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Seismic Analysis of Flat Slab Structure Using ETABS Software

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ABSTRACT

Civil Engineers are facing a great challenge in structural designing. The design must fulfil various parameters which include economical structure, durability and serviceability. But taking these points in mind it becomes very difficult for an Engineer to fulfil all these requirements at a time when a design is performed manually. This digital tool used in civil engineering and comparing their results by taking in mind the requirements of the above points. In this research process a building is taken for analysis and design on well-known Software ETABS.

Due to the freedom of space design, quicker construction time, architectural functionality, and economic factors, flat-slab building designs have significant advantages over typical slab-beam-column systems. The lack of deep beams and shear walls makes flat-slab structural systems far more flexible for lateral stresses than standard RC frame systems, which increases the system's susceptibility to seismic occurrences. The critical moment in design of these systems is the slab-column connection, i.e., the shear force in the slab at the connection, which should retain its bearing capacity even at maximal displacements.

In this study we are comparing a G+10 High rise building frame considering three different slab conditions i.e. conventional slab, flat slab and flat slab with staggered beams. For analysis we are utilizing analysis tool etabs.

Keywords: Response Spectrum Analysis, Flat Slab, Flat Slab with Perimeter Beam, ETABS , story displacement, story stiffness, story drift, time period.

I. INTRODUCTION

The building codes permit performance-based style, but there isn't a lot of particular guidance. Numerous necessary guiding principles for the shaky design of tall buildings have recently been published in distinct styles. These focuses advance the usage of various kind of burden refusal embracement which was not out there for the plan in the plan local area. Parallel burdens as a result of wind and quake supervises the design rather than the upward loads.

The developments made to help vertical burdens probably won't have the option to help side burdens. The justification for why sidelong loads are more huge and increment rapidly with level than vertical loads that would be supposed to increment straightforwardly with height is on the grounds that they are flat. The disrupting second at the foundation of a design so tall is huge and changes comparable to the square under a consistent breeze and tremor stacks. A structure will normally work as a cantilever on the grounds that the level burdens are excessively weighty at the popular narrative contrasted with the establishment story. These equal powers will in everyday impact the packaging. Neither in an extensive part of the seismic slanted regions there are a couple of instances of dissatisfaction of designs which are nor been planned f0r quake loads. This all reaction has examination of effect of the sidelong burden huge.

1.2 Reinforced Concrete Slab System

Buildings' flat surfaces (floors and ceilings) are provided by reinforced concrete slabs, which are an essential structural component. Slabs are typically divided into one-way slabs and two-way slabs depending on the reinforcement that is present, the support provided by the beam, and the ratio of the spans. The former is supported on two sides, and there is a greater than two-to-one ratio between the long and short spans. The latter, however, is supported on four sides and has a shorter long to short span ratio than two.

Regarding the type of building, architectural arrangement, aesthetic elements, and span length, various variables and requirements call for the selection of an acceptable and affordable concrete slab. Concrete slabs, therefore, are further classified into one-way joist slab, flat slab, flat plate, waffle slab, hollow core slab, precast slab, slabs on grade, hardy slab, and composite slab.

Seismic Loading on Multi Storey Structure

The purpose of seismic analysis is to identify the various earthquake responses of buildings and to decide whether to adapt existing structures. For earthquake-prone regions like Japan, the North-East of India, Nepal, the Philippines, and many others, it is a crucial instrument. When designing RCC building components such beams, columns, and slabs in compliance with IS 13920:2016, this type of analysis is crucial. The load carrying ability, ductility, wetness, stiffness, and mass of the dynamic seismic forces are tested. Multi-story buildings are seismically analysed using IS 1893:2016.

Objectives behind the research

- To determine the behaviour of high rise building frame under seismic load as per I.S. 1893-I:2016
- To determine the effectiveness of flat slab in comparison with conventional grid slab.
- To determine the utilization of etabs software in analysis of high rise RCC building structure.
- To provide comparative analysis results of conventional, flat slab and flat slab with staggered beam structure in terms of forces, moment, displacement and drift.

II. Review of Literature Survey

Denis K, Mateng'e and Manu SE (2022) In a study, the seismic behaviour of multistory buildings for flat slab constructions with variously shaped drop panels was examined. Using the dynamic analytical method, slabs with rectangular and square drop panels were examined under earthquake stresses. Using ETAB's software, square flat slab buildings with plan areas of 28m x 28m were modelled and assessed for earthquake zones III and IV. Storey drift, displacement, and base shear were the parameters employed to assess the seismic behaviour.

Results stated that displacement in the flat slab with a rectangular drop panel structure was more than that of the structure with square shaped drop panel by

69.61% at the top story and 28.78% at the bottom story for seismic zone III. In seismic zone IV the displacement of the structure with rectangular drop panel was more than that of the structure with square drop panel with the same percentage however the values for this zone were higher. The story drift for the structure with rectangular drop panels was more than that of the structure with square drop panels by 88.40% at the top story and 28.78% at the bottom story. The base shear and story shears was more for the building with square drop panels than that with rectangular drop panels.

Manish Kumar Pandey and Dr. Raghvendra Singh (2021) objective of the research paper was to investigate the behavior of different types of slab and secondary beam in a structure considering a G+10 multistory building taking different variations on slabs and introducing a secondary beam in the structure. RSA (Response Spectrum Analysis) was used for the analysis of model on parameters of Storey displacement, base shear, overturning moments and storey shears. Results stated that most preferable long span slab was building with waffle or ribbed slab.

Nitish A. Mohite et.al (2021) in the research paper, Using CSI ETABS software version 2016, three-dimensional analytical models of G+20 storey buildings were created and examined. A G+20 story structure with a flat slab (with drops) and conventional slab system was analysed and designed while taking seismic zone III into consideration. The structures were designed and analysed using the equivalent static method in accordance with the Indian Standard Code for earthquake-resistant structures, and comparisons were made based on factors such story drift, story displacement, story stiffness, and time period.

Results stated that that story drift was 10% more in conventional slab as compared to flat slab; story displacements was observed linearly increasing with height of the building and was 11% more in conventional slab as compared to flat slab.

Shital Borkar et.al (2021) The primary motive of research was to analyze the seismic behaviour of different types of slab structures i.e. Flat slab structure, conventional slab structure, flat slab structure with drop under different earthquake zones considering G+5 storey building using ETAB software. Author also analyzed a comparison of behavior of flat bit of material building with old common 2 way bit of material system for different bands, parts like band, part zone-II, part zone-III, part zone-IV, part zone-V in respect with the greatest point making bent moment.

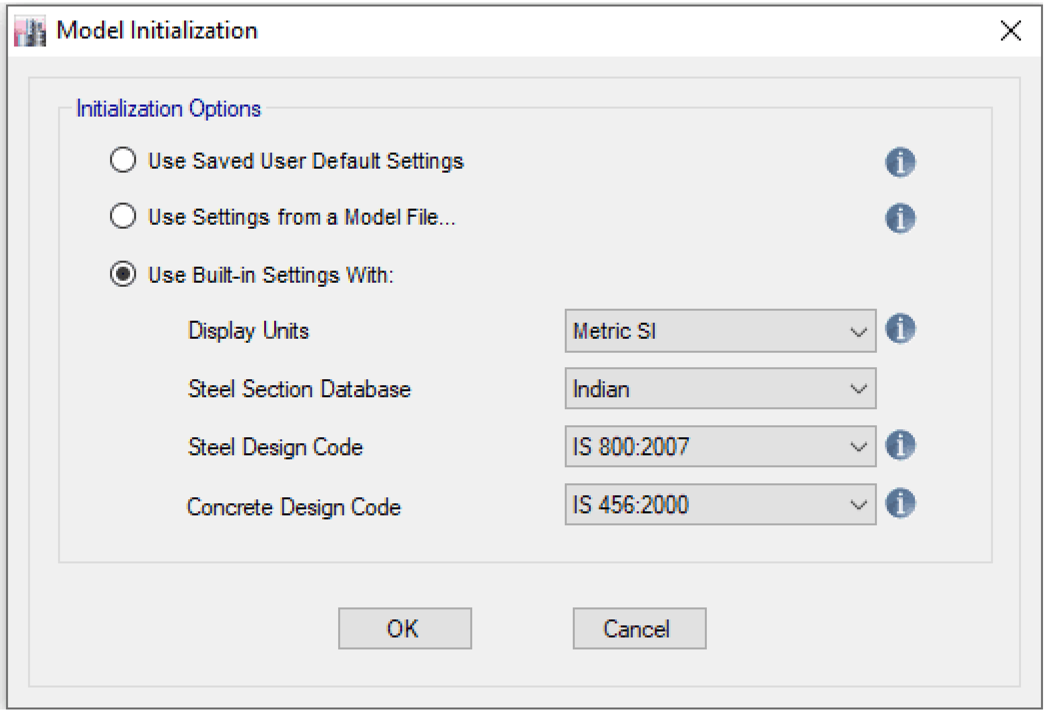
According to the findings, for both regular and irregular structures, the storey displacement was greatest in flat systems and lowest in typical slab systems throughout the seismic zone. For both regular and irregular structures, story shear was greatest in the flat slab system and lowest in the flat slab with drop system across the seismic zone.

III. METHODOLOGY

Steps involved in the Analysis

Step 1- Firstly research papers from different authors were studied to identify the scope of research and have an elaborate study about the research done till date. Authors have studied the structure behaviour with change in size of column and this led us to identify the research topic as such research are still untouched for high rise structures.

Step 2: The first step is to define the units in ETABS for the purpose of modelling. Here the display units as metric SI and the further values are defined as per the Indian standards for different material involved in the process of construction. The pre-defined properties as per the categories are defined in the software where the different country codes are available as ASI standards, Chinese standards, Indian standards and Australian standards.



Initialization Options

○ Use Saved User Default Settings

○ Use Settings from a Model File...

● Use Built-in Settings With:

Display Units: Metric SI

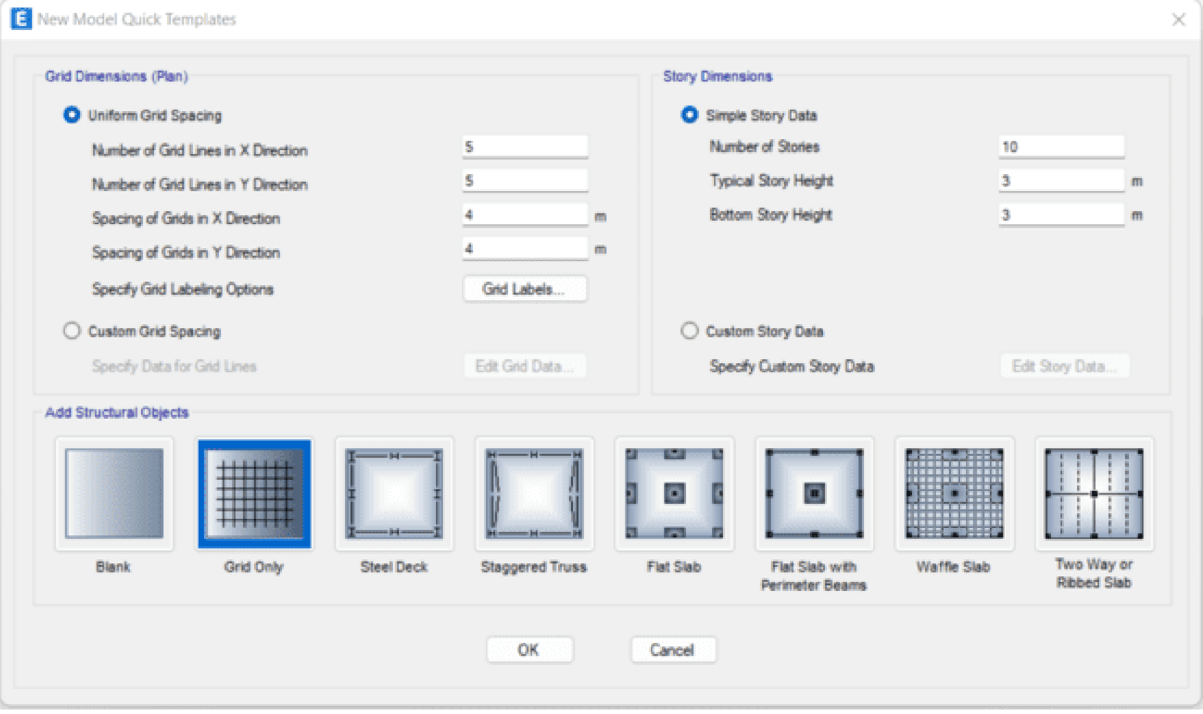
Steel Section Database: Indian

Steel Design Code: IS 800:2007

Concrete Design Code: IS 456:2000

Fig 1 Model Initialization

Step 3: This step involves defining the grid as ETABS provides the provision to choose from the predefined grid system proving its ease for modelling the structure.



Grid Dimensions (Plan)

● Uniform Grid Spacing

Number of Grid Lines in X Direction: 5

Number of Grid Lines in Y Direction: 5

Spacing of Grids in X Direction: 4 m

Spacing of Grids in Y Direction: 4 m

Specify Grid Labeling Options

○ Custom Grid Spacing

Specify Data for Grid Lines

Story Dimensions

● Simple Story Data

Number of Stories: 10

Typical Story Height: 3 m

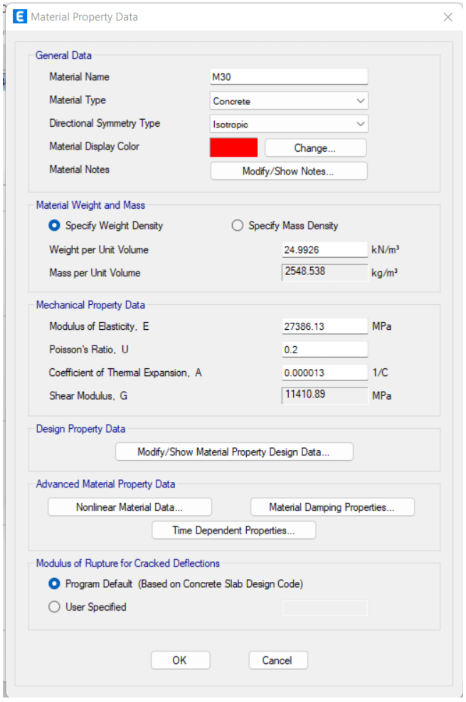
Bottom Story Height: 3 m

○ Custom Story Data

Specify Custom Story Data

Fig 2 Model Quick Template

Step 4: Defining material properties for concrete, steel, infill and rebar. In this study, M30 concrete is considered along with HYSD415 rebar.



General Data

Material Name: M30

Material Type: Concrete

Directional Symmetry Type: Isotropic

Material Display Color: 🟥

Material Notes

Material Weight and Mass

● Specify Weight Density ○ Specify Mass Density

Weight per Unit Volume: 24.9926 kN/m³

Mass per Unit Volume: 2548.538 kg/m³

Mechanical Property Data

Modulus of Elasticity, E: 27386.13 MPa

Poisson's Ratio, U: 0.2

Coefficient of Thermal Expansion, A: 0.000013 1/C

Shear Modulus, G: 11410.89 MPa

Design Property Data

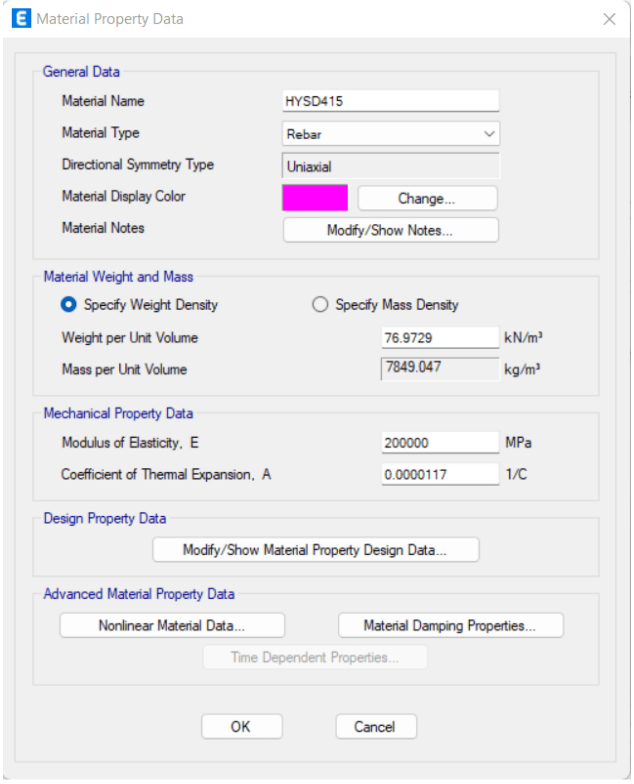
Advanced Material Property Data

Modulus of Rupture for Cracked Deflections

● Program Default (Based on Concrete Slab Design Code)

○ User Specified

Fig 3 Concrete Property



General Data

Material Name: HYSD415

Material Type: Rebar

Directional Symmetry Type: Uniaxial

Material Display Color

Material Notes

Material Weight and Mass

● Specify Weight Density ○ Specify Mass Density

Weight per Unit Volume: 76.9729 kN/m³

Mass per Unit Volume: 7849.047 kg/m³

Mechanical Property Data

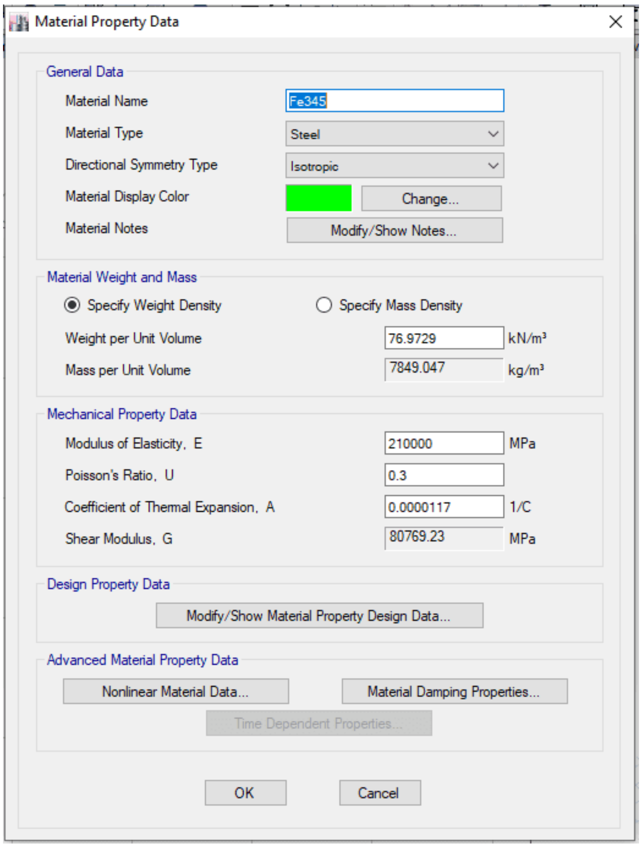
Modulus of Elasticity, E: 200000 MPa

Coefficient of Thermal Expansion, A: 0.0000117 1/C

Design Property Data

Advanced Material Property Data

Fig 4 Rebar Property



Material Property Data

General Data

Material Name: Fe345

Material Type: Steel

Directional Symmetry Type: Isotropic

Material Display Color: 🟩

Material Weight and Mass

● Specify Weight Density ○ Specify Mass Density

Weight per Unit Volume: 76.9729 kN/m³

Mass per Unit Volume: 7849.047 kg/m³

Mechanical Property Data

Modulus of Elasticity, E: 210000 MPa

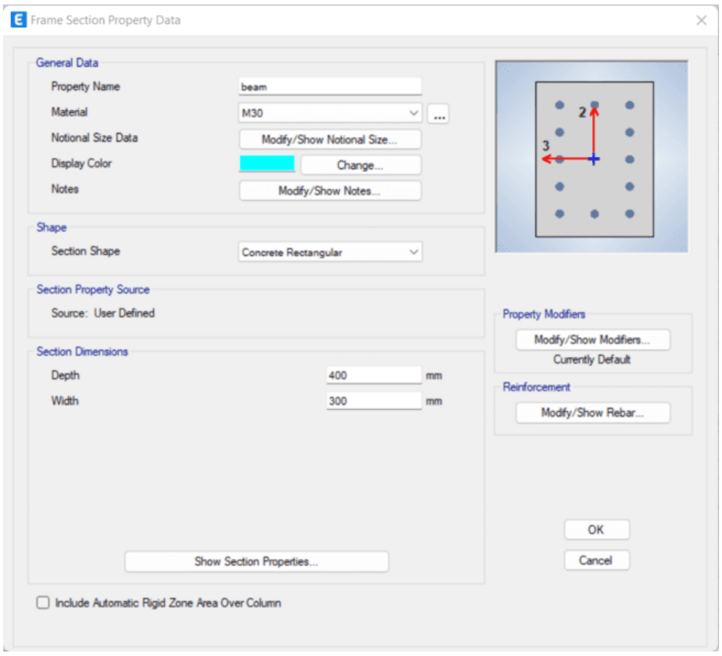
Poisson's Ratio, U: 0.3

Coefficient of Thermal Expansion, A: 0.0000117 1/C

Shear Modulus, G: 80769.23 MPa

Fig 5 Properties of Steel

Step 5 Defining sections properties for column, beam 400x300mm and slab.



Frame Section Property Data

General Data

Property Name: beam

Material: M30

Display Color: 🟦

Shape

Section Shape: Concrete Rectangular

Section Property Source

Source: User Defined

Section Dimensions

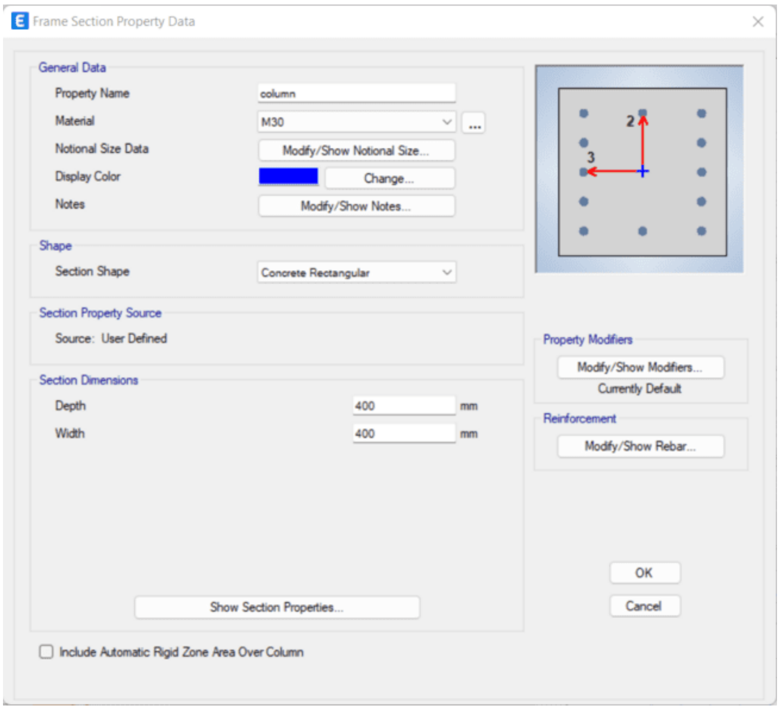
Depth: 400 mm

Width: 300 mm

Property Modifiers: Currently Default

☐ Include Automatic Rigid Zone Area Over Column

Fig 6 Section properties of beam


Frame Section Property Data

General Data

Property Name: column

Material: M30

Shape

Section Shape: Concrete Rectangular

Section Property Source

Source: User Defined

Section Dimensions

Depth: 400 mm

Width: 400 mm

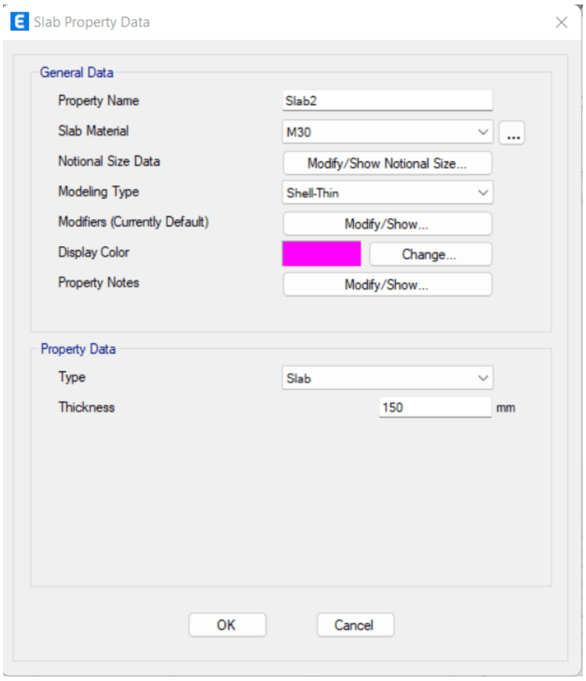
Property Modifiers

Currently Default

Reinforcement

☐ Include Automatic Rigid Zone Area Over Column

Fig 7 Section Properties of Column 400x400mm


Slab Property Data

General Data

Property Name: Slab2

Slab Material: M30

Modeling Type: Shell-Thin

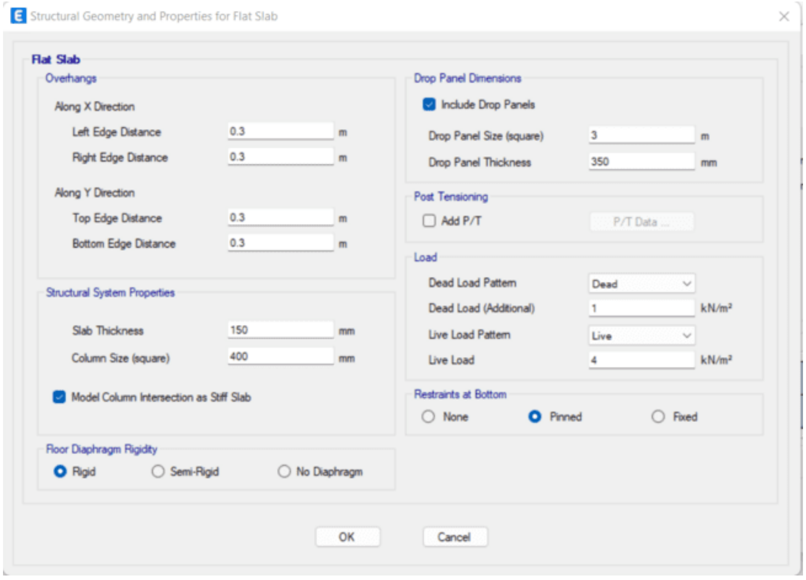
Modifiers (Currently Default)

Property Data

Type: Slab

Thickness: 150 mm

Fig 8 Section Properties of Conventional Slab



Flat Slab

Overhangs

Along X Direction
Left Edge Distance 0.3 m
Right Edge Distance 0.3 m

Along Y Direction
Top Edge Distance 0.3 m
Bottom Edge Distance 0.3 m

Structural System Properties
Slab Thickness 150 mm
Column Size (square) 400 mm
☑ Model Column Intersection as Stiff Slab

Floor Diaphragm Rigidity
● Rigid ○ Semi-Rigid ○ No Diaphragm

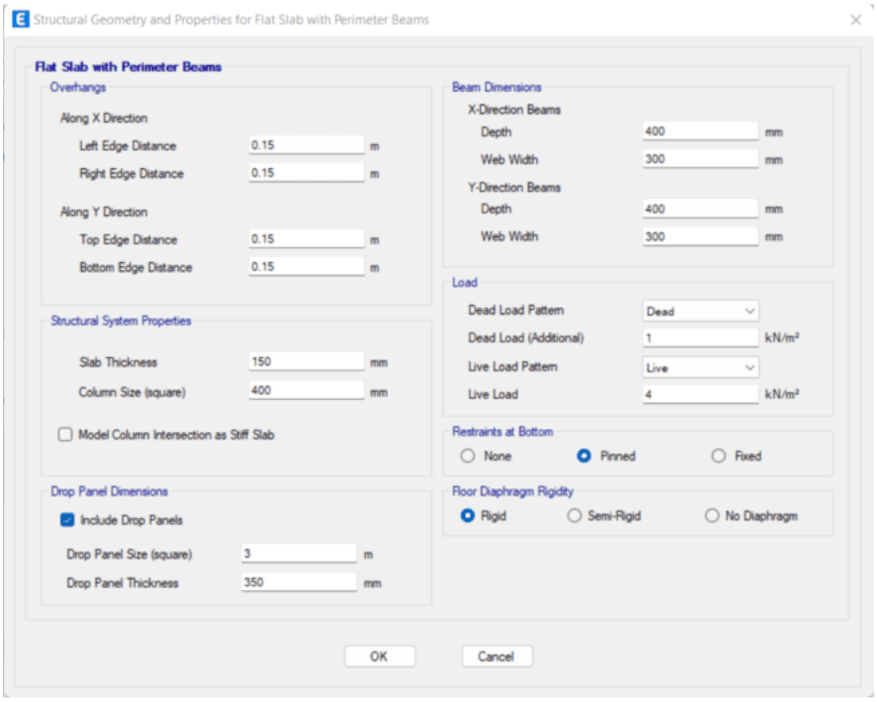
Drop Panel Dimensions
☑ Include Drop Panels
Drop Panel Size (square) 3 m
Drop Panel Thickness 350 mm

Post Tensioning
☐ Add P/T

Load
Dead Load Pattern Dead
Dead Load (Additional) 1 kN/m²
Live Load Pattern Live
Live Load 4 kN/m²

Restraints at Bottom
○ None ● Pinned ○ Fixed

Fig 9 Structural Geometry and Properties for Flat Slab



Flat Slab with Perimeter Beams

Overhangs

Along X Direction
Left Edge Distance 0.15 m
Right Edge Distance 0.15 m

Along Y Direction
Top Edge Distance 0.15 m
Bottom Edge Distance 0.15 m

Structural System Properties
Slab Thickness 150 mm
Column Size (square) 400 mm
☐ Model Column Intersection as Stiff Slab

Drop Panel Dimensions
☑ Include Drop Panels
Drop Panel Size (square) 3 m
Drop Panel Thickness 350 mm

Beam Dimensions
X-Direction Beams
Depth 400 mm
Web Width 300 mm
Y-Direction Beams
Depth 400 mm
Web Width 300 mm

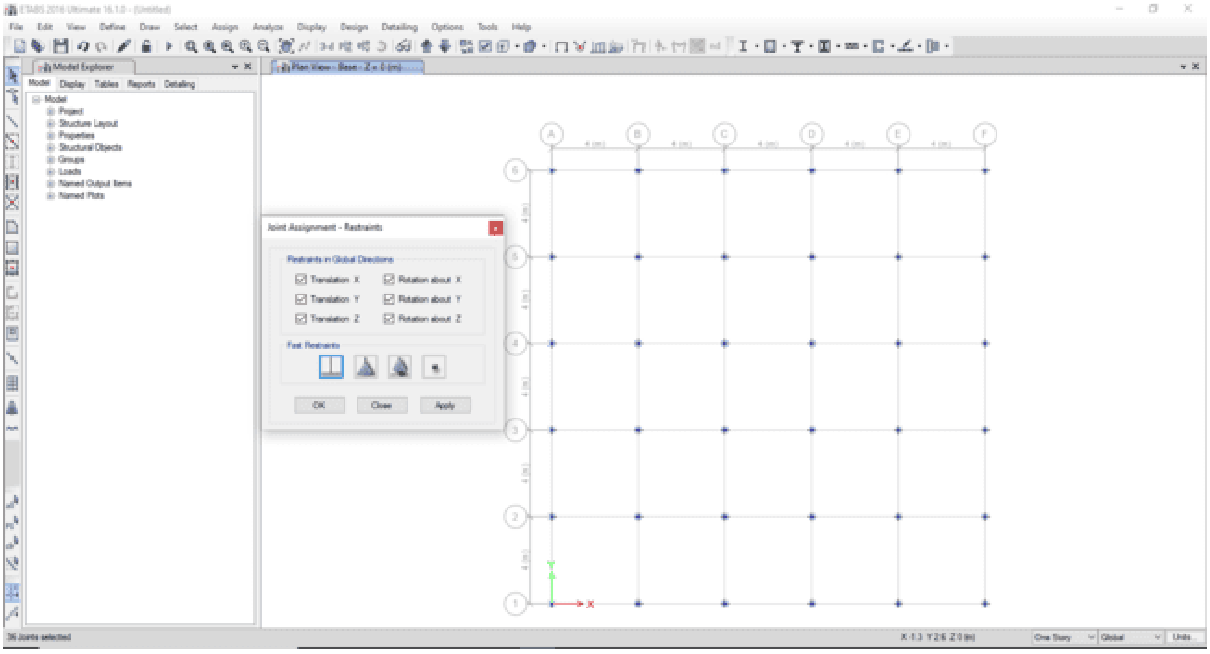
Load
Dead Load Pattern Dead
Dead Load (Additional) 1 kN/m²
Live Load Pattern Live
Live Load 4 kN/m²

Restraints at Bottom
○ None ● Pinned ○ Fixed

Floor Diaphragm Rigidity
● Rigid ○ Semi-Rigid ○ No Diaphragm

Fig 10 Geometrical Properties of Flat Slab with Perimeter beam

Step 6 Assigning Fixed Support at bottom of the structure for X, Y and Z-direction.



Joint Assignment - Restraints

Restraints in Global Directions

☑ Translation X ☑ Rotation about X

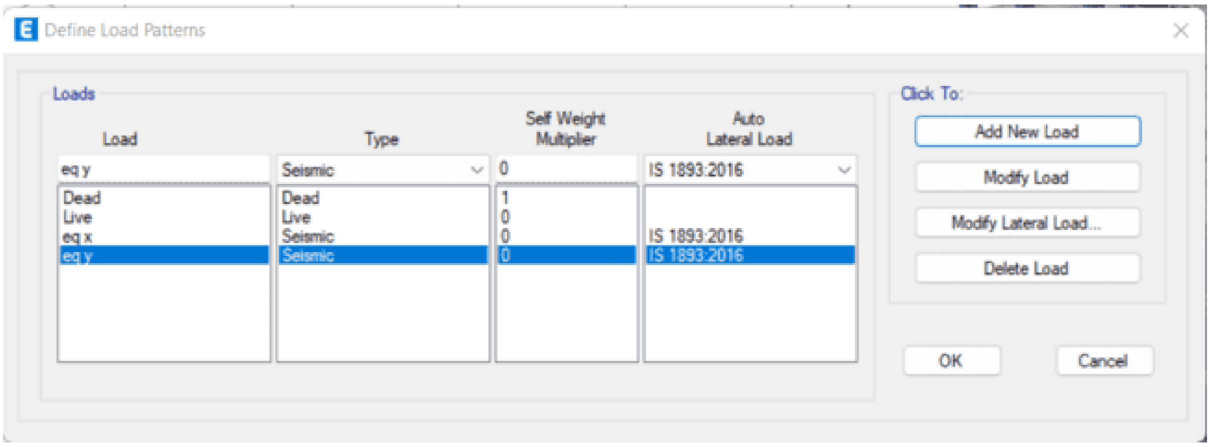
☑ Translation Y ☑ Rotation about Y

☑ Translation Z ☑ Rotation about Z

Fast Restraints

Fig 11 Assigning Fixed Support

Step 7 Defining Loading conditions for live load, dead load and seismic loads.

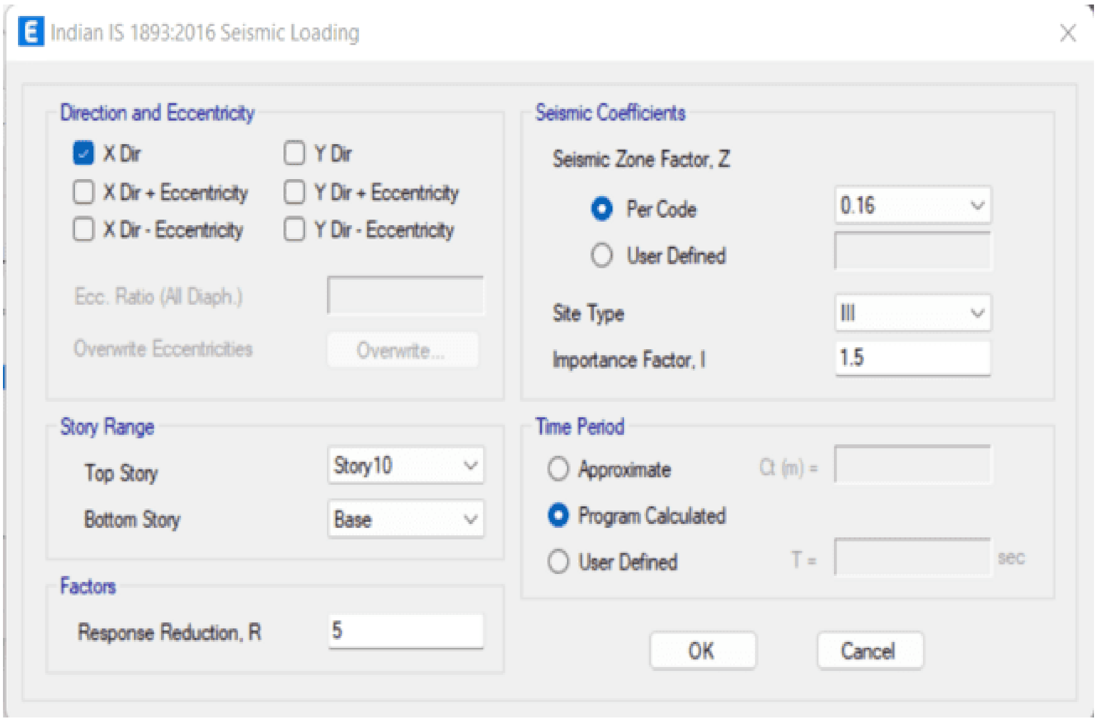


Define Load Patterns

Loads

Load	Type	Self Weight Multiplier	Auto Lateral Load
eq y	Seismic	0	IS 1893:2016
Dead	Dead	1	
Live	Live	0	
eq x	Seismic	0	IS 1893:2016
eq y	Seismic	0	IS 1893:2016

Fig 12 Defining Load patterns



Indian IS 1893:2016 Seismic Loading

Direction and Eccentricity

☑ X Dir
☐ Y Dir
☐ X Dir + Eccentricity
☐ Y Dir + Eccentricity
☐ X Dir - Eccentricity
☐ Y Dir - Eccentricity

Ecc. Ratio (All Diaph.)

Overwrite Eccentricities

Seismic Coefficients

Seismic Zone Factor, Z

● Per Code: 0.16
○ User Defined

Site Type: III

Importance Factor, I: 1.5

Story Range

Top Story: Story10

Bottom Story: Base

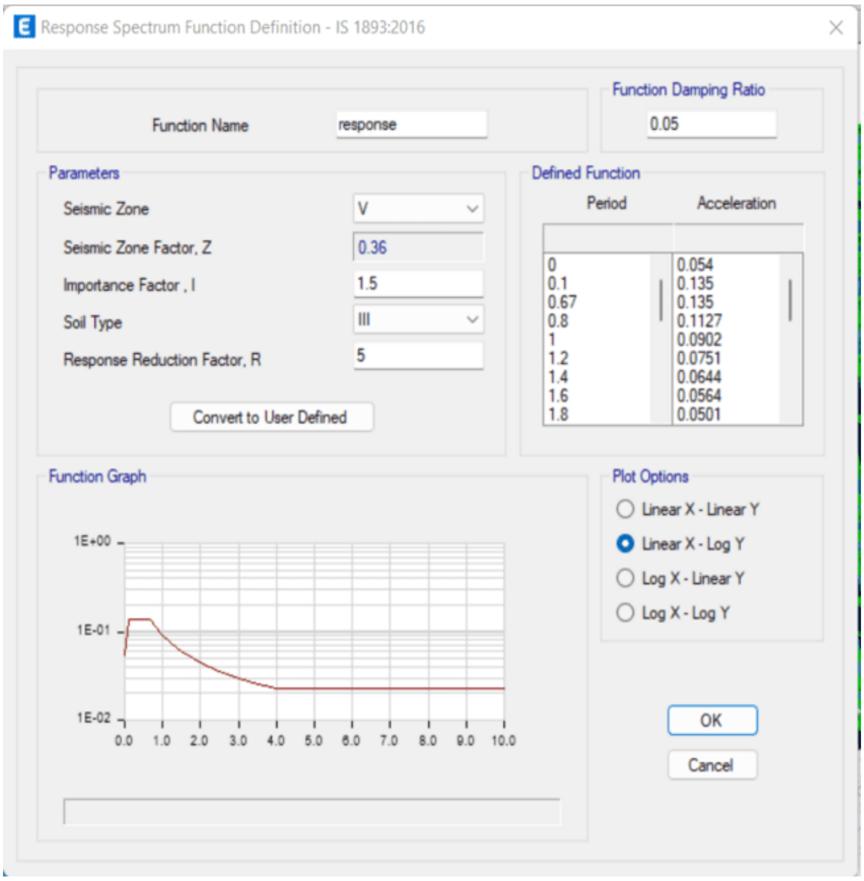
Time Period

○ Approximate Ct (m) =
● Program Calculated
○ User Defined T = sec

Factors

Response Reduction, R: 5

Fig 13 Seismic load as per IS 1893:2002.



Response Spectrum Function Definition - IS 1893:2016

Function Name: response

Function Damping Ratio: 0.05

Parameters

Seismic Zone: V

Seismic Zone Factor, Z: 0.36

Importance Factor , I: 1.5

Soil Type: III

Response Reduction Factor, R: 5

Defined Function

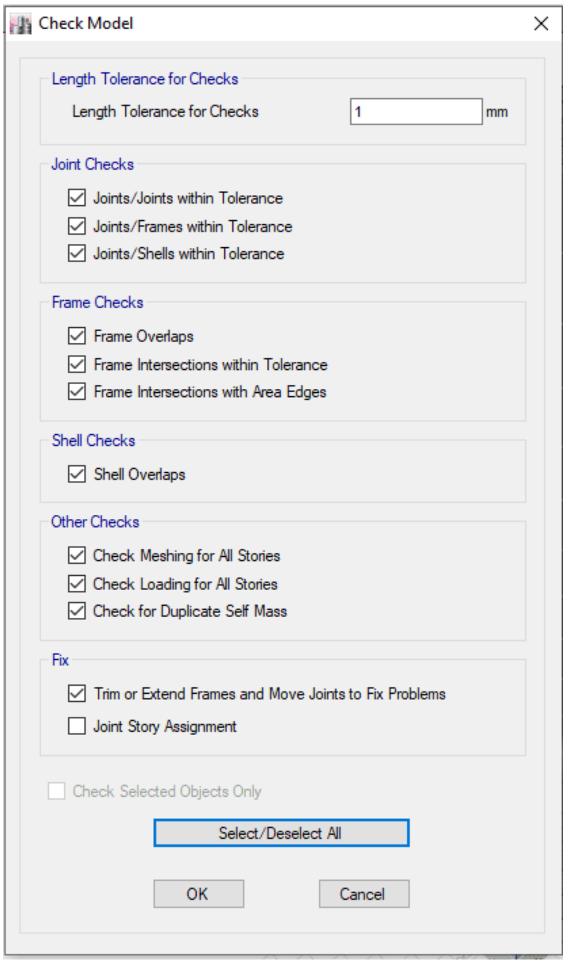
Period	Acceleration
0	0.054
0.1	0.135
0.67	0.135
0.8	0.1127
1	0.0902
1.2	0.0751
1.4	0.0644
1.6	0.0564
1.8	0.0501

Plot Options

○ Linear X - Linear Y
● Linear X - Log Y
○ Log X - Linear Y
○ Log X - Log Y

Fig 14 Response Spectrum Analysis

Step 8 Checking the model for the analysis



Check Model

Length Tolerance for Checks

Length Tolerance for Checks: 1 mm

Joint Checks

☑ Joints/Joints within Tolerance
☑ Joints/Frames within Tolerance
☑ Joints/Shells within Tolerance

Frame Checks

☑ Frame Overlaps
☑ Frame Intersections within Tolerance
☑ Frame Intersections with Area Edges

Shell Checks

☑ Shell Overlaps

Other Checks

☑ Check Meshing for All Stories
☑ Check Loading for All Stories
☑ Check for Duplicate Self Mass

Fix

☑ Trim or Extend Frames and Move Joints to Fix Problems
☐ Joint Story Assignment

☐ Check Selected Objects Only

Fig 15 Checking the model

Step 9 Results were generated on parameters of storey displacement, shear force, bending moment and axial force.

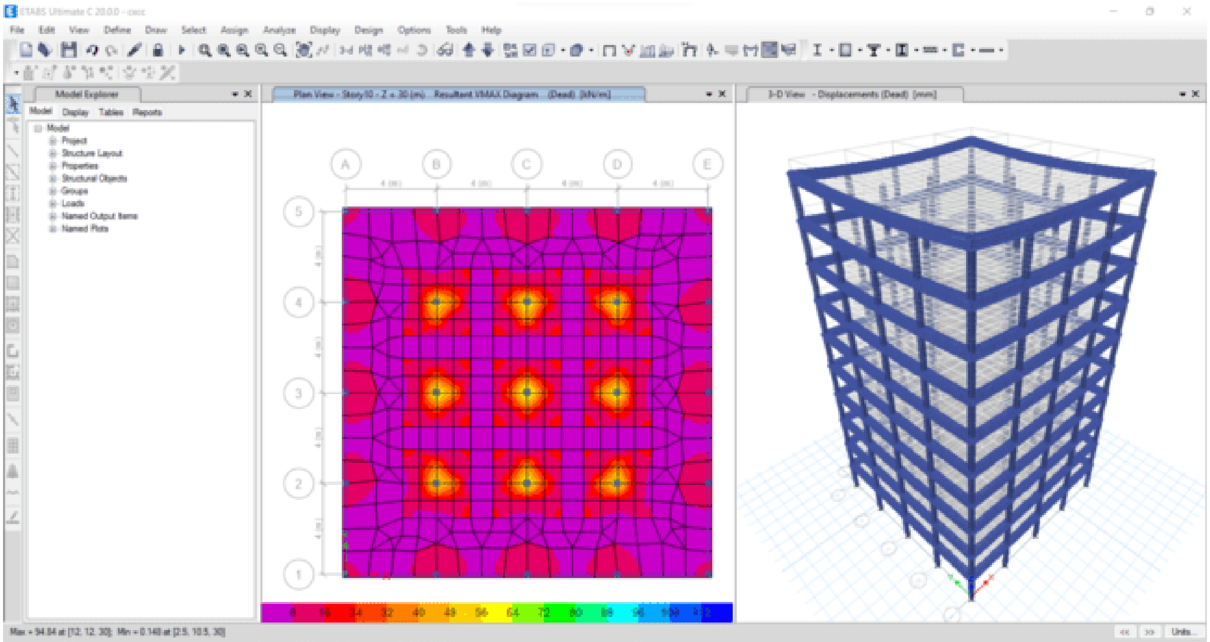


Fig 16 Stress Analysis of structure

Flow Chart

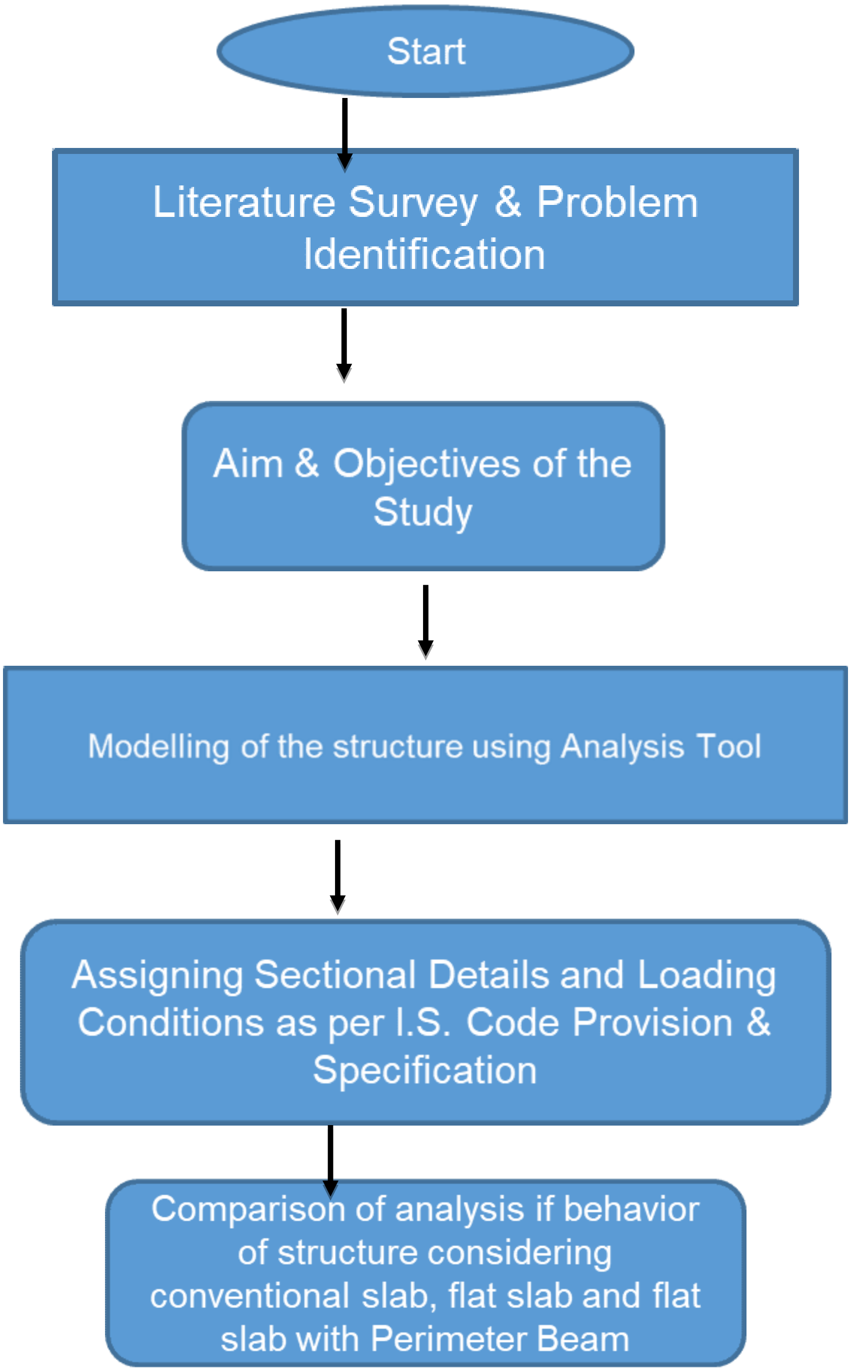


Fig 17 Flow Chart of the Study

Case I G+10 with Conventional Slab.

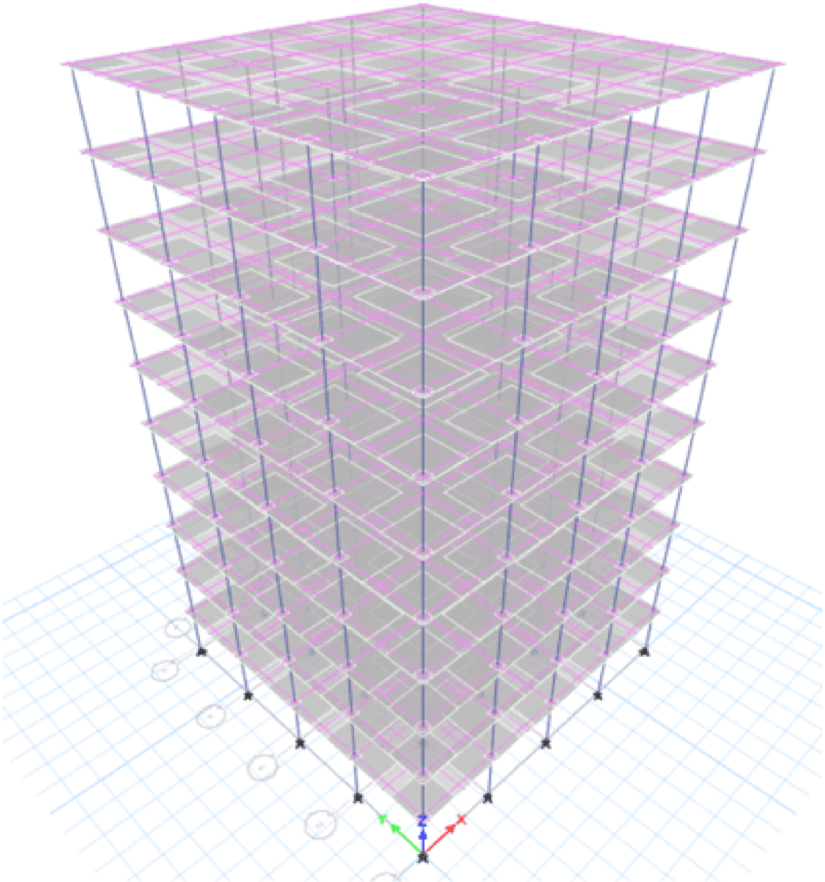


Fig 17 G+10 Structure with Conventional Slab

Here in the G+10 storey structure is considered with a conventional slab at each floor.

Case II G+10 Structure with Flat Slab

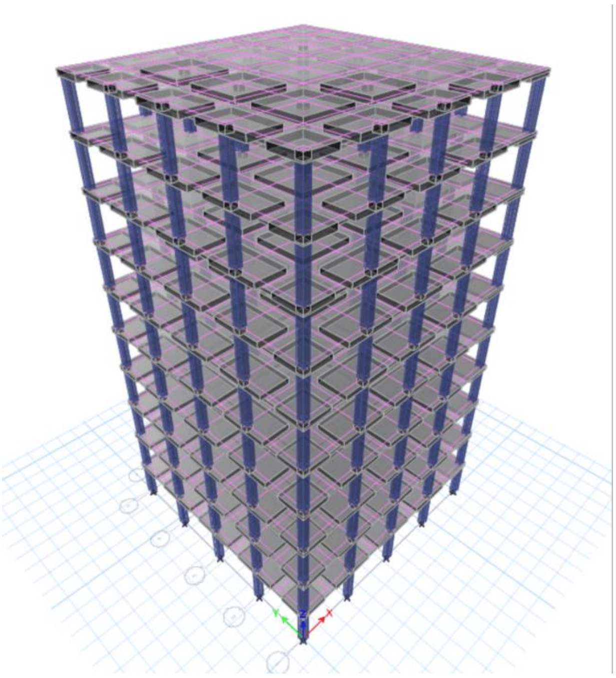


Fig 18 G+10 Structure with Flat slab

Here in the G+10 storey structure is considered with a flat slab at each floor.

Case III G+10 Structure with Flat Slab and Staggered Beam

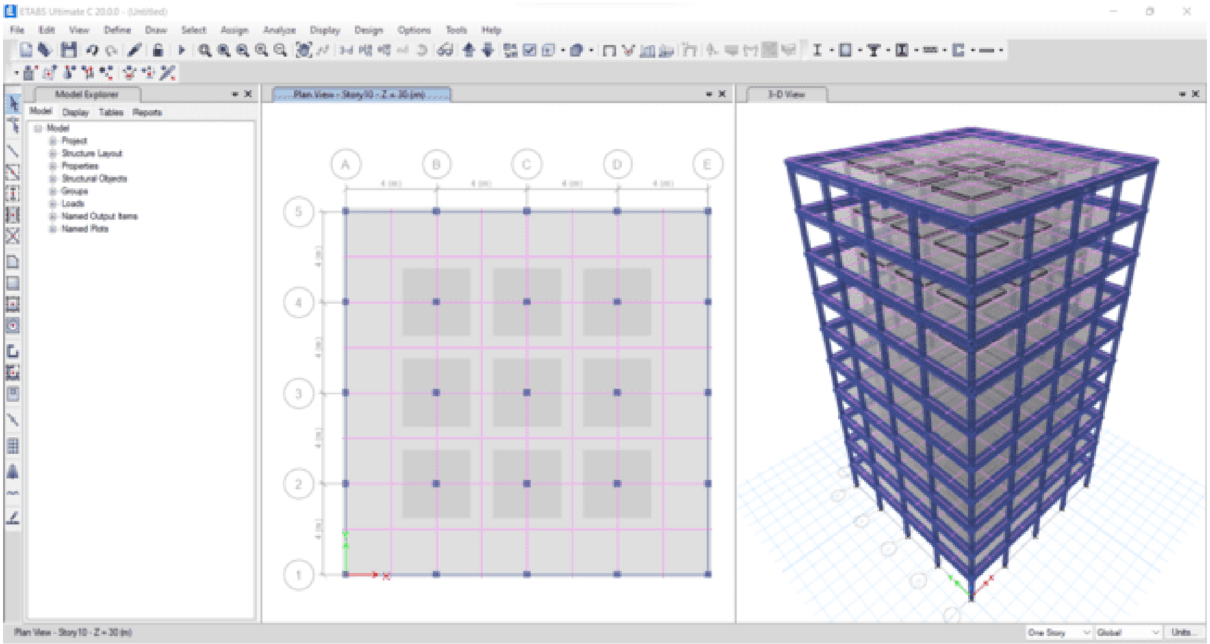


Fig 19 G+10 Structure with Flat Slab and Staggered Beam

Here in the G+10 storey structure is considered with a flat slab and staggered beam at each floor.

Table 1 Building Geometry

Building Description	
Length x Width	28mx28m
No. of storeys	10
Storey height	3m
Bottom Storey Height	3m
Number of Grid Line in X-direction	5
Number of Grid Line in Y-direction	5
Spacing of Grid in X-direction	4m
Spacing of Grid in Y-direction	4m
Beam Size	400mmx300mm
Column Size	400mmx400mm
Column Size C2	400x400mm

Conventional Slab Thickness	150mm
Flat Slab	150mm
Flat Slab with Perimeter Beam	150 mm

IV. ANALYSIS RESULT

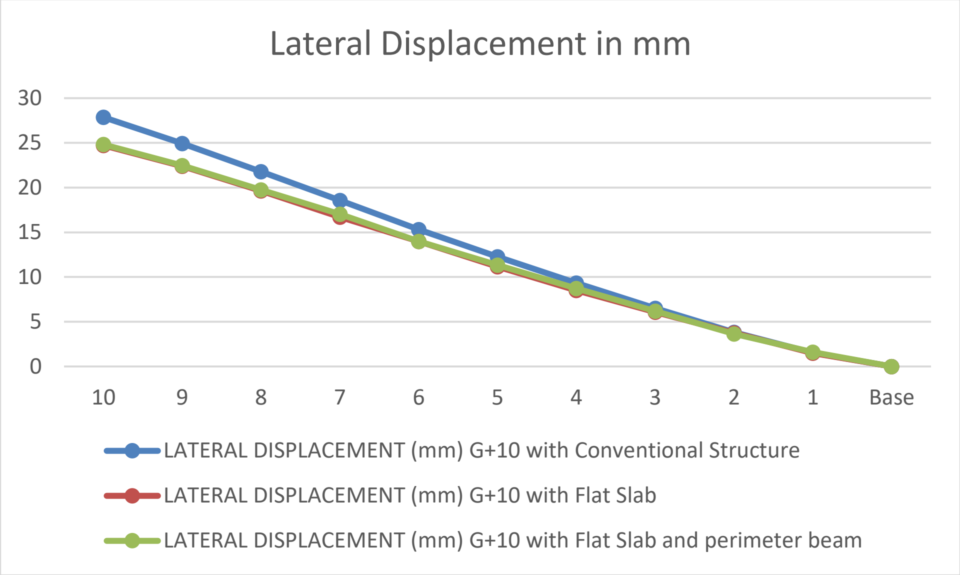


Fig 20 displacement

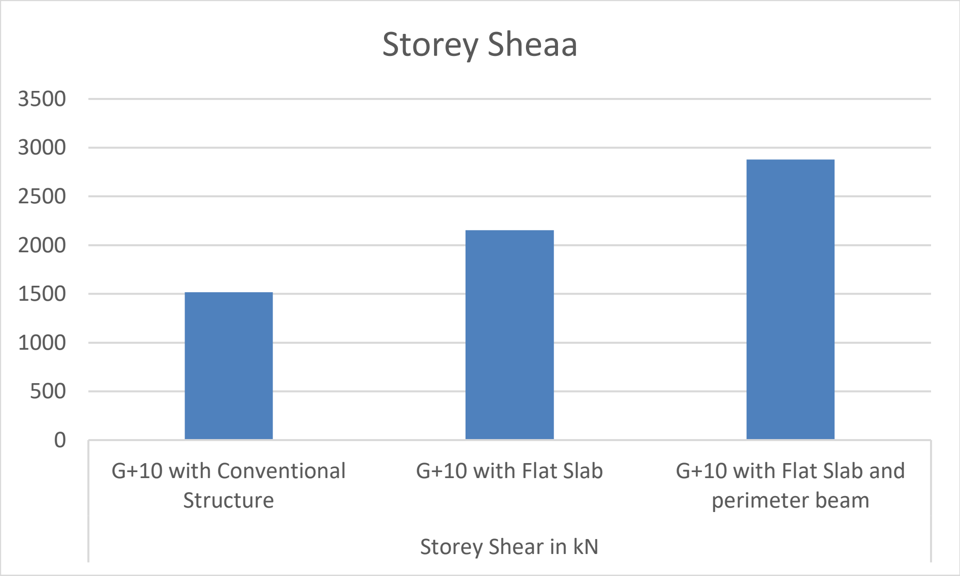


Fig 21 Storey Shear

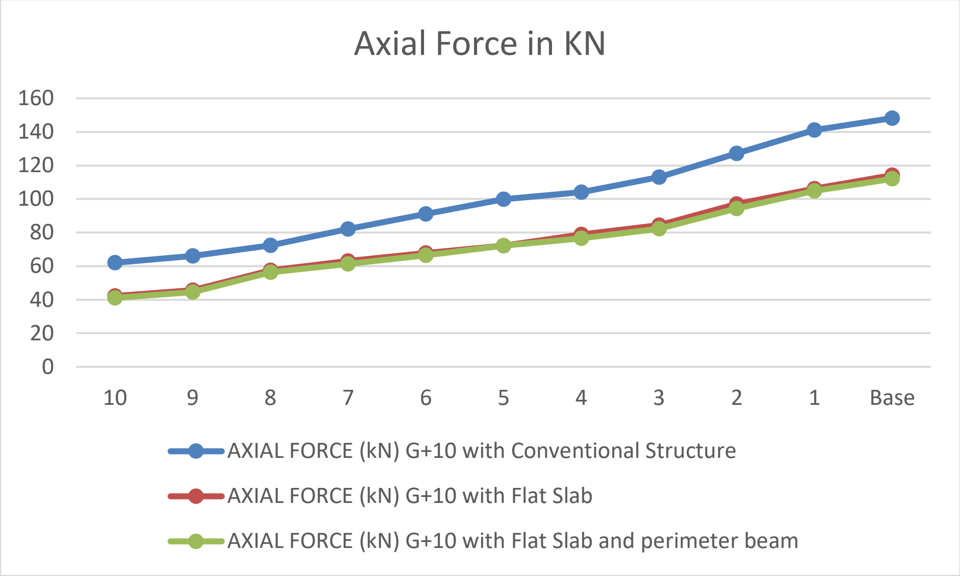


Fig 22: Axial Force

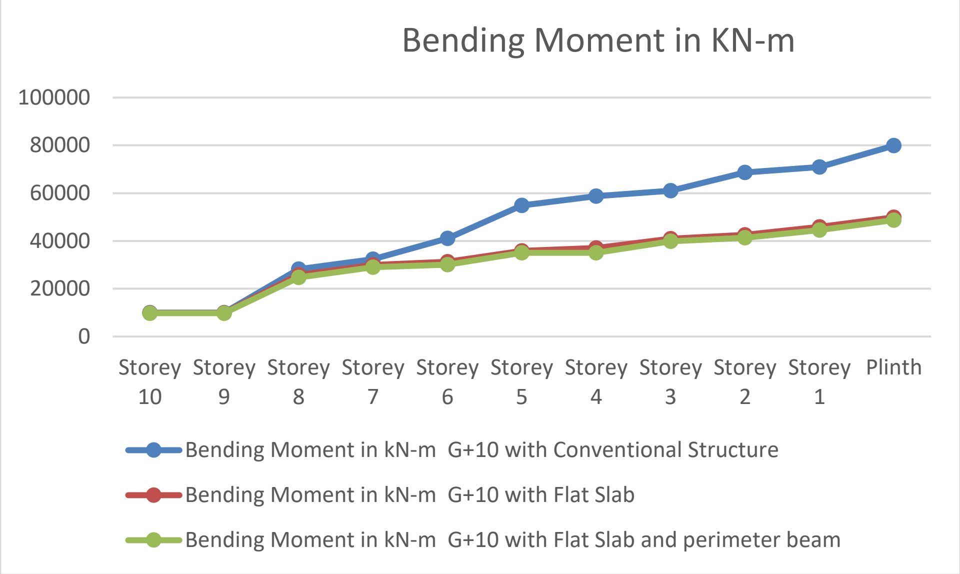


Fig 23: Moment

V. Conclusion

Storey Displacement

When structures are subjected to lateral loads like earthquake and wind loads, lateral displacement is crucial. As a building's height rises and becomes more flexible to lateral loads, structures become more sensitive, hence lateral displacement is dependent on the height and slenderness of the structure. Lateral displacement was maximum for structure with conventional slab and structure with flat slab and structure with flat slab and perimeter beam were found stable in handling lateral forces. Marginal difference was seen of 0.2% in G+10 structure with flat slab and G+10 structure with flat slab and perimeter beam.

Storey Drift

Lateral (story) drift is the amount of sidesway between two adjacent stories of a building caused by lateral (wind and seismic) loads. For a single-story building, lateral drift equals the amount of horizontal roof displacement. Lateral drift was found least in G+10 structure with flat slab and perimeter beam proving to be 2.3% less than G+10 structure with Flat Slab and 4.5% less than G+10 structure with conventional slab. Maximum storey drift was visible in storey 5 and storey 6.

Storey Shear

Storey shear factor is the ratio of the story shear force when story collapse occurs to the story shear force when total collapse occurs. Through a series of dynamic analyses, simple equations are provisionally proposed to calculate the necessary story shear safety factor that can be used to prevent story collapse. Storey shear was maximum for G+10 structure with flat slab and perimeter beam, 12% higher when compared to G+10 structure with flat slab and 18% higher than G+10 structure with conventional slab. Maximum Storey shear for G+10 structure with flat slab and perimeter beam was 2876.87 kN.

Axial Force

Axial force refers to a load whose line of action runs along the length of a structure or perpendicular to the structure's cross-section. Moreover, the line of force goes through the center of gravity of the member's cross-section. When this load tends to compress the member along its line of action, it is an axial compression load and carries a negative sign by convention. While if the load extends the member along its line of action, it is an axial tension load, carrying a positive sign. Axial force was 7.12% higher in G+10 structure with conventional slab when compared to G+10 structure with flat slab and G+10 structure with Flab slab Perimeter beam.

Storey Stiffness

The bottom of the storey is the only part that is restricted from moving laterally; the remainder of the storey is free to rotate. Storey stiffness is calculated as the lateral force causing unit translational lateral deformation in that storey. Storey stiffness was 3.1% higher in G+10 structure with conventional slab when compared to G+10 structure with Flat Slab and G+10 structure with flat slab perimeter beam.

Bending Moment

flat slab with staggered beam is comparatively more stable and observing low moment in comparison which states that it is comparatively more economical whereas flat slab case is second best in comparison.

VI. Future Scope

From the above researches a broad conclusion can be taken on flat slabs and their behaviors, further studies can be carried out on the fallowing aspects.

1. Flat slab with grid mesh model with various shapes analysis can be made using finite element software.
2. In the present study flat slab with periphery beams is considered for structure, further study may also be undertaken by flat slab without periphery beam structure.
3. In this research fixed base is considered for the structure, in future study can be made using soil structure interaction.
4. Through response spectrum method structure analysis can be made and time history analysis can be carried out.
5. The structure can be analysed by different software.

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