Analysis and Design of Grid Slab in Building Using Response Spectrum Method

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Abstract: **Grid floor/Ribbed floor slab consists of beams spaced at regular intervals in perpendicular directions which are monolithic with slab. These slabs are generally used for architectural purpose for large spans such as public assembly halls, auditoriums; show rooms were the slab has to cover a large column free space is required. Since gird slab offers more stiffness the rectangular voided pattern is used in present study. In the present study G+4 building is considered, analyzed and designed for both gravity, seismic and wind loading conditions as per IS codes. The structure is analyzed using ETABS software and design has been done manually. Analysis with respect to seismic activity majorly involves Equivalent method and Response spectrum method.**

***KEYWORDS*- Response Spectrum, Grid Slab, Time history, Nonlinear Analysis and ETABS.**

I. INTRODUCTION

A building is a man-made structure with a roof and walls standing more or less permanently in one place. Buildings come in a variety of shapes, sizes and functions, and have been adapted throughout history for a wide number of factors, from building materials available, to weather conditions, to land prices, ground conditions, specific uses and aesthetic reasons. To better understand the term building compares the list of nonbinding structures. Buildings serve several needs of society – primarily as shelter from weather, security, living space, privacy, to store belongings, and to comfortably live and work. A building as a shelter represents a physical division of the human habitat (a place of comfort and safety) and the outside (a place that at times may be harsh and harmful).

II. GRID SLAB

An assembly of intersecting beams placed at regular interval and interconnected to a slab of nominal thickness is known as Grid floor or Waffle floor. These slabs are used to cover a large column free area and therefore are good choice for public assembly halls. The structure is monolithic in nature and has more stiffness. It gives pleasing appearance. The maintenance cost of these floors is less. However, construction of the grid slabs is cost prohibitive. By investigating various parameters the cost effective solution can be found for the grid slabs, for which proper method of analysis need to be used. There are various approaches available for analyzing the grid slab system. They are generally employed for architectural reasons for large rooms such as auditoriums, vestibules, theatre halls, show rooms of shops where column free space is often the main requirement. The rectangular or square void formed in the ceiling is advantageously utilized for concealed architectural lighting. The sizes of the beams running in perpendicular directions are generally kept the same.

They offer the following features:

- ✓ All elements of the space grid contribute to the load carrying capacity.
- ✓ Loads are distributed more evenly to the supports.
- ✓ This can reduce the cost of the supporting structures especially when heavy moving loads may be applied to the space grid (e.g. overhead cranes).
- ✓ Deflections are reduced compared to plane structures of equivalent span, depth and applied loading, assuming that the structural elements are of similar size.
- ✓ The open nature of the structure between the two plane grids allows easy installation of mechanical and electrical services.
- ✓ They are used on flat sites.
- ✓ No beam excavation is required.
- ✓ No controlled or rolled fill is used.
- ✓ Cardboard slab panel/void formers are used.
- ✓ Slab panels are on 1 meter grids (approximately).
- ✓ Trench mesh or individual bars can be used.
- ✓ Slab thickness is 85 – 100 mm.
- ✓ Internal beams are 110 – 200 mm.
- ✓ There is minimal concrete volume.
- ✓ No beam down drag from clay (above ground slab) occurs.
- ✓ Shrinkage of slab is lower than stiffened rafts and footing slabs.
- ✓ They used 30% less concrete than a stiffened raft.
- ✓ They use 20% less steel than a stiffened raft.

➢ ***Uses of Grid slabs***

- Grid slabs can be used as both ceiling and floor slab
- Used in the areas where number of columns are provided i.e., it is basically used in the areas which has huge spans.
- Used for specialized projects that involves clean rooms, spaces requiring seclusion from low frequency vibration or those needing low floor deflections.
- The concrete grid slab is often used for industrial and commercial buildings while wood and metal waffle slabs are used in many other construction sites.
- This form of construction is used in airports, parking garages, commercial and industrial buildings, residences and other structures requiring extra stability.
- The main purpose of employing this technology is for its strong foundation characteristics of crack and sagging resistance. Grid slab also holds a greater amount of load compared with conventional concrete slabs.

Figure 1.1 Grid slab

III. METHODS OF ANALYSIS

The analysis can be performed on the basis of external action, the behavior of structure or structural materials, and the type of structural model selected. Based on the type of external action and behavior of structure, the analysis can be further classified as given below

A. 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 analysis method is sufficient. This is permitted in most codes of practice for regular, low- to medium-rise buildings. This procedure does not require dynamic analysis, however, it account for the dynamics of building in an approximate manner. The static method is the simplest one; it requires less computational efforts and is based on formulae given in the code of practice. First, the design base shear is computed for the whole building, and it is then distributed along the height of the building. The lateral forces at each floor levels thus obtained are distributed to individual lateral load resisting elements. (Duggal S K, 2010).

B. Nonlinear Static Analysis

It is a practical method in which analysis is carried out under permanent vertical loads and gradually increasing lateral loads to estimate deformation and damage pattern of structure. Nonlinear static analysis is the method of seismic analysis in which behaviour of the structure is characterized by capacity curve that represents the relation between the base shear force and the displacement of the roof. It is also known as Pushover Analysis.

C. Response Spectrum Method

Response spectrum method is the linear dynamic analysis method. In this method the peak responses of a structure during an earthquake is obtained directly from the earthquake responses. The maximum response is plotted against the undamped natural period and for various damping values, and can be expressed in terms of maximum relative velocity or maximum relative displacement. (Duggal S K, 2010).

D. Time History Method

It is the non-linear dynamic analysis & is the most complicated of all. Time History analysis is a step by step analysis of the dynamic response of the structure at each increment of time when its base is subjected to specific ground motion time history. To perform such an analysis, a representative earthquake time history is required for a structure being evaluated. It is used to determine the seismic response of a structure under dynamic loading of representative earthquake. (Wilkinson S and Hiley R, 2006)

IV. METHODOLOGY

1. Modeling Phase
2. Analysis Phase (Response spectrum)
3. Design Phase

1. Modeling Phase

Modeling phase is the first stage of design. Here in this Phase all dimensions of structural elements like Slabs, Beams, Columns, Staircase and Shear Walls are assumed and modeled. Based on the assumed dimension of elements dead load / Self weight are determined. Also based on structural function ability of structure from IS 875-PART II Live Load on slabs are determined there by total load are determined

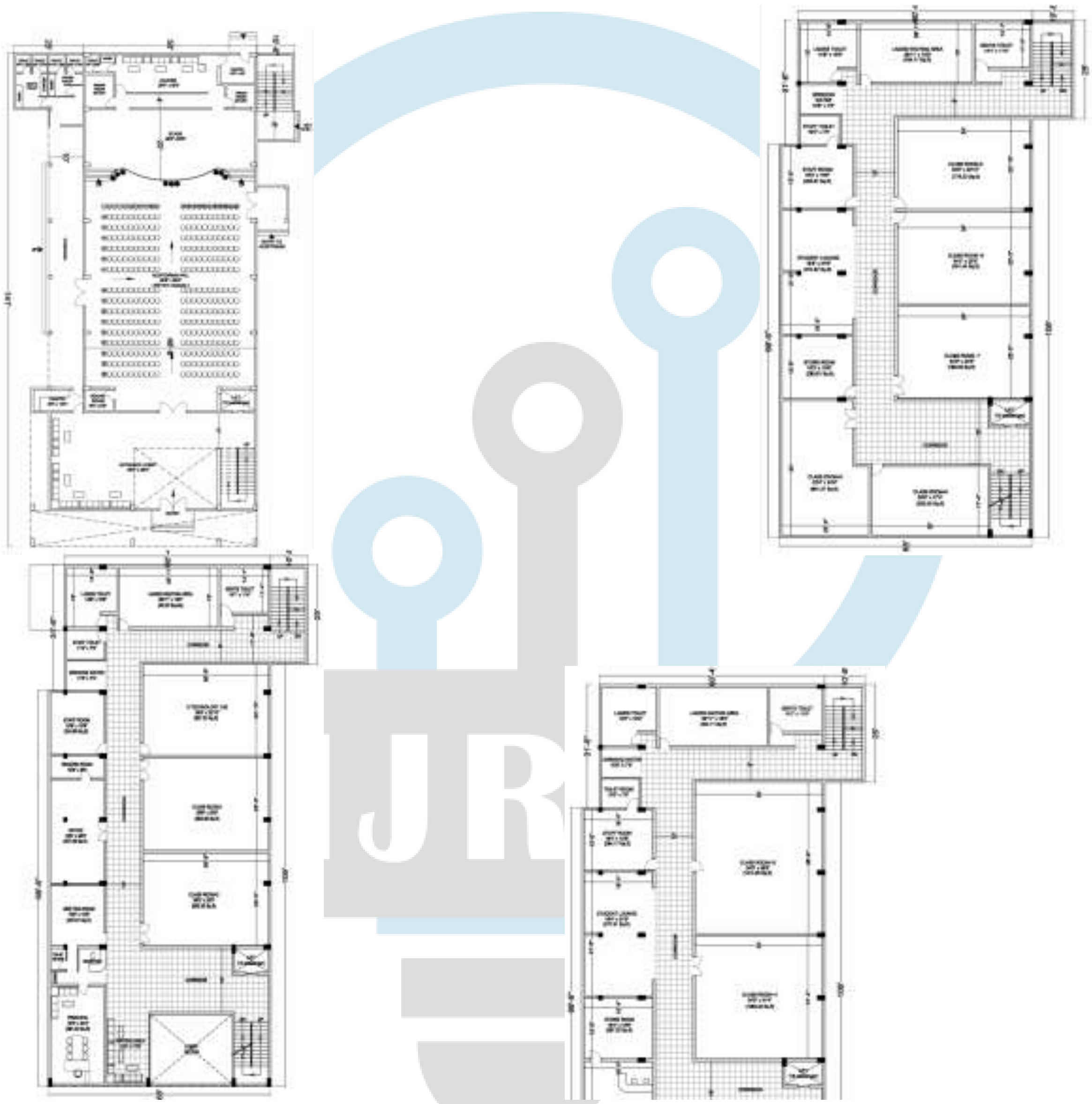

Figure 1.2 architectural plan of ground, first, typical, fourth floor

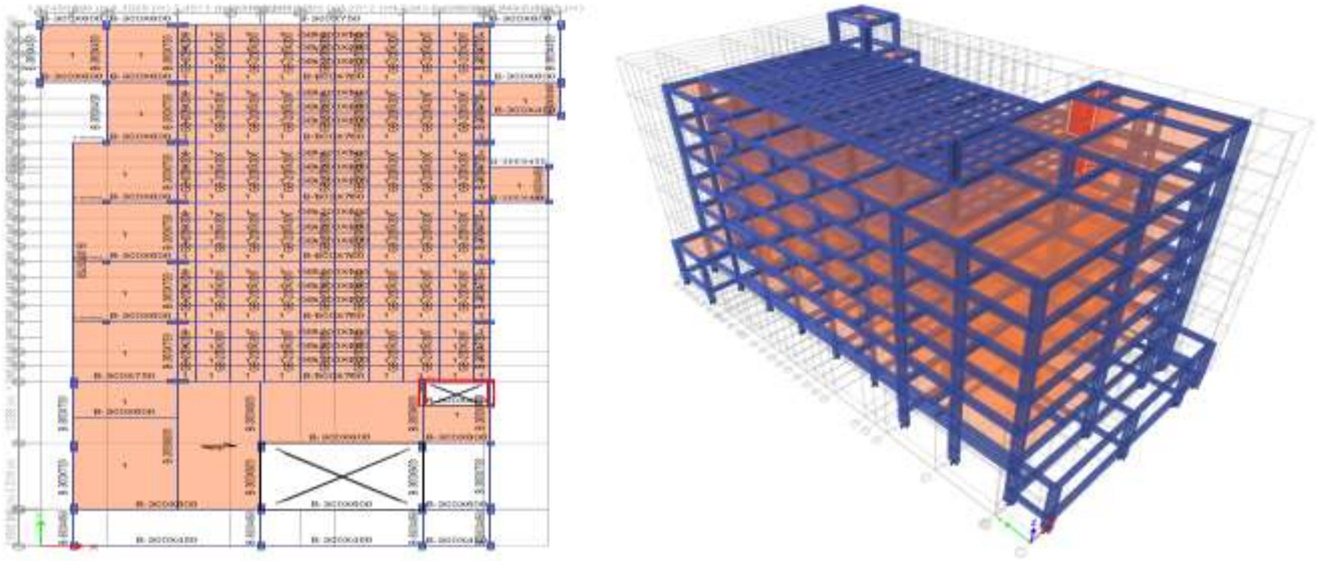

Figure 1.3 Grids floor modeling and 3D view

2. Analysis Phase

In this phase the Loads which are applied on slabs and beams are analyses by using E-tabs. Here in this phase, all bending moment, Shear Force, Axial forces are obtained at each and every points of element and also its maximum value. Following data should be considered for the analysis of this Structure

- Gravity Analysis Data –
  - Live Load – 2 KN/Sqm (On Slabs)
  - Floor Finish Load – 1 KN/Sqm (On Slabs)
  - Partition Wall Load – 1 KN/Sqm (On Slabs)
  - Peripheral Wall Load – 5 KN/m (On Beams)
  - Bearing Capacity of Soil – 250 KN/Sqm
- Seismic Analysis Data -
  - Zone Factor = Z = 0.10
  - Type Of Soil = Hard Soil
  - Period = Program calculated
  - Importance Factor = I = 1.0
  - Response Reduction Factor = R = 3.0
- Wind Analysis Data –
  - Along X Direction –
    Wind Ward Coefficient – 0.70
    Lee Ward Coefficient – 0.30
    Wind Speed – 33 m/s
    Terrain – 3
    Structure Class – B
    K1 and K3 Factor – 1
  - Along Y Direction –
    Wind Ward Coefficient – 0.70
    Lee Ward Coefficient – 0.10
    Wind Speed – 33 m/s
    Terrain – 3
    Structure Class – B
    K1 and K3 Factor – 1

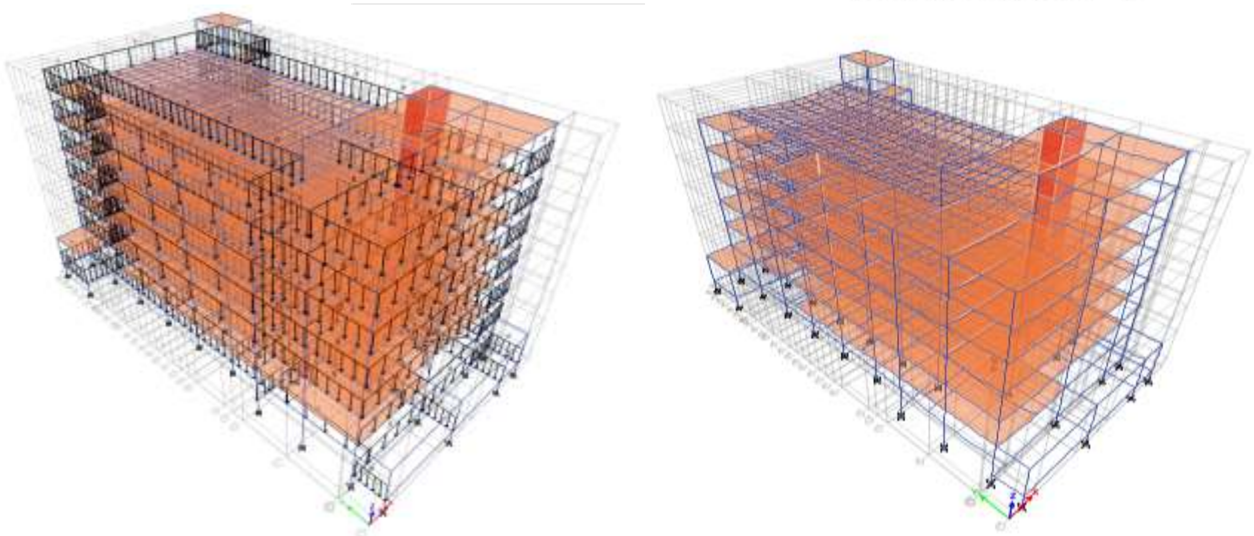

Figure 1.4 Loading pattern and Deformed shape of the structure

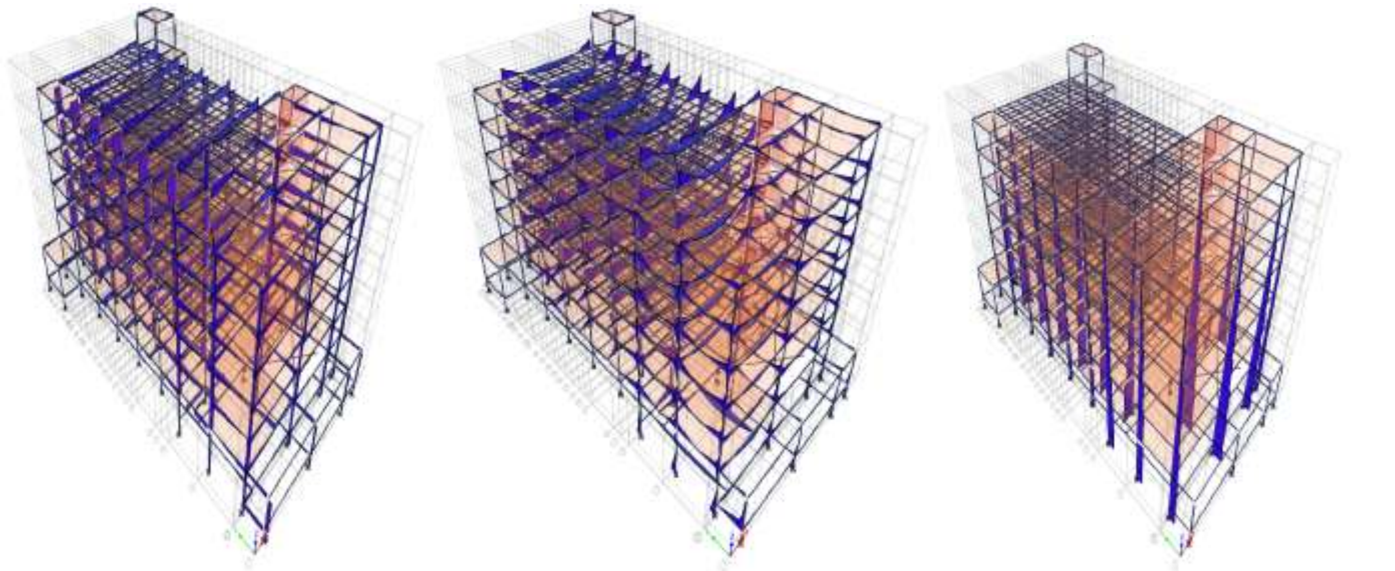

Figure 1.5 Shear force , bending moment and axial force

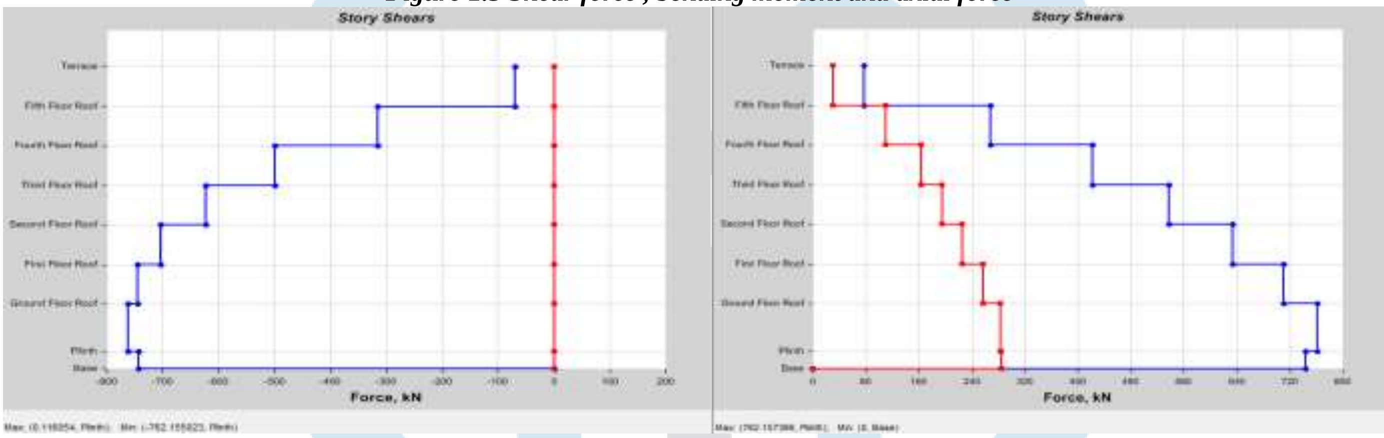

Figure 1.6 base shear along EQX and SPECT X

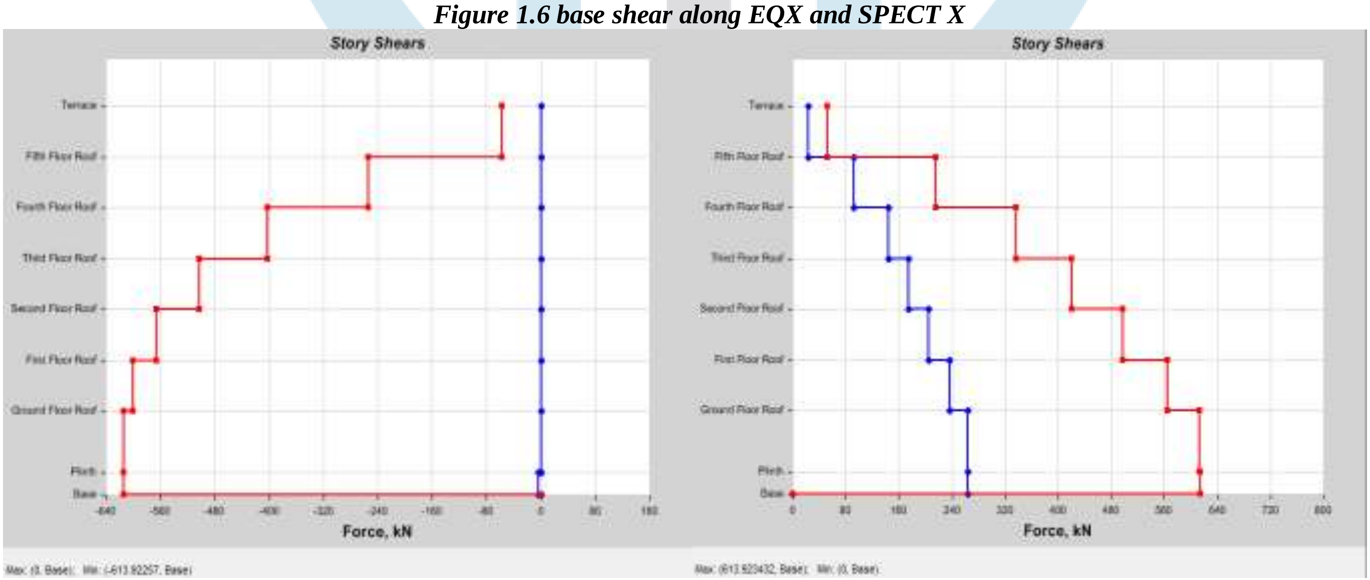

Figure 1.7 base shear along EQY and SPECT Y

➢ Thus by this we can observe that Base shear along X direction is found to be 762.157 KN and along Y direction is found to be 613.923 KN.

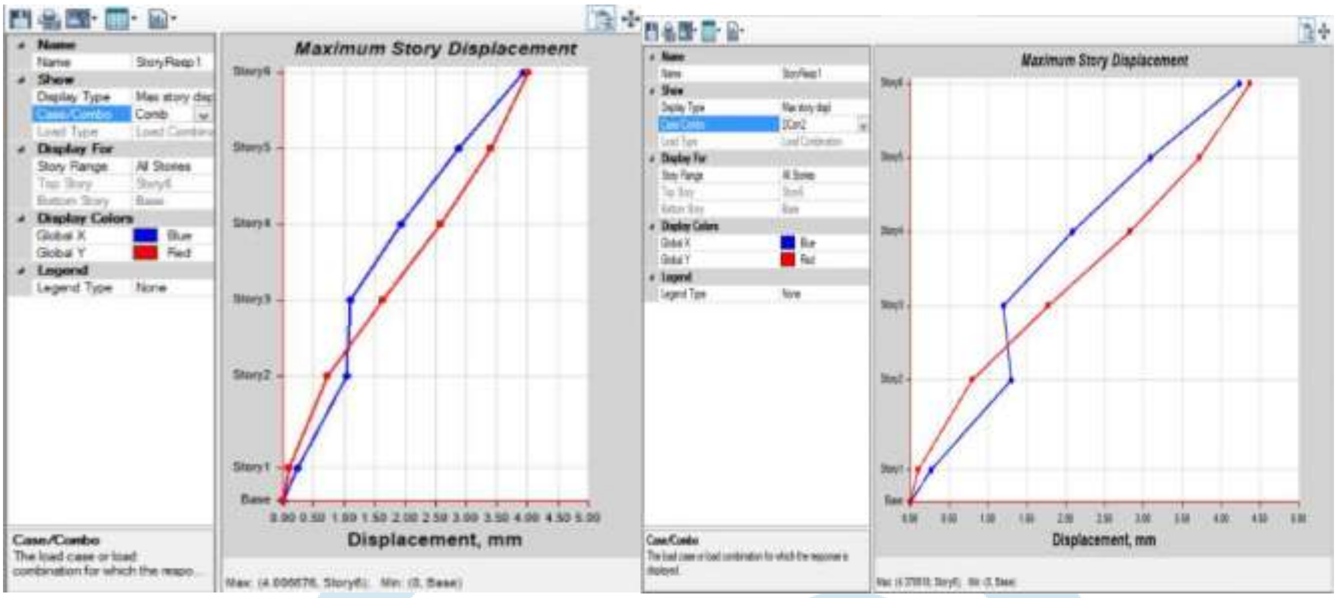

Figure 1.8 Lateral displacements under normal load condition and Dcon2 condition (worst condition)

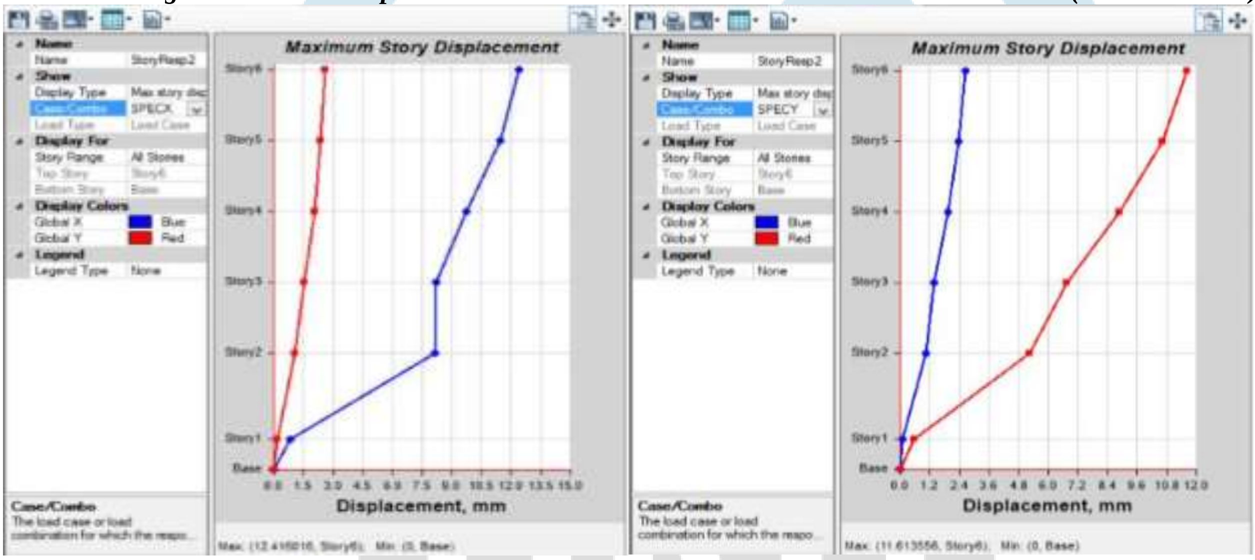

Figure 1.9 Lateral displacements along SPECT X and SPECT Y

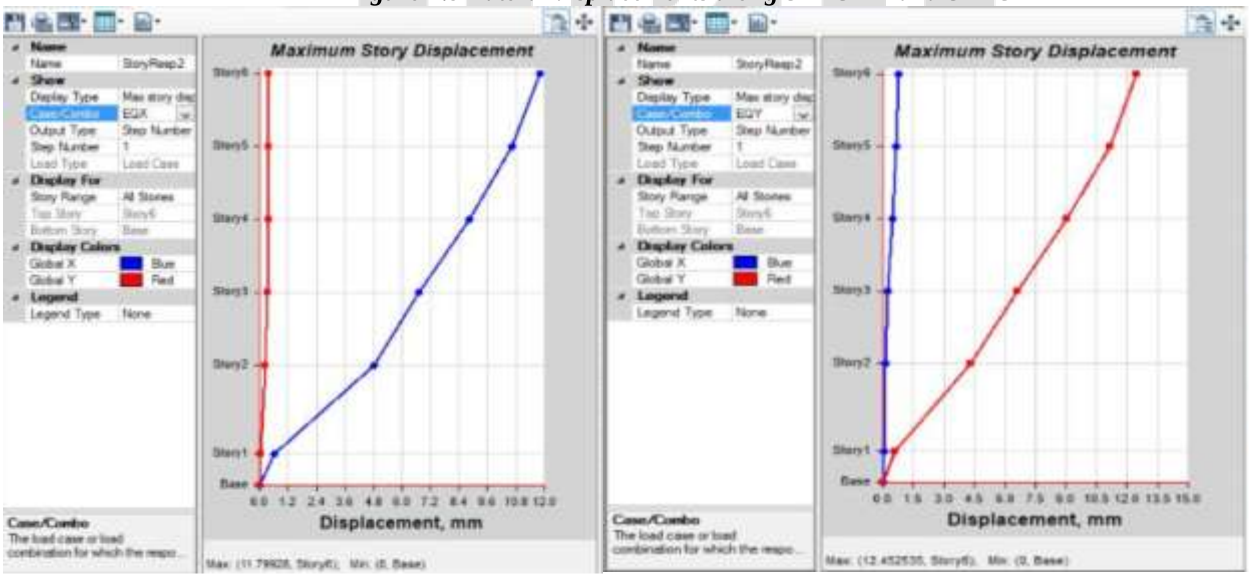

Figure 2.0 Lateral displacements along EQX and EQY

Maximum displacement in the building as for codal provision from IS1893-2002 is H/250. in the present case total height of the structure is 18.26m

Maximum allowable displacement in the structure is = (18.26*1000)/250

= 73.04mm

In the present case(both EQX, EQY, SPECT X , SPECT Y, Normal load condition and worst load condition) maximum lateral displacement is lesser than the maximum allowable displacement hence the structure is safe under lateral displacement.

Table 1.1 Axial Load in Columns

Column Number	Range	P in KN	No of Columns
C1	2000-2250	2010	4
C2	1750-1800	1770	8
C3	1500-1750	1550	2
C4	1250-1500	1340	6
C5	500-750	700	9
C6	150-300	200	10
C7	7250-7500	7330.78	1

3. Design Phase.

In this phase, all elements of structure are designed based upon their Maximum bending Moment Values and Shear Force Values within a group for Beams, Also based upon their spans within group Slabs are designed. Similarly, Based upon Axial Forces and type of bending within group, Columns and Footings are designed.

A. Design Of Footings

These are also flexural member which will be subjected to Bending.

Following are the types of Shallow Footings

- ✓ Wall Footing
- ✓ Isolated Footing
- ✓ Combined Footing
- ✓ Strap Footing
- ✓ Strip Footing
- ✓ Raft Footing

➢ **Wall Footings** – These are those which are provided for walls of building.

➢ **Isolated Footing** – These are those which are provided for each and every individual Column.

➢ **Combined Footing** – These are those which are provided for two adjacent Columns. This type if preferred when two individual isolated footings overlap with each other.

➢ **Strap Footing** – These are the type of Isolated footings, but a beam called Strap are connected between tow footings in order to transfer the load. These are preferred when one of the Columns are on Site Boundary.

➢ **Strip Footing** – These are those which are provided for Series of Columns which are on the same straight line.

➢ **Raft Footing** – These are those which are provided for all Columns of building as a single base slab. This shall be provided when the load from Super Structure is heavy and also when the bearing capacity of soil is very less.

B. Design Of Columns

It is a Compression member which will be subjected to axial load with moments which are transferred from beams. Based on Slenderness ratio, they are classified into following three types –

- ✓ Short Column
- ✓ Intermediate Column
- ✓ Long Column

➢ **Short Column** – These are those whose Slenderness ratio values will be less than 12(i.e., Effective length/Least cross section dimension<12) These Columns will fail by Crushing.

➢ **Intermediate Column** – These are those whose Slenderness ratio values will be equal to 12(i.e., Effective length/Least cross section dimension=12) These Columns will fail by Crushing as well as by Buckling.

➢ **Long Column** – These are those whose Slenderness ratio values will be greater than 12(i.e., Effective length/Least cross section dimension>12) These Columns will fail by Buckling. Therefore it is always desirable to Design column as Short Columns.

C. Design Of Beams

Beam is a Structural member which under goes bending hence it is referred as flexural member.This structural element supports Slabs there by it takes up the load from slab.

Usually there are two types of sections which we can except in case of Flexural members (i.e., in case if Slabs, Beams, Staircases, Footings) and they are as follows –

- **Singly Reinforced Sections**
- **Doubly Reinforced Sections**

❖ **Singly Reinforced Sections –**

They are those were the Steel attains Ultimate Strength as compared to that of Concrete. This type of sections is more preferred because it provides sufficient warning before the structure collapse. In this type, longitudinal reinforcement will be provided only in tension zone.

❖ **Doubly Reinforced Sections –**

They are those were the Concrete attains Ultimate Strength as Compared to that of Steel.

In this type, longitudinal reinforcement will be provided in both tension and Compression zone. Based on Geometry of sections, the beams are also classified into following three types

- ✓ Rectangular Beams
- ✓ T-Beams
- ✓ L-Beams

➢ ***Rectangular Beams***– They are most commonly adopted on site. Here the entire length of beam will be rectangular in shape. In this type of beams both at mid-span and at corners it shall be designed as Rectangular Sections. All interior Secondary beams are designed as Rectangular beams.

➢ ***T-Beams*** – In this type of beams, the flange portion forms a part of Slab.Here in this type, Beams are designed as Rectangular at Supports and as T-Beam at Mid span.Compared to rectangular beams, these beams are stiffer and also most economical section.All interior Primary beams are designed as T-Beams.

➢ ***L-Beams*** – This is Similar to T-Beams, except that at mid span these are designed as L-Beams and at Supports as Rectangular beams. All peripheral Beams shall be designed as L-Beams.

D. Design Of Slab

These are also flexural member which undergoes bending.

Depending upon its Lateral Dimensions they are broadly classified as –

- ✓ One Way Slab/ One Way Continuous Slab.
- ✓ Two Way Slab/ Two Way Continuous Slab.

➢ **One Way Slab**

A Slab is Said to be One-way, If ly/lx>2.

Here – ly – Lateral dimension along longer span. lx – Lateral dimension along shorter span.

Here in this type of Slab, Bending moment is maximum along shorter span.In this type of Slab, Main reinforcement shall be provided along Shorter Span and Minimum reinforcement will be provided along longer span in order to take care of Serviceability criteria such as Cracking, Shrinkage etc.If this type of Slab is said to be continuous over more than one span then they are called as One-Way Continuous Slab.

➢ **Two Way Slab**

A Slab is Said to Two Way, if ly/lx<=2.

In this type we can observe Maximum bending moment along both longer span and shorter span.Hence therefore, Maximum reinforcement will be provided along both the directions. Here in case of Two way slabs, there are chances of uplifting at corners, Hence therefore, Minimum reinforcement should be provided in two layers at all four corners which will take care of Torsion.

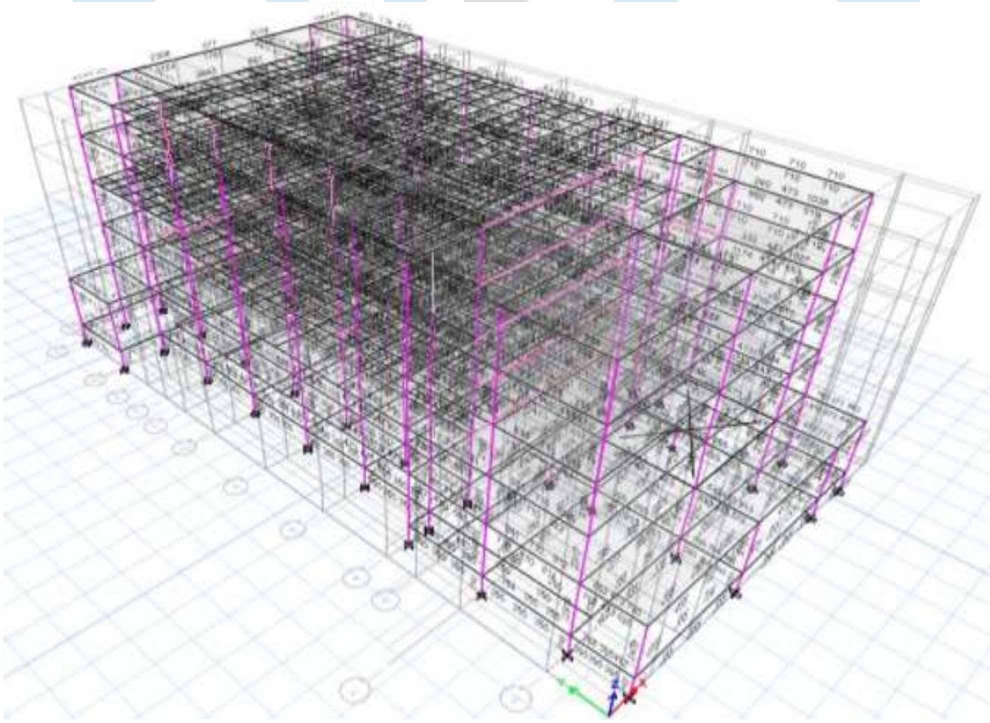

Figure 2.1 Model of the structure after analysis

V. CONCLUSIONS

The behavior multistory building with grid slab is studied in the present paper. In this paper we got the results from mathematical model for models. The graph clearly shows the base shear, lateral displacement. It is also observed that the results are more conservative in Static analysis as compared to the dynamic method resulting uneconomical structure. Because of the Box effect of modular type scheme, it is increasing overall stiffness of the building thus, reducing the sway problem in the structure. As building is in irregular the behavior in both directions is not similar. Further, the comparison between regular and modular type indicates the overall feasibility of the scheme without affecting its stability in gravity as well as lateral loads.

- ✓ The story drift values in x and y direction is higher for earth quack load than the wind load.
- ✓ In the top stories location the story shear is maximum for spectrum loads.
- ✓ For the bottom stories location the story shear increases from top story to bottom story and will be maximum for bottom story
- ✓ The support reaction values are maximum for Fz.
- ✓ The column forces are maximum for M3
- ✓ Designing by Software's like ETABS reduces ton of your time in design work.

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