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ANALYSIS AND DESIGN OF BUILDING (B+G+10) WITH FLAT SLABS IN ZONE 'II' USING ETABS AND SAFE SOFTWARE

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ABSTRACT

Structural Engineering is a Branch of civil engineering which deals in the determination of behaviour of structures in order to predict the responses of real structures like bridges, Buildings, etc. under the improvement of expected loading and external environment during the service life of the structure. Structural Engineers these days are up against the challenging task of striving for the most efficient and most economical design with accuracy in solution while guaranteeing the final design of a building is serviceable for its design lifetime. In reality it's very difficult to predict with certainty how much damage a building will experience for a given level of ground motion, because there are number of factors that affect the behaviour of the structural systems.

The objective is to emphasize on structural behaviour of a commercial building (basement + ground+10 stories) installed with flat slabs for Bangalore (Zone 2) pertaining to medium soil.

The building model is designed and analysed using ETABS (Extended Three dimensional analysis of Building System) and SAFE. ETABS is the ultimate integrated software package for the structural analysis and design of buildings. SAFE is the ultimate tool for designing concrete floor and foundation systems.

The lateral loads induced from wind and earthquakes in the design and analysis of building is considered. The dead loads are calculated as per IS 875(part 1)-1987, live load is taken as per IS 875(part 2)-1987, earthquake load has been taken as per IS 1893-2002(part 1) and wind load has been taken from IS 875 (part 3)1987.

The manual calculations for the design of structural members were compared with the software results which were found to be satisfactory. All the design and detailing procedures for structural members were carried out as per the guidelines of Bureau of Indian Standard code books.

INTRODUCTION

The population of our country is increasing at a faster rate and the demand for the various commodities is increasing as a result of it. The availability of resources is limited and that too is diminishing day by day with its continuous use. Similarly, the need of land for construction purposes is also increasing day by day which is resulting in the conversion of agricultural land into dwellings. So it has become very important for the civil engineers to tackle with such problem. Thus, in spite of doing any further horizontal expansion, they are more of concentrating on vertical expansion.

Since our economy is a developing one, commerce sector is playing a very vital role. Various foreign companies are establishing their roots in our country. Even the young minds in our country are coming up with innovative ideas. For proper functioning of these enterprises and companies, they need a fully established place to operate within the country. Hence it becomes the duty of the civil engineers to provide them with a work place with high end facilities and safety.

High rise structures mainly face problem with loads pertaining to wind and earthquakes. Structures which have regular geometry, stiffness in plan and elevation and distribution of mass uniformly throughout the building suffer little damage than the irregular configurations.

Earthquakes are caused mainly due to release of strain-energy by faults movement, ground shaking occurs when a seismic waves travel inside the earth layer. These seismic waves will have differential level of energy, amplitudes and different time interval to reach the surface. Depending on the ground shaking severity during earthquake it is categorized based on the occurrence and size in to minor, moderate and strong/major. The damage of the earthquake is measured by magnitude (M) which is recorded on seismograms. There may be some variations in the level of performance when an earthquake occurs at different buildings located on same site.

EARTHQUAKE

An earthquake is a vibration that travels through the earth’s crust. The waves are called seismic waves. In an earthquake, the initial movement that causes seismic vibrations occurs when two sides of a fault suddenly slide past each other. A fault is a large fracture in rocks, across which the rocks have moved. Earthquakes are the manifestations of sudden release of strain energy accumulated in the rocks over extensive periods of time in the upper part of the earth. These elastic waves radiate outwards from the focus and vibrate the ground.

WHAT CAUSES EARTHQUAKE?

Earthquakes are caused by the movement of the earth’s tectonic plates. A number of smaller size earthquakes take place before and after a big earthquake. Those occurring before the big one is called Foreshocks and the ones after are called Aftershocks. Shocks smaller than magnitude 2.5 are usually not felt and those with magnitude 7 cause serious damage over large areas. Intensity of shaking is measured on the modified Mercalli scale, ranging from 1 far from the epicentre to a maximum near it, which can reach 12 in the strongest earthquakes.

TERMINOLOGIES USED IN EARTHQUAKE

Epicenter: The geographical point on the surface of earth vertically above the focus of the earthquake.

Hypocentre or Focus: The originating earthquake source of the elastic waves inside the earth which causes shaking of ground due to earthquake.

Epicentral distance: Distance between epicentre and recording station in km.

Focal depth: The depth of focus from the epicentre is called focal depth. It is an important parameter in determining the damaging potential of an earthquake. Most of the damaging earthquakes have shallow focus with focal depths less than about 70km.

Fault: A fracture in the rocks along which strain is occasionally released as an earthquake. By definition, only active faults are associated with earthquakes.

Magnitude of Earthquake: Magnitude is a quantitative measure of the actual size of the earthquake. The magnitude of earthquake is a number, which is a measure of energy released in an earthquake. It is defined as logarithm to the base 10 of the maximum trace amplitude, expressed in microns, which the standard short-period torsion seismometer would register due to the earthquake at an epicentral distance of 100km

Intensity of earthquake: The intensity of an earthquake at a place is a measure of the strength of shaking during the earthquake, and is indicated by a number according to the modified Mercalli scale or M.S.K scale of seismic intensities. It is a qualitative measure of the actual shaking at a location during an earthquake, and is assigned as Roman Capital Numerals. There are many intensity scales. Two commonly used ones are the Modified Mercalli Intensity (MMI) scale and the MSK scale. Both scales are quite similar and range from I (least perceptive) to XII (most severe).

Importance Factor (I): It is a factor used to obtain the design seismic force depending on the functional use of the structure, characterized by hazardous consequences of its failure, its post-earthquake functional need, historic value, or economic importance.

Natural Period (T): Natural period of a structure is its time period of undamped free vibration.

Response Reduction Factor (R): It is the factor by which the actual base shear force, which would be generated if the structures were to remain elastic during its response to the Design Basis Earthquake (DBE) shaking, shall be reduced to obtain the design lateral force.

Seismic Mass: It is the seismic weight divided by acceleration due to gravity.

Seismic Weight (W): It is the total dead load plus appropriate amounts of specified imposed load.

Zone factor (Z): It is a factor to obtain the design spectrum depending on the perceived maximum seismic risk characterized by Maximum Considered Earthquake (MCE) in the zone in which the structure is located. The basic zone factors included in this structure are reasonable estimate of effective peak ground acceleration.

Structural Response Factors (S_a/g): It is a factor denoting the acceleration response spectrum of the structure subjected to earthquake ground vibrations, and depends on natural period of vibration and damping of the structure.

ANALYTICAL METHODS

The seismic methods for analysis are mainly considered from IS 1893(Part1):2002 are defined as follows:

a) **Linear Static Analysis**
   - Equivalent-linear static technique

b) **Linear Dynamic Analysis**
   - Response spectrum technique
   - Time-history analysis.

- **Equivalent lateral force method (used for analysis in the project)**

  In this method the total lateral-loads acting on a building is known as base shear, based on the structural masses, corresponding mode shape and fundamental time period base shear calculations are done. This method is usually conservative for low to medium height buildings with regular configurations, the formulas and provisions are given by the code IS-1893(part1):2002.

METHODOLOGY AND TASK PERFORMED

DESCRIPTION OF THE MODEL CONSIDERED

For all the above plans the models are considered for medium soil and for Bangalore (seismic zone-2).The models considered for the analysis are of B+G+10 storey buildings. The analysis is carried out in ETABS 16.0.3and SAFE 14.2.0 Software.

MATERIAL PROPERTIES AND GEOMETRY OF THE BUILDING

- Layout of the Plan :62.5 X 50.8
- Number of Storey : B+G+10
- No of staircase : 3

- No of lifts : 5
- Height of the Building : 45.5m
- Support Condition : Fixed
- Height of each Storey : 4m
- Grade of Concrete : M30
- Grade of Steel : Fe500
- Thickness of Main Wall : 200mm, 300mm, 450mm
- Slab Thickness : 150mm,200mm,225mm,275mm,445mm, . 550mm, 750mm
- Beam size : 200X450mm,200X600mm,200X750mm, . 300X500mm, 300X600mm, 300X625mm, . 300X750mm, 400X1050mm, 500X900mm
- Column Size : 450X1300mm,500X1300mm, 600X900mm, . 900X900mm
- Type of Construction : Flat Slab System
- Type of Construction : Concrete block walls
- Footing : Isolated and combined footing/Raft foundation

SEISMIC PARAMETERS CONSIDERED

- Seismic Action: Both X and Y direction
- Seismic Zone: II (BANGALORE)
- Soil Type: Medium
- Importance Factor: 1.5 (Ref Table 6, IS: 1893-2002)
- Response Reduction Factor: 3
- Design horizontal seismic : (Z/2)*(Sa/g)*(I/R) Coefficient (Ah)
- Code used: IS 1893 (Part 1): 2002, IS 875 (Part 1, Part 2, Part : 3, Part 5): 1987, IS 456: 2000
- Method of analysis: Static analysis (equivalent lateral force method)

DEAD LOADS ON STRUCTURE

- Floor finish : 1.50 kN/m^2
- Glazing : 8.00 kN/m^2
- Wall 8"(200mm) : 15.62 kN/m^2
- Parapet Wall(Concrete) : 5.28 kN/m^2

LOAD COMBINATIONS FOR SEISMIC ANALYSIS

- 1.5 (DL + IL)
- 1.2 (DL + IL ± EL)
- 1.5 (DL ± EL)

- 0.9 DL ± 1.5 EL
- 1.5 (DL ± WL)
- 1.2 (DL + IL ± WL)
- 0.9 DL ± 1.5 WL

MODELLING AND ANALYSIS OF THE STRUCTURE

PROCEDURE OF MODELLING OF STRUCTURE AND ITS ANALYSIS

- The architectural plan was imported to ETABS.
- In ETABS we define the materials property i.e. concrete and steel and the section property i.e. beams columns, slabs and walls.
- After that beam columns and slabs were placed according to shuttering layout.
- Then dead and live loads are added and later applied to the model.
- Seismic loads were added to the model in static load cases. Which were named as EQX (X direction) and EQY (Y direction).
- Wind loads were added to the model in static load cases which were named as WINDX (X direction) and WIND Y (Y direction).
- Later diaphragm are added and assigned to the model.
- The model was completed for one storey and check was done.
- The errors found were removed and then again check was done and then no errors were generated.
- Now the model was replicated to the 10 storey's above the ground level and one storey below ground level is basement which does not include slabs.
- After that again model is checked and debug the errors if found.
- Now the default load combinations are assigned.
- Once the analysis was completed the model was designed with concrete frame design tool.
- For the maximum load combination the result were obtained.
- Then the deflection was checked whether it lies within the maximum deflection.
- For the obtained axial load and maximum moment the isolated footings are designed manually.
- The model was exported to SAFE.
- The model was imported to safe and for the model the analysis was done.
- We get the moments along the X direction as M11 and in the Y direction as M22.
- The moment contours were obtained for the different values fed.

- With the help of these the reinforcement provided were calculated.

SL NO	MATERIAL PROPERTIES	GRADE
1	Characteristic compressive strength of concrete	M 30
2	Characteristic strength of Reinforcement	Fe 500

- The design of structural components were done manually and compared with the values obtained from the software.

SETUP GRID LINES AND STOREY DATA

Analysis and modeling using ETABS-2016.0.3 and SAFE 14.2.0 for square G+15 storey c building procedure is explained step by step in detail.

SL NO	DATA	DIMENSION
1	No. Of Storeys	B+G+10
2	Storey Height	4 m
3	Building Height	45.5 m

TABLE 1 STOREY DETAILS

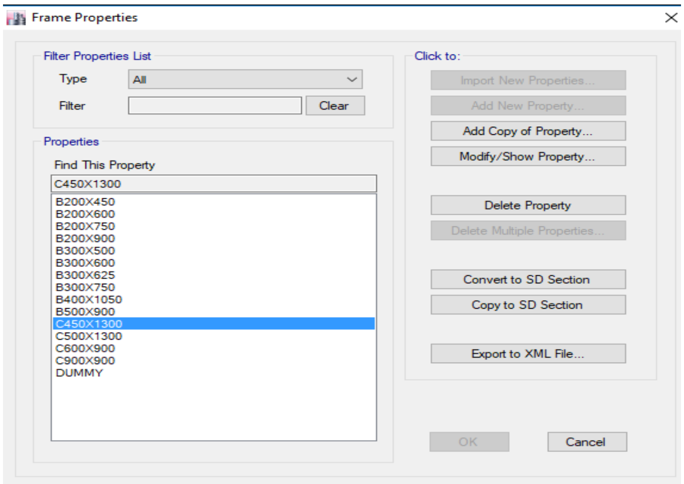
DEFINING MATERIAL PROPERTIES

TABLE 2 MATERIAL PROPERTIES

Material properties of entire members considered in the project for the analysis of structure are as follows:

DEFINING COLUMN PROPERTIES

Properties of column for entire structural element considered in this project are as follows:



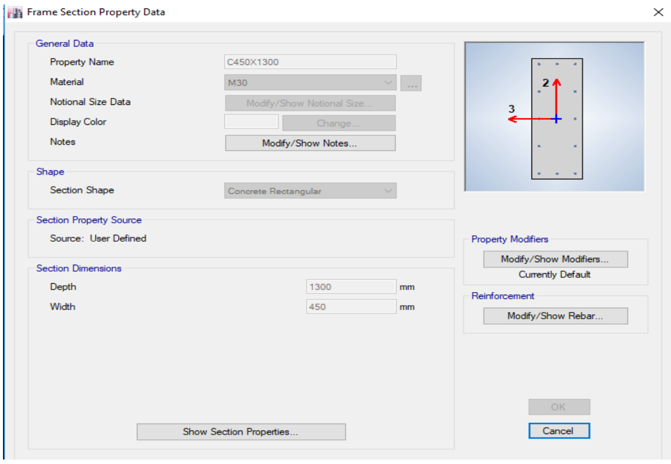
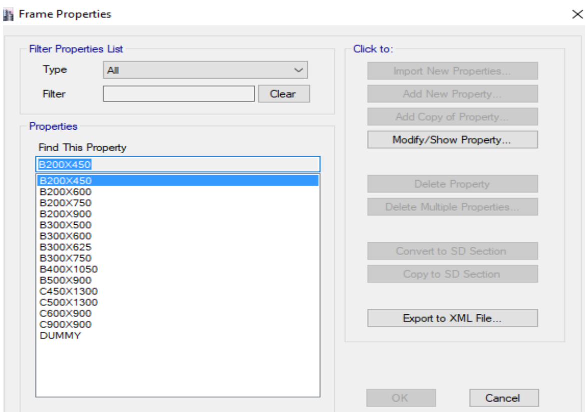


FIG 1 COLUMN PROPERTY

DEFINING BEAM PROPERTIES

Properties of beam for entire structural element considered in this project are as follows:



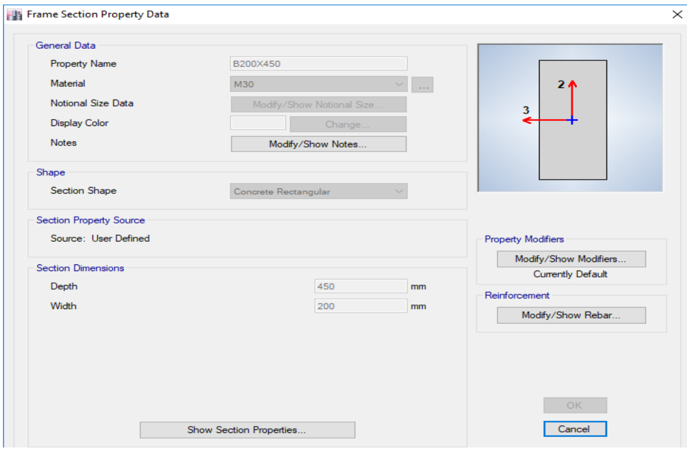
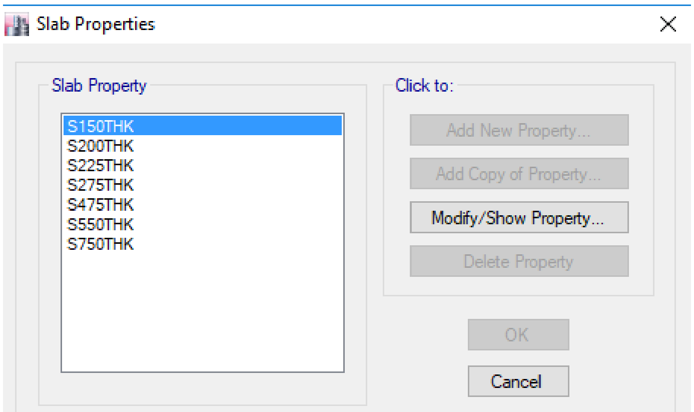


FIG 2 BEAM PROPERTY

DEFINING SLAB PROPERTIES

Properties of slab for entire structural element considered in this project are as follows:



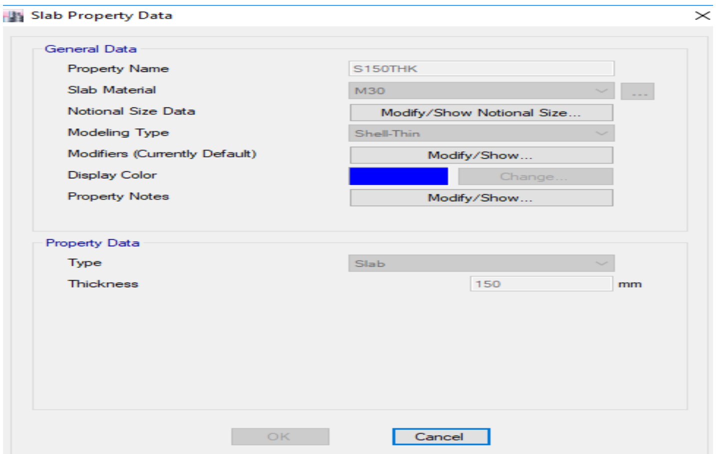


FIG 3 SLAB PROPERTY

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3D VIEW OF BUILDING

After assigning the columns, beams, slab and support conditions, a 3D model with the structural components get generated, as shown in the figure for only regular model.

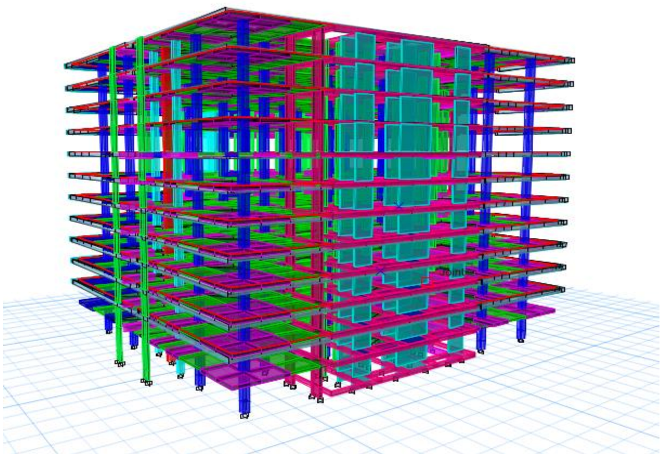


FIG 4 3D VIEW OF THE BUILDING

DEFINING LOAD PATTERNS

After completion of assigning Beams, Columns and Slabs, next is to define load patterns i.e. the loads that act on a structure. The load patterns are as shown below:

SL NO.	LOAD	TYPE	SELF WEIGHT MULTIPLIER
1	Dead	Dead	1
2	Live	Live	1
3	Floor Finish	Super Dead	1

TABLE 3 LOAD PATTERNS

DEFINING DIAPHRAGM

We want to define diaphragm and make structure as semi-rigid and define the diaphragm. To assign diaphragm, select all the slabs and go for assign->shell-> define D1 properties on each slab.

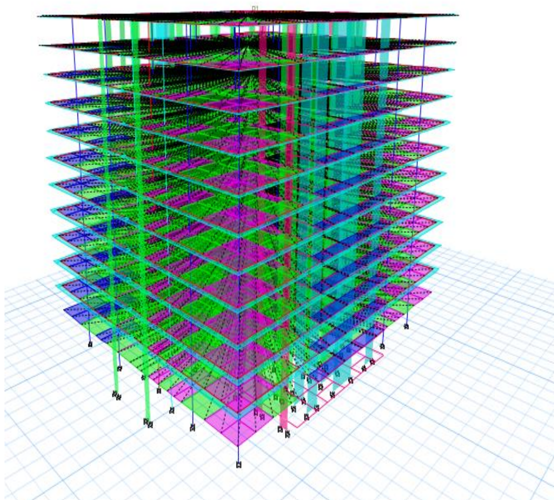
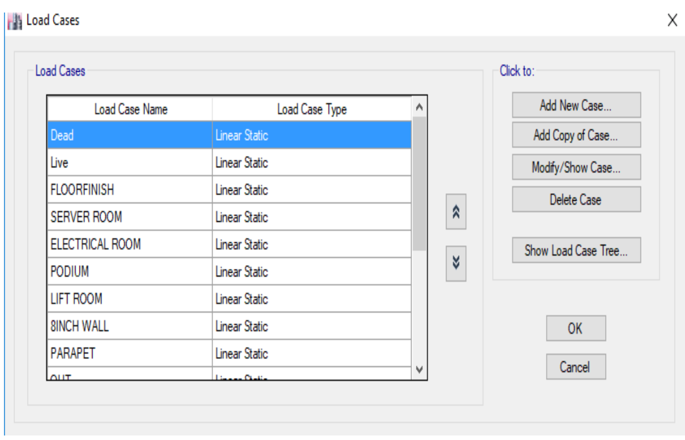


FIG 5 DEFINING DIAPHRAGM

DEFINING LOAD CASES



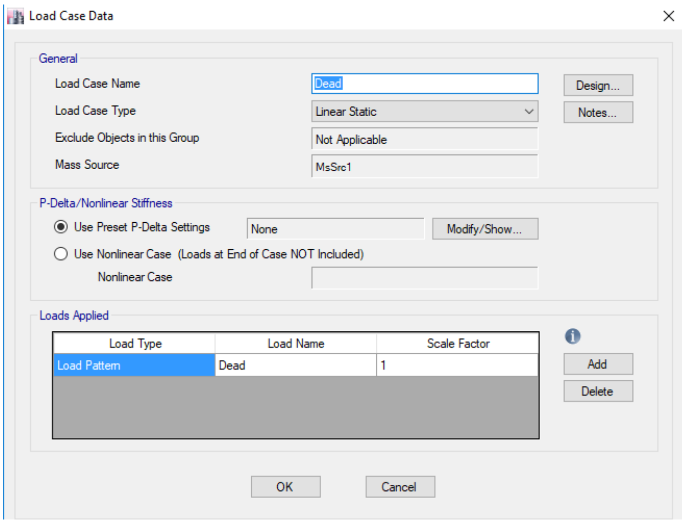


FIG 6 LOAD CASES

DEFINING LOAD PATTERNS

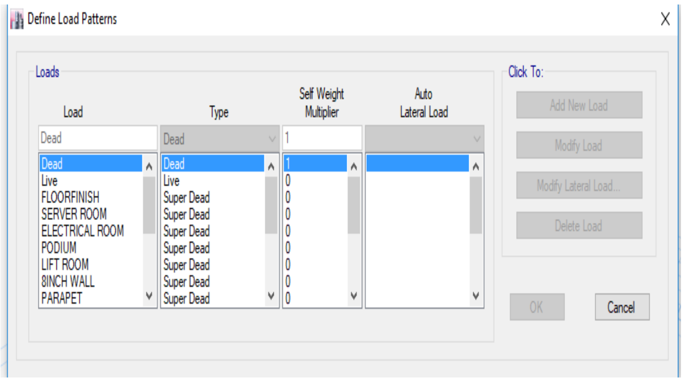
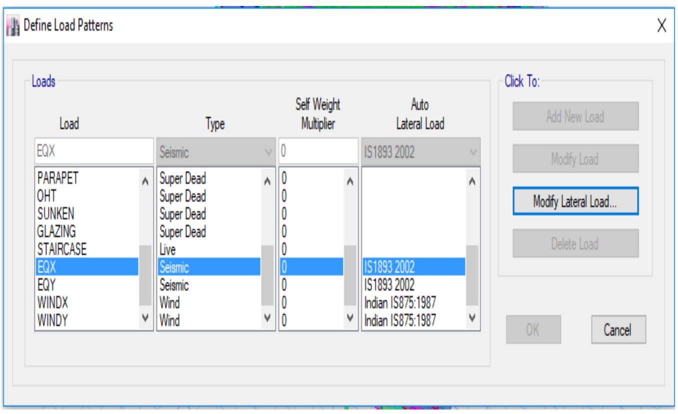
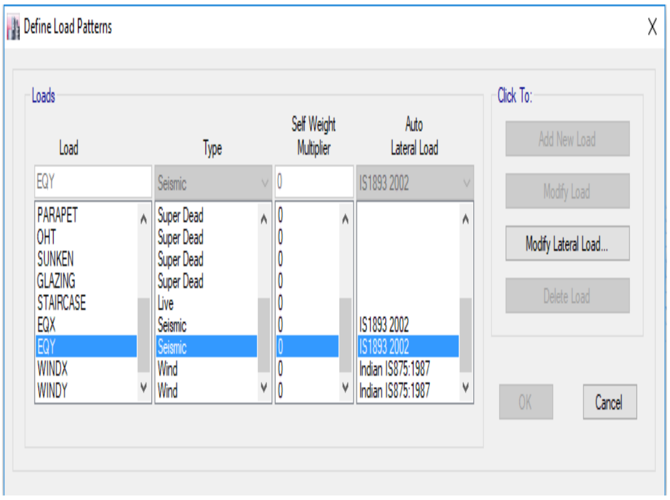


FIG 7 DEFINING LOAD PATTERNS

DEFINING SEISMIC LOAD IN X AND Y DIRECTION





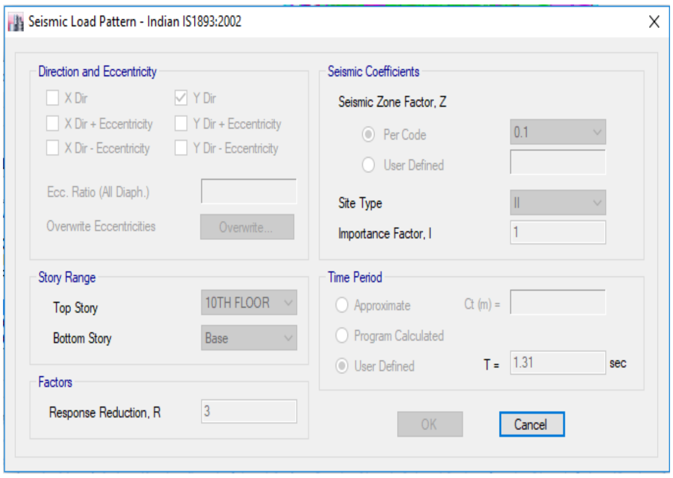
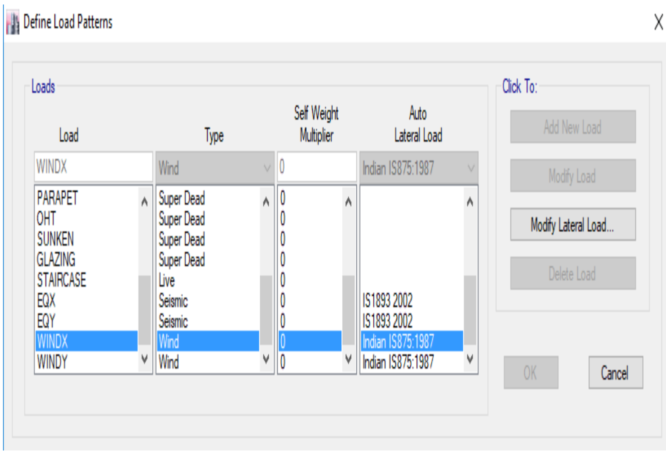
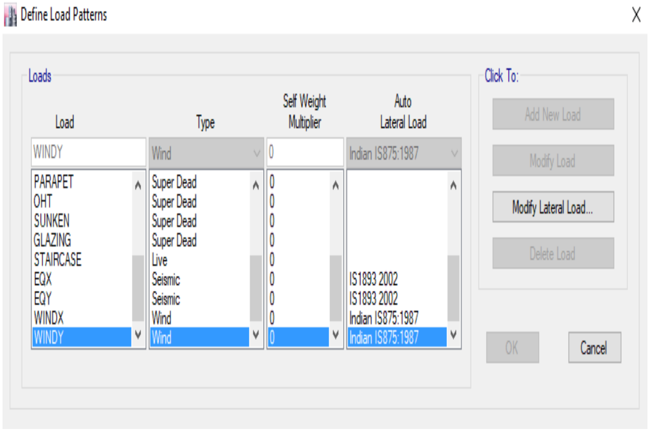


FIG 8 SEISMIC LOAD IN X AND Y DIRECTION

DEFINING WIND LOAD AND WIND SPEED IN X AND Y DIRECTION





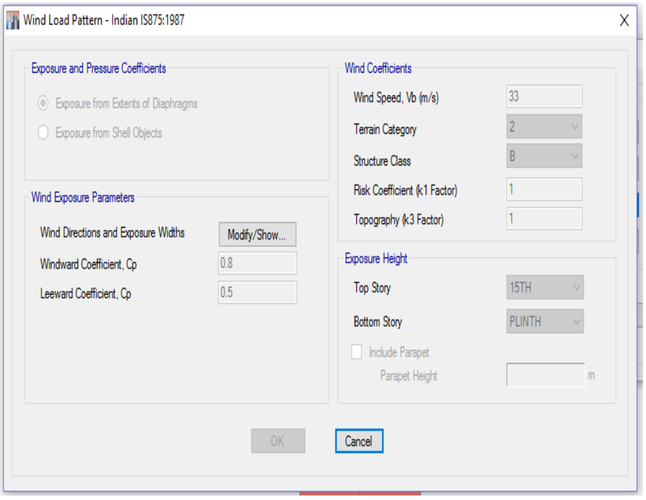


FIG 9 WIND LOAD IN X AND Y DIRECTION

CHECK FOR EARTHQUAKE LOAD

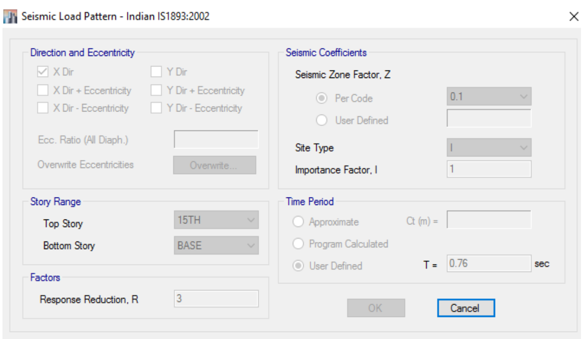


FIG 10 EARTHQUAKE LOAD

SAFE MODEL-M11MOMENTS ALONG X DIRECTION

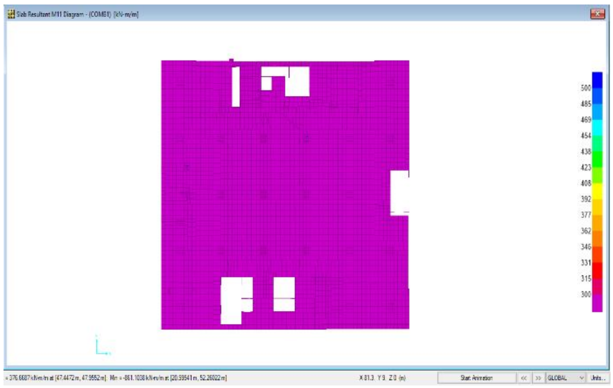


FIG 11 MOMENT ALONG X DIRECTION

SAFE MODEL-M12MOMENTS ALONG Y DIRECTION

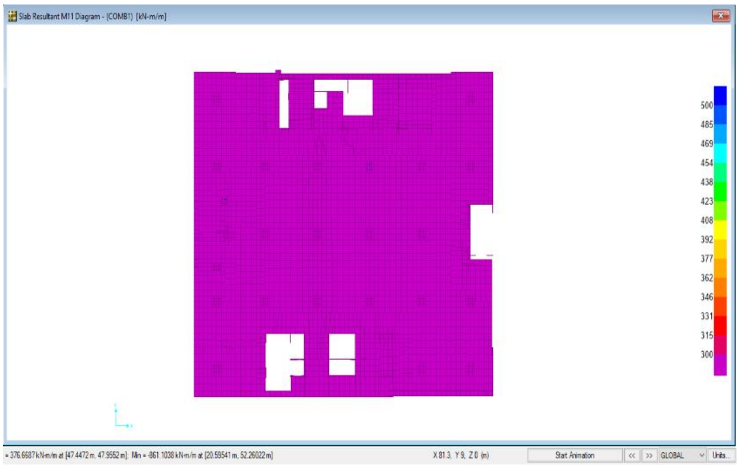


FIG 12 MOMENT ALONG Y DIRECTION

EQUIVALENT STATIC ANALYSIS

- All design against seismic loads must consider the dynamic nature of the load. However, for simple regular structures, analysis by equivalent linear static methods is often sufficient.

- This is permitted in most codes of practice for regular, low- to medium-rise buildings. It begins with an estimation of base shear load and its distribution on each story calculated by using formulas given in the code.
- Equivalent static analysis can therefore work well for low to medium-rise buildings without significant coupled lateral-torsional modes, in which only the first mode in each direction is considered.
- Tall buildings (over, say, 75 m), where second and higher modes can be important, or buildings with torsional effects, are much less suitable for the method, and require more complex methods to be used in these circumstances.

DESIGN PHILOSOPHY

A structure is an assembly of members each of which is subjected to bending or to direct force (either tensile or compressive) or to a combination of bending or direct force. Concrete is arguably the most important building material, playing a part in all building structures. Its virtue is its versatility, i.e. its ability to be moulded to take up the shapes required for the various structural forms. It’s also very durable and fire resistant when specification and construction procedures are correct.

Reinforced concrete is a composite material comprising concrete and steel reinforcement. The successful use of these materials in structural elements is attributed to the bond between steel and concrete which ensures strain compatibility so that the loads on the structural elements is shared between steel and concrete without disruption of the composite material.

CONCLUSION

- The analysis of the building element was carried out using ETABS and SAFE and the results were found to be satisfactory.
- The manual calculations for the design of structural members were compared with the computer analysis engine results which were found to be satisfactory.
- All the design and detailing procedures for structural members were carried out as per the guidelines of Bureau of Indian Standard code book.

SCOPE FOR FURTHER STUDIES

- Similar studies can be carried out for flat plates, shear walls.
- Different storey-heights and different dimensions of the structure can be considered for study.
- Other lateral-load-resisting systems like shear wall, tube frame etc.., can also be included.

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