganti Janardhana, A. Meher Prasad, Devdas Menon, "Studies On the behaviour of Glass Fiber Reinforced Gypsum Wall Panels", Structural engineering division, IIT Madras

14. GFRG/RAPIDWALL Building Structural Design Manual, prepared by Structural Engineering Division, Department of Civil Engineering, IIT Madras,2012.

15. Arvind reddy, R. J. Fernandes, "Seismic analysis of RC regular and irregular frame structures" International Research Journal of Engineering and Technology, Volume. 02, Issue 05, Aug 2015

16. Rapid wall manufacturer (2012) Rapidwall installation manual, Building Materials & Technology Promotion Council, Ministry of Housing & Urban Poverty Alleviation, Government of India.

17. Cost Model For Using Glass Fibre Reinforced Gypsum System (GFRG) Mohamed Said Meselhy Elsaeed International Journal of Development and Economic Sustainability Vol.4, No.3, pp.33- 47, June 2016.

BIOGRAPHIES

Mr. Siddhant Singhal was born in 1995 in Varanasi, (U.P.). He received his Bachelor Degree in Civil Engineering from AKTU, Lucknow in 2017. He is currently pursuing his Masters Degree in Structural Engineering from Babu Banarasi Das University, Lucknow.

Mr. Bilal Siddiqui was born in 1992 in Barabanki, (U.P.). He received his Bachelor Degree in Civil Engineering from AKTU, Lucknow in 2014. He received his Masters Degree in Structural Engineering from Integral university, Lucknow in 2016. He is currently working as Assistant Professor in Civil Engineering Department in Babu Banarasi Das University, Lucknow.

BBDU-PG- FORM 01

BABU BANARASI DAS UNIVERSITY, LUCKNOW

CERTIFICATION OF FINAL THESIS SUBMISSION

(To be submitted in Duplicate)

1. Name: …………………………………………………………..........................……...
2. Enrollment No. :…………………………………………………….......……………
3. Thesis title: …………………………………………………………………………...
   ………………………………………………………………………………………..
   ………………………………………………………………………………………..
4. Degree for which the thesis is submitted: ………………………………………………
5. Faculty of the university to which the thesis is submitted: ……………………………….
   ………………………………………………………………………………………..
6. Thesis Preparation Guide was referred to for preparing the thesis. [ ]YES [ ]NO
7. Specification regarding thesis format have been closely followed. [ ]YES [ ]NO
8. The contents of thesis have been organized based on the guideline. [ ]YES [ ]NO
9. The thesis has been prepared without resorting to plagiarism. [ ]YES [ ]NO
10. All sources used have been cited appropriately. [ ]YES [ ]NO
11. The thesis has not been submitted elsewhere for a degree. [ ]YES [ ]NO
12. All the corrections have been incorporated [ ]YES [ ]NO
13. Submitted 3 hard bound copies plus one CD. [ ]YES [ ]NO

(Signature of the Candidate)

Name: ………………………………..

Roll No.: ……………………………..

Enrollment No.: ……………………...

BBDU-PG- FORM 02

BABU BANARASI DAS UNIVERSITY, LUCKNOW

CERTIFICATION OF FINAL THESIS SUBMISSION

(To be submitted in Duplicate)

1. Name: ……………………………………………………………..........................……...
2. Enrollment No. :…………………………………………………………......……………
3. Thesis title: …………………………………………………………………………………...
   ……………………………………………………………………………………………..
   ……………………………………………………………………………………………..
4. Degree for which the thesis is submitted: …………………………………………………
5. Faculty of the university to which the thesis is submitted: ……………………………….
   ……………………………………………………………………………………………..
6. Thesis Preparation Guide was referred to for preparing the thesis. [ ]YES [ ]NO
7. Specification regarding thesis format have been closely followed. [ ]YES [ ]NO
8. The contents of thesis have been organized based on the guideline. [ ]YES [ ]NO
9. The thesis has been prepared without resorting to plagiarism. [ ]YES [ ]NO
10. All sources used have been cited appropriately. [ ]YES [ ]NO
11. The thesis has not been submitted elsewhere for a degree. [ ]YES [ ]NO
12. All the corrections have been incorporated [ ]YES [ ]NO
13. Submitted 3 hard bound copies plus one CD. [ ]YES [ ]NO

(Signature of Supervisor)

Name: …………………………….

(Signature of the Candidate)

Name: ………………………………..

Roll No.: ……………………………..

Enrollment No.: ……………………...