ANALYSIS AND DESIGN OF COMMERCIAL BUILDING WITH FLAT SLAB BY USING E-TABS

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ABSTRACT

With the increase in population and development of civilization, the demand for HOUSING is increasing at a peak rate. Especially in towns due to rapid industrialization, the demand is very high. Adapting the construction of Multi-storied Building not only matches with demand but also decreases the price of the single house.

Hence an Engineer to be knowledgeable about the planning and designing of such Multi-storied Buildings. Advancements of computer packages have given many tools to the designer towards achieving the best and accuracy in their work.

The aim of our project is to design a G+13 building with flat slabs instead of conventional slab. It is designed by using M25 grade concrete and Fe415 steel. The dead load, live load and seismic load are applied and the design for beams, columns, footing is obtained. Analysis & Design of the building with flat slab is done by using ETABS software.

I.INTRODUCTION

1.1 General

Now days, there is an increase in housing requirement with increased population and urbanization. Therefore, building sector has gained increasing prominence. However, the fact that the suitable lands for building/construction-especially in the areas in which people live intensively- are limited and expensive shows that there is a necessity for optimal evaluation of these lands. Additionally, continuously increasing prices leads to increase in building costs; so, both dimensional and cost optimization becomes necessary and even indispensable.

When a building is projected, geometrical dimensions of elements belonging to carrier system of the structure are usually determined by using engineering capability and experiences gained over time. In sizing, the tensile forces to which the material to be subjected to should comply with the specifications. In the building design, the pre-sizing details provided are generally not changed much; sizes obtained in second or – at most third solution are taken as carrier system sizes. In fact, carrier system can be sized in infinite possibilities in a manner to ensure all the necessary conditions; and the cost of each carrier system alternative can be different from each other. The basic aim in the engineering is to find a design having lowest cost, and ensuring predicted limitations.

1.2 Flat Slab

Flat slabs system of construction is one in which the beams used in the conventional methods of constructions are done away with. The slab directly rests on the column and load from the slab is directly transferred to the columns and then to the foundation. To support heavy loads the thickness of slab near the support with the column is increased and these are called drops, or columns are generally provided with enlarged heads called column heads or capitals.

Absence of beam gives a plain ceiling, thus giving better architectural appearance and also less vulnerability in case of fire than in usual cases where beams are used.

1.2.1 Basic Definition of Flat Slab

In general normal frame construction utilizes columns, slabs & Beams. However it may be possible to undertake construction without providing beams, in such a case the frame system would consist of slab and column without beams. These types of Slabs are called flat slab, since their behavior resembles the bending of flat plates.

A reinforced concrete slab supported directly by concrete columns without the use of beams

Figure 1: Slabs with columns

1.3 Components of Flat Slabs

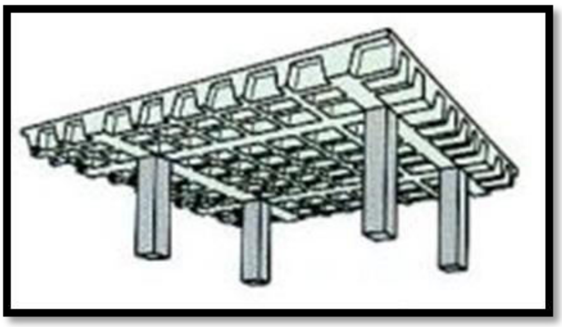
a. **Drops:** To resist the punching shear which is predominant at the contact of slab and column Support, the drop dimension should not be less than one -third of panel length in t hat direction.

b. **Column Heads:** Certain amount of negative moment is transferred from the slab to the column at the support. To resist this negative moment the area at the support needs to be increased .this is facilitated by providing column capital/heads.

Flat slabs are appropriate for most floor situations and also for irregular column layouts, curved floor shapes, ramps etc. The benefits of choosing flat slabs include a minimum depth solution, speed of construction, flexibility in the plan layout (both in terms of the shape and column layout), a flat soffit (clean finishes and freedom of layout of services) and scope and space for the use of flying forms.

The flexibility of flat slab construction can lead to high economy and yet allow the architect great freedom of form.

Examples are; solid flat slab, solid flat slab with drop panel, solid flat slab with column head, coffered flat slab, coffered flat slab with solid panels, banded coffered flat slab.



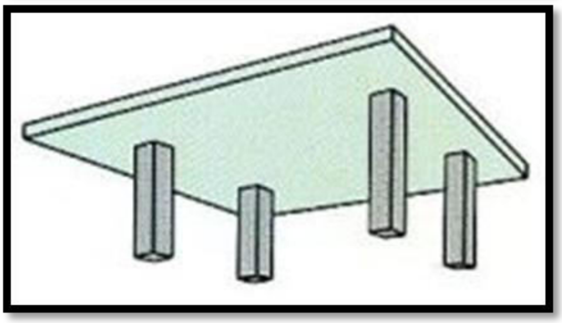


Fig: 1.2 Solid Flat Slab

Fig: 1.3 Coffered Flat Slab

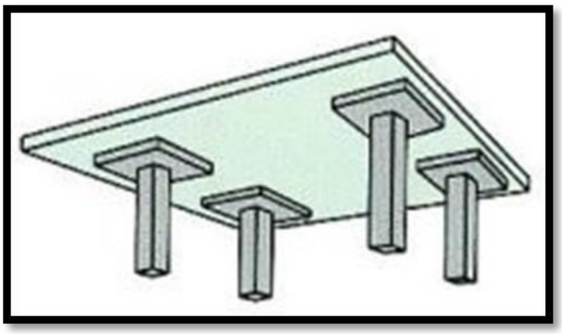


Fig: 1.4 Solid Flat slab with Drop Panels

A flat slab is a flat section of concrete. These slabs are classically used in foundations, although they can also be used in the construction of roadways, paths, and other structures. Depending on the size and complexity of a flat slab, it may need to be designed by an engineer who is familiar with the limitations and needs of slabs, or it may be possible for a handy do it yourself to make one in an afternoon for a simple project.

Typically, a flat slab is made with reinforced concrete, in which rebar is criss-crossed in the forms to provide support and reinforcement once the concrete is poured and hardened. The slab design is designed to be reinforced in several directions so that it can withstand stresses such as shifting ground, earthquakes, frost, and so forth. Failure to fully reinforce a flat slab can cause it to crack or give along weak lines in the concrete, which will in turn cause instability.

For some sites, a flat slab is poured in situ. In this case, the site is prepared, forms for the concrete are set up, and the reinforcing rebar or other materials are laid down. Then, the concrete is mixed, poured, and allowed to cure before moving on to the next stage of construction. The time required can vary considerably, with size being a major factor; the bigger the slab, the more complex reinforcement needs can get, which in turn adds to the amount of time required for set up. Once poured, the slab also has to be examined and tested to confirm that the pour was good, without air pockets or other problems which could contribute to a decline in quality.

In other cases, a flat slab may be prefabricated off site and transported to a site when it is needed. This may be done when conditions at the site do not facilitate an easy pour, or when the conditions for the slab's construction need to be carefully controlled. Transportation of the slab can be a challenge if it is especially large. Barges, cranes, and flatbed trucks may be required to successfully move it from the fabrication site to the site of the installation.

The flat slab foundation is not without problems. It can settle on uneven ground, allowing the structure to settle as well, for example, and during seismic activity, a slab foundation cannot hold up if the soils are subject to liquefaction. A flat slab can also become a major source of energy inefficiency, as structures tend to lose heat through the concrete.

1.4 Advantages & Disadvantages

1.4.1 Advantages

Advantages of flat-slab reinforced concrete structures are widely known but there are also known the disadvantages concerning their earthquake resistance. It is remarkable that both Greek codes, Reinforced Concrete Code and Seismic Code do not forbid the use of such structural systems however both Codes provide specific compliance criteria in order such structures to be acceptable. The advantages of these systems are:

- The ease of the construction of formwork.
- The ease of placement of flexural reinforcement.
- The ease of casting concrete
- The free space for water, air pipes, etc between slab and a possible furred ceiling.
- The free placing of walls in ground plan.
- The use of cost effective pressurizing methods for long spans in order to reduce slab thickness and deflections as also the time needed to remove the formwork.
- The reduction of building height in multi-storey structures by saving one storey height in every six storey's

thanks to the elimination of the beam height.

These structural systems seem to attract global interest due to their advantages mainly in countries in which the seismicity is low. The application of flat-slab structures is restrained due to the belief that such structures are susceptible to seismic actions. Moreover, it is known that in Central America, at the beginning of 1960's, flat-slab structures displayed serious problems during earthquake actions.

1.4.2 Disadvantages:

There are two main failure modes of flat slabs:

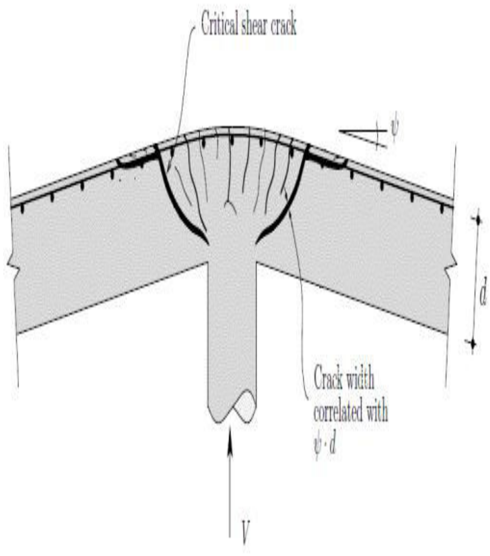
a. Flexural Failure

b. Punching Shear Failure

Slabs are designed to fail by flexural failure, the failure mode is ductile therefore giving relatively large deflections under excessive loading and also cracks will appear on the bottom surface before failure occurs. These signs allow the problem to be addressed before failure occurs.

Punching shear failure by comparison is a brittle failure mode when shear reinforcement is not added, meaning failure will occur before significant deflections take place, in addition to this any cracks that will develop before failure will propagate from the top surface. Since this surface is typically covered, it is unlikely that there will be sufficient warning available before failure occurs.

However, Thornsteinsson noted that it can be difficult to classify a failure mode to be an ideal representation of either flexural or punching shear failure and instead these modes often interact.



Punching shear failure in flat slabs

1.5 Key Messages:

1. For spans from 5 to 9 m, thin flat slabs are the preferred solution for the construction of in-situ concrete frame buildings where a square or near-square grid is used. For spans over 9 m post-tensioning should be considered.

2. Eliminating drops results in simpler false work and formwork arrangements, enabling rapid floor construction and giving maximum flexibility to the occupier.

3. The benefits associated with flat slab construction may well outweigh those of other structural solutions, which could be more complicated, time-consuming and ultimately more costly.

1.6 Proprietary Punching Shear Reinforcement Systems:

Thin flat slab construction will almost certainly require punching shear reinforcement at columns. This has traditionally taken the form of a large number of individual shear links arranged on a series of perimeters from the edge of the column. However, proprietary shear reinforcement systems are now available, which can greatly speed up the fixing process. These are described in a companion Best Practice Guide: Prefabricated punching shear reinforcement or reinforced concrete flat slabs. The savings in labour and time make these systems almost always worthwhile.

1.7 Objective

The main objective of this study is to identify various parameters that affected the ANALYSIS AND DESIGN OF MULTI-STORY BUILDING FOR FLAT FLOOR SYSTEM USING ETABS. The ETABS stands for extended 3D (Three-Dimensional) Analysis of Building Systems. This is based on the stiffness matrix and finite element based software. The analysis and design is done to satisfy all the checks as per Indian standards.

1.8 Scope of Work

PLANNING

Planning is the first step of project management philosophy of planning, organizing and controlling the execution of the projects. Project planning and project scheduling is two separate and distinct function of the project management.

At its inception a building normally begins as an inspiration or an idea in someone's mind. Once the person or the client has a clear concept of what he/she wants, in order for that thought to be a reality, the idea must then be converted into a Construction Project. All Construction Projects have 4 major phases: Initiation, Planning & Design, Implementation and Completion.

TYPES:

There are several types of project planning. The three major types of construction project planning are:

1. Strategic planning: This involves the high-level selection of the project objectives and it is done by the owner's corporate planners,

2. Operational planning: This involves the detailed planning required to meet the strategic objectives and it is done by construction teams. They ask certain questions before making operational plan for the project,

3. Scheduling: This puts the detailed operational plan on a time scale set by the strategic objectives.

DESIGN

Design is the creation of a plan or convention for the construction of an object or a system so designing can be done manually or by software such as Etab and Staadpro.

The components to design are foundation, plinth beam, columns, beams, slab and staircases.

II.MODELLING AND ANALYSIS

The analysis and design of RCC building was carried out using the software ETABS. It is the most popular structural engineering software product for 3D model generation, analysis and multi-material design. It has an intuitive, user-friendly GUI, visualization tools, powerful analysis and design facilities and seamless integration to several other modeling and design software products. For static or dynamic analysis of bridges, containment structures, embedded structures (tunnels and culverts), pipe racks, steel, concrete, aluminum or timber buildings, transmission towers, stadiums or any other simple or complex structure, has been the choice of design professionals around the world for their specific analysis needs.

2.1 Materials and Properties:

2.1.1 Building Materials:

The required material properties like mass, weight density, modulus of elasticity, shear modulus and design values of the material used can be modified as per requirements or default values can be accepted. Beams and column members have been defined as 'frame elements' with the appropriate dimensions and reinforcement. Soil structure interaction has not been considered and the columns have been restrained at the base.

The height of all the stories is 3m. The modulus of elasticity and shear modulus of concrete has been taken as E = 2.55 ×107 KN/m³ and G = 1.06 ×107 kN/m².

2.2 Loads:

2.2.1 Dead loads & Live loads:

After having modeled the structural components, all possible load cases are assigned. In this study we are primarily concerned with observing the deformations, forces and moments induced in the structure due to dead, live loads and earthquake loads. The load case 'Dead Load (DL) takes care of the self-weight of the frame members and the area sections. The wall loads have been defined under the case 'Live load (LL)'.

1. Floor finish is assigned as 1 kN/m².
2. Live load is assigned as 2 kN/m²

As per Table 8, Percentage of Imposed load to be considered in the Seismic weight calculation, IS 1893 (Part 1): 2002, since live load class is up to 5kN/m², 0.5% of imposing load has been considered.

2.3 Load Combination:

The structure has been analyzed for load combinations considering all the previous loads in proper ratio. In the first case a combination of self-weight, dead load, live load and wind load was taken in to consideration. In the second combination case instead of wind load seismic load was taken into consideration.

All the load cases are tested by taking load factors and analyzing the building in different load combination as per **IS456** and analyzed the building for all the load combinations and results are taken and maximum load combination is selected for the design load factors as per **IS456-2000.**

III.DESIGN PHILOSOPHIES

3.1 Methods of Design:

Some of the popular design methods are:

3.1.1 Working Stress Method.

3.1.2 Ultimate Load Method.

3.1.3 Limit State Method.

3.1.1 Working Stress Method:

This is also known as MODULAR RATIO METHOD, F.O.S. METHOD and ELASTIC METHOD.

In this method, analysis is based on the elastic theory assuming that both materials obey Hook's Law. It is a traditional method which is used for the design of reinforced concrete design where it is assumed that concrete and steel act together and are perfectly elastic at all stages and relationship between the loads and stresses is linear upto the collapse of the structure. It is based on the criteria that the actual stresses developed in the material under the action of the working loads is limited to a set of allowable values. Thus, the sections are designed in such a way that the stresses are within the permissible limits. This leads to un-economical sections, as the method doesn't utilize the full strength of the material resulting in heavier sections.

Design Loads = working /service loads.

Design Stresses = characteristic values /F.O.S

F.O.S For concrete = 3 ---- for bending

4 ---- for shear / compression

F.O.S for Steel = 1.78 ---- for bending, shear & compression.

DEFECTS:

It neither shows its real strength nor gives true factor of safety of structure against failure.

It results in larger % of compressive steels then limit state design.

IV.STRUCTURAL PLANNING

Structural planning is first stage in any structural design. It involves the determination of appropriate form of structure, material to be used, the structural system, the layout of its components and the method of analysis.

As the success of any engineering project measured in terms of safety and economy, the emphasis today is being more on economy. Structural planning is the first step towards successful structural design.

4.1 Structural Planning Of Reinforced Concrete Framed Building:

Structural planning of R.C framed building involves determination of

4.1.1 Column Positions

Following are some of the guidelines principles for positioning of columns.

Column should be preferably located at or near the corner of the building and at intersection of the walls, because the function of the column is to support beams which are normally placed under walls to support them. The columns, which are near to property line, can be exception from above consideration as the difficulties are encountered in providing footing for such columns.

When center to center distance between the intersection of the walls is large or where there are no cross walls, the spacing between two columns is governed by limitations on spans of supported beams because spacing of column beside the span of the beams. As the span of the beam increase as the required depth increase and hence its self weight. On the other hand increase in total load is negligible in case of column due to increase in length. Therefore, columns are generally cheaper compared to beams on basis of unit cost. Therefore, large spans of beam should be avoided for economy reasons.

4.1.2 Orientation of columns:

Column normally provided in the building are rectangular width of the column not less than the width of support for effective load transfer. As far as possible, the width of the column shall not exceed the thickness of the walls to avoid the offsets. Restrictions on the width of the column necessitate the other side (the depth) of the column to be larger the desired load carrying capacity. This leads to the problems of orientation of columns.

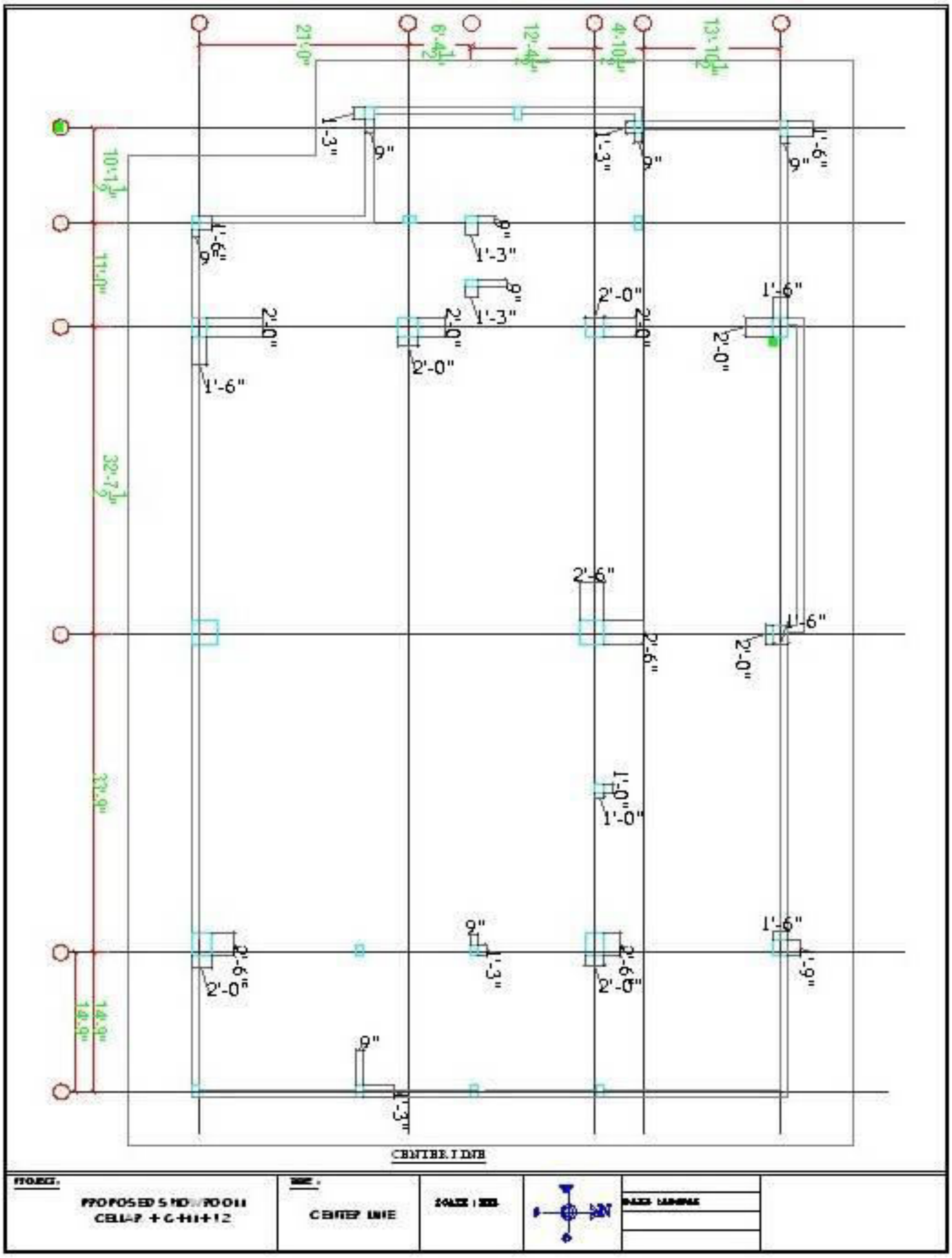


Figure 2 : Column Positions

4.1.3 Beam Locations

Following are some of the guiding principles for the positioning of beams:

a. Beams shall, normally be provided under the walls and below a every concentrated load to avoid these loads directly coming on slabs. Basic principle in deciding the layout of a component member is that heavy loads should be transferred to the foundation along the shortest path.

b. Since beams are primarily provided to support slabs, its spacing shall be decided by the maximum spans of slabs which decide the spacing of beams is governed by loading and limiting thickness. The maximum practical thickness for Residential/Office/Public building is 200mm, while minimum is 100mm.

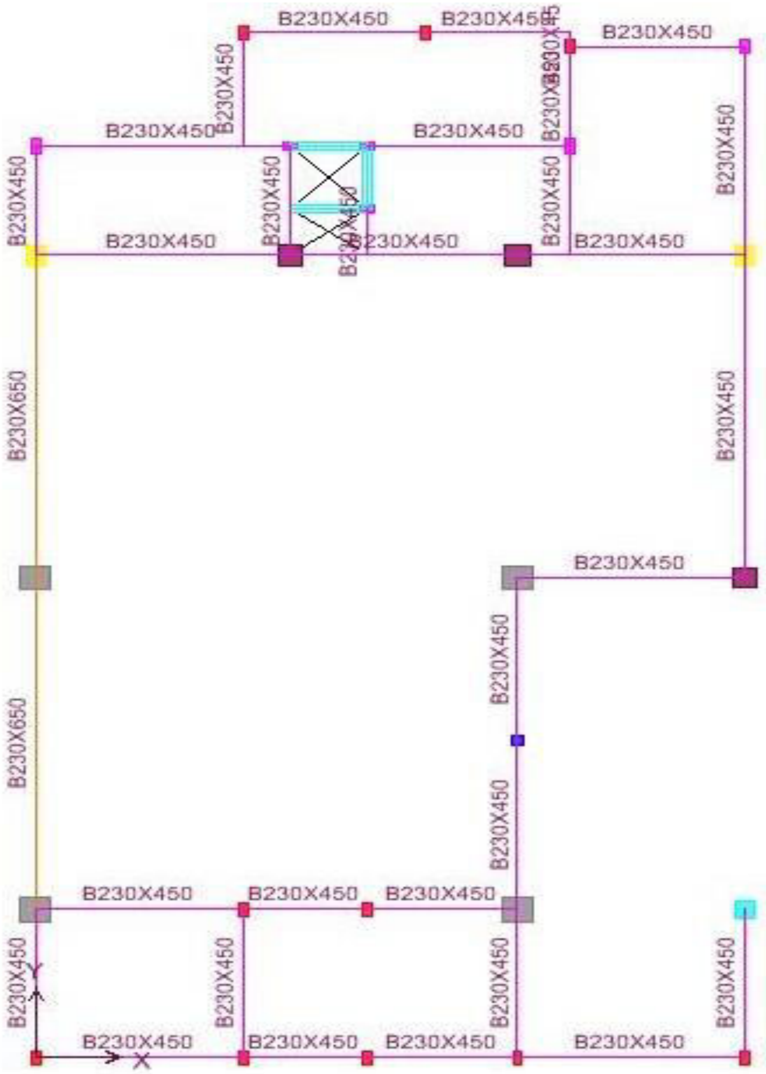


Figure 3 : Beams Location

V.LOADINGS

5.1 Load Conditions and Structural System Response:

The concepts presented in this section provide an overview of building loads and their effect on the structural response of typical wood-framed homes. As shown in Table, building loads can be divided into types based on the orientation of the structural action or forces that they induce: vertical and horizontal (i.e., lateral) loads.

Vertical Loads:

Gravity loads act in the same direction as gravity (i.e., downward or vertically) and include dead, live, and snow loads. They are generally static in nature and usually considered a uniformly distributed or concentrated load. Thus, determining a gravity load on a beam or column is a relatively simple exercise that uses the concept of tributary areas to assign loads to structural elements, including the dead load (i.e., weight of the construction) and any applied loads (i.e., live load). For example, the tributary gravity load on a floor joist would include the uniform floor load (dead and live) applied to the area of floor supported by the individual joist. The structural designer then selects a standard beam or column model to analyze bearing connection forces (i.e., reactions) internal stresses (i.e., bending stresses, shear stresses, and axial stresses) and stability of the structural member or system a for beam equations.

Lateral Loads:

The primary loads that produce lateral forces on buildings are attributable to forces associated with wind, seismic ground motion, floods, and soil. Wind and seismic lateral loads apply to the entire building. Lateral forces from wind are generated by positive wind pressures on the windward face of the building and by negative pressures on the leeward face of the building, creating a combined push and-pull effect. Seismic lateral forces are generated by a structure's dynamic inertial response to cyclic ground movement. The magnitude of the seismic shear (i.e., lateral)load depends on the magnitude of the ground motion, the buildings mass, and the dynamic structural response characteristics (i.e. dampening, ductility, natural period of vibration ,etc) for houses and other similar low rise structures, a simplified seismic load analysis employs equivalent static forces based on fundamental Newtonian mechanics (F=ma) with somewhat subjective (i.e., experience-based) adjustments to account for inelastic, ductile response characteristics of various building systems. Flood loads are generally minimized by elevating the structure on a properly designed foundation or avoided by not building in a flood plain. Lateral loads from moving flood waters and static hydraulic pressure are substantial. Soil lateral loads apply specifically to foundation wall design, mainly as an "out-of-plane" bending load on the wall. Lateral loads also produce an overturning moment that must be offset by the dead load and connections of the building.

VI.DESIGNING

6.1 Flat Slab

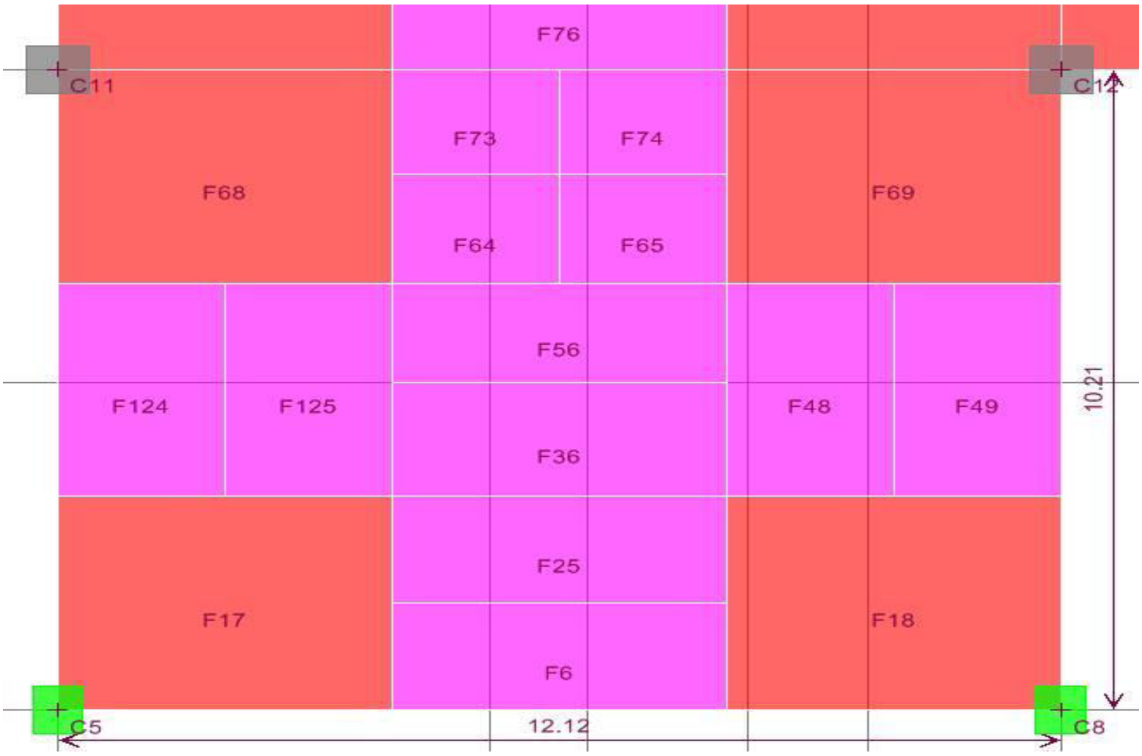


Figure 4 : flat slab representation

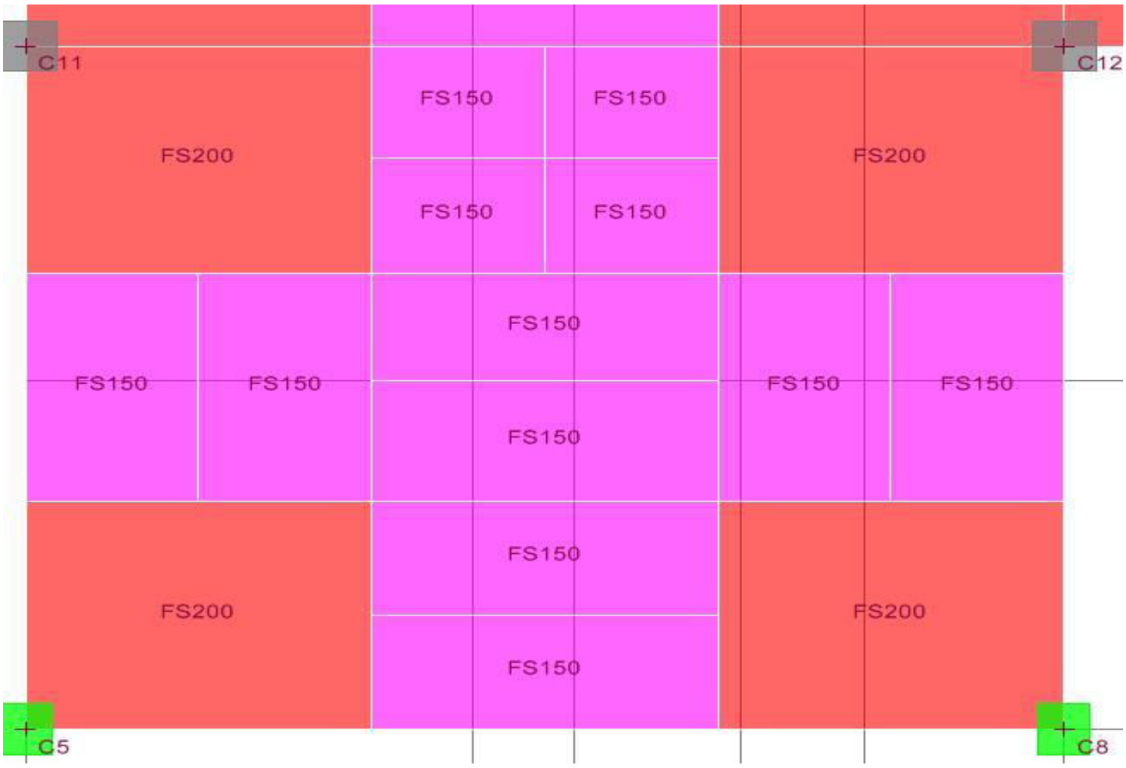


Figure 5 : flat slab sizes

Flat-slab building structures possesses major advantages over traditional slab-beam-column structures because of the free design of space, shorter construction time, architectural – functional and economical aspects. Because of the absence of deep beams and shear walls, flat-slab structural system is significantly more flexible for lateral loads then traditional RC frame system and that make the system more vulnerable under seismic events.

The purely flat-slab RC structural system is considerably more flexible for horizontal loads than the traditional RC frame structures which contributes to the increase of its vulnerability to seismic effects. The critical moment in design of these systems is the slab-column connection, i.e., the penetration force in the slab at the connection, which should retain its bearing capacity even at maximal displacements. The ductility of these structural systems is generally limited by the deformability capacity of the column-slab connection. To increase the bearing capacity of the flat-slab structure under horizontal loads, particularly when speaking about seismically prone areas and limitation of deformations, modifications of the system by adding structural elements are necessary.

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  2. IS 1893 (part-1) 2002 criteria for earthquake resistant design of structures Part-1 general provision & buildings,
  3. IS 456:2000 for RCC design,
  4. IS 875 – part I for weight and density of materials (RCC = 25

kN/m^3, PCC = 24 kN/m^3, Brick = 18-20 kN/m^3 ect.),

5. IS 875 – part II for live load,
6. IS 875 – part III for wind load and
7. IS 875 – part V for load combination.