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# To Study Comparative Analysis and Design of Flat and Waffle Slab System in Same Building under Seismic Condition

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***Abstract*: A grid slab or two-way joist slab is a concrete slab made up of reinforced concrete with concrete ribs running in two directions on its underside. Grid slabs are preferred for spans greater than 76 feet (23.3 m), as they are much stronger than flat slabs, flat slabs with drop panels, two-way slabs, one-way slabs, and one-way joist slabs. The grid floor system consists of beams spaced at regular intervals in the perpendicular direction, monolithic with the slab. The proposed construction site is at Nashik. The length of the slab of 40.m and the width of 10 m total area of the slab is 400 sq.m. It is designed by using M30 grade concrete and Fe415 steel. The flat slab and grid slab has been analyzed by using Etabs software under the seismic condition of zone 3.**

***Keywords*:** Analysis And Design of Flat and Grid Slab system, ETAB, grid slab with a drop, flat slab with a drop, seismic condition.

## I. INTRODUCTION

Structural Engineering is a branch of Civil Engineering where the study is done to know how the structure behaves when a building is constructed in a real environment and to identify the various forces like axial force and shear force, bending moment and displacement, etc. acting on the structure. When the analysis comes to a complex structure or multi-story structure the manual calculation will be difficult to perform and hence there is various software available to perform these calculations, These software are STAAD Pro V8i, ANSYS, ETAB, SAP-2000, etc. In the present study, "Comparative analysis and design of flat slab and grid slab system with conventional slab system" comparison of parameters like the quantity of concrete, quantity of steel, cost of the structure, bending moment, shear force, and displacement of flat slab system and grid slab system with conventional slab system. In this study, slab system design and analysis for G+10 building for seismic zone III and having medium soil condition by using STAAD Pro V8i and these slab system analyzed for different plan area or grid size/ spacing of the column. The analysis and design of the slab system are done as per IS 456-2000 and IS 1983-2002. Design of the slab system is done for different spacing/ grid sizes of the column to find out which grid size of the column or plan area which slab is economical.
Grid floor/Ribbed floor slab consists of beams spaced at regular intervals in perpendicular directions which are monolithic with the slab. These slabs are generally used for the architectural purpose for large spans such as public assembly halls, and auditoriums; showrooms where the slab has to cover a large column-free space is required. Since the gird slab offers more stiffness the rectangular voided pattern is used in the present study. In the present study, a 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 the design has been done manually. Analysis with respect to seismic activity majorly involves the Equivalent method and Response spectrum method.

An assembly of intersecting beams placed at regular intervals and interconnected to a slab of nominal thickness is known as a Grid floor or Waffle floor. These slabs are used to cover a large column-free area and therefore are a good choice for public assembly halls. The structure is monolithic and has more stiffness. It gives a pleasing appearance. In the present study, an attempt is made to compare the bending moment, shear force, and displacement obtained from the dynamic analysis using ETABS software for various grid patterns. The size of grid patterns is 9mx9m and five basic grid patterns are selected which are varied by increasing the intermediate beams. It is important to note that the grids are analyzed for G+4 buildings. IS 1893:2002 is referred to applying dynamic loading on the grids and the Response spectrum method is followed to apply the dynamic loading on the grids. The main aim of the study is to compare the above-mentioned results obtained from the dynamic analysis of various grid patterns and study the behavior of various grids under dynamic loading.

An assembly of intersecting beams placed at regular intervals and interconnected to a slab of nominal thickness is known as a Grid floor or Waffle floor. These slabs are used to cover a large column-free area and therefore are a good choice for public assembly halls. The structure is monolithic and has more stiffness. It gives a pleasing appearance. The maintenance cost of these floors is less. However, the 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 a proper method of analysis needs 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, and showrooms 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.

## II. FLAT SLAB

The flat slab is usually thickened closed to supporting columns to supply adequate strength in shear and to scale back the amount of negative reinforcement within the support regions. The thickened portion of the projection below the slab is understood as a drop or drop panel.

*A. Design of Flat Slab:*

The flat slabs designing methods are as follows:
The empirical method
The sub-frame method
The yield line method
Finite–element analysis
For smaller frames, empirical methods are used but the sub-frame method is employed just in case of more irregular frames. The foremost cost-effective and homogenous installation of reinforcements is typically achieved by applying the yield line method. A radical visualization in terms of a complete examination of separate cracking and deflection is required since this procedure utilizes only the collapse mechanism. Deflections and cracked width also can be calculated using Finite- element analysis.

## III. GRID SLAB

These slabs are wont to cover an oversized column-free area and thus are a good selection for public assembly halls. It gives a pleasing appearance. The upkeep cost of those floors could also be a smaller amount. By investigating various parameters the price effective solutions is often found for the grid slabs that proper method of study got to be used. [6] There are various approaches available for analyzing the grid slab system. They're generally employed for architectural reasons for giant rooms like auditoriums, vestibules, theater halls, showrooms or outlets where column-free space is usually the foremost requirement. The oblong or square void formed within the ceiling is advantageously utilized for concealed architectural lighting. The sizes of the beams running in perpendicular directions are generally kept an equivalent. The absolute best surface of a grid section could even be a smooth surface, almost kind of a typical building surface, they're commonly provided within the structures like theaters, traditional corridors, and shopping centers where section-free space is usually the principal necessity.

## IV. METHODS OF ANALYSIS

The analysis is typically performed on the thought of external action, the behavior of structure or structural materials, and thus the sort of structural model selected. supported the type of external action and behavior of the structure, the analysis is often further classified as given below.

*Equivalent Static Analysis:*

For straightforward regular structures, analysis by equivalent linear static analysis method is sufficient. this is often permitted in most codes of practice for normal, low- to medium-rise buildings. This procedure doesn't require dynamic analysis, however, it accounts for the dynamics of building approximately. The static method is the only one; it requires less computational effort and is based on the formula given within the code of practice. First, the planning base shear is computed for the entire building, and it's then distributed along the peak of the building.

## V. METHODOLOGY

*A. General:*

The building considered in the present report is G+6 Conventional Frame structure, complete analysis is carried out for dead load, live load & seismic load using ETABS software. All combinations are Considered as per IS 1893:2002.

*B. Method of Analysis:*

In this study method of analysis is done by using the Dynamic analysis method (only response spectrum method) for seismic loads acting on the structure.

1. Seismic analysis is the calculation of the building response of the structure to earthquake and is a relevant part of structural design where earthquakes are prevalent.

2. The seismic analysis of a structure involves the evaluation of the earthquake forces acting at various levels of the structure during an earthquake and the effectiveness of such forces on the behavior of the overall structure.

3. In the process of structural analysis system the analysis is carried out to predict its behaviors by using mathematical equations and physical laws.

4. Under various load effects, the main objective of structural analysis is to determine internal forces, stresses, and deformation of structures.

*C. Dynamic analysis:*

It should be performed to get the design seismic force and its allotment to different levels along with the height of the building and different lateral load resisting elements. Though in both methods, the planning base shear (Vb) should be compared with a base shear (vb) calculated employing a basic period Ta. When (Vb) is a smaller amount than (vb) all the response quantities shall be multiplied by Vb /vb. The values of damping for a building may be taken as 2 and 5 percent of the critical, for dynamic analysis of steel and reinforced concrete buildings, respectively.

*D. Response Spectrum Analysis*:

The response spectrum is a useful tools for earthquake engineering. The height response of the building is often estimated by reading the worth from the bottom response spectrum for the appropriate frequency if you'll determine the natural frequency of the structure. A response spectrum may be a plot of the utmost response amplitude (displacement, velocity, or acceleration) versus the period of the many linear single degrees of freedom oscillators to a given component of ground motion. The resulting plot is often wont to select the response of any linear SDOF oscillator, given its natural frequency of oscillation. Response spectroscopy (RSA) is an elastic method of study and lies in between the equivalent force method of study and nonlinear analysis methods in terms of complexity. RSA is predicated on the theory of structural dynamics and may be derived from the essential principles (e.g. Equation of motion). Damping of the structures is inherently taken under consideration by employing a design (or response) spectrum with a predefined damping level. The maximum response of every mode is a particular solution. The sole approximation utilized in RSA is the combination of modal responses.

RCC Frames with G+12 have been considered in the study. The fundamental period of vibration of the frame with fixed support using the modal formula in IS 1893(Part I):2002 and model analysis has been evaluated. To understand the resistance effect of earthquake and stability of structure has been modeled as response spectrum method by using Etabs.

Response spectra method of analysis of the models are performed using Etabs Effects flat slab and grid slab on different parameters are studied i.e. story drift, displacement, Shear force and bending moment.

*F. Structural Modeling:*

General

6 storied buildings are modeled using flat slabs & grid slabs respectively. These buildings were given rectangular geometry. These are then analyzed using the response spectrum method for earthquake zone III of India. The details of the modeled building are listed below. Modal damping of 5% is considered with SMRF and Importance Factor (I) =1. The isometric 3D view and elevation of the building model are shown below.

*G. Structure Data:*

*Site Properties:*

- Details of building:: G+6
- Dimension:: 30m x 36m
- Length in X- direction:: 30m
- Length in Z- direction:: 36m
- Total height of Building:: 23.2m
- Soil Type:: Hard
- Spacing:: 6m
- Base story height:: 5m
- Floor height::3.2 m

*Seismic Properties:*

- Seismic zone:: III
- Zone factor:: 0.16
- Importance factor:: 1
- Response Reduction factor R:: 5

*Material Properties:*

- Grade of concrete:: M30
- Grade of Steel:: Fe500

*Loading on structure:*

- Dead load :: self-weight of structure +1kN/m2
- Live load:: 4kN/m2
- Wind load:: Not considered
- Seismic load:: Seismic Zone II

*Optimized Sizes of members*

*Flat slab design parameters*

- Column:: 700mm x 700mm
- Flat Slab thickness:: 250mm
- Drop:: 1.5m
- Drop thickness:: 350mm

*Grid slab Design parameters*

- Column:: 700mm x 700mm
- Beam:: 400mm x 500mm
- Slab thickness:: 250mm
- Grid Size:: 1m

*H. Models to be considered for the study are:*

- Model 1- Flat Slab with Drop by the effect of Diaphragm for zone II.
- Model 2- Grid Slab by the effect of Diaphragm II.

The above types of the slab are analyzed for the seismic zone by Response Spectrum Method.

I. *Load combinations as per IS 1893:2016 (part 1)*

By using IS 1893:2016 the analysis of the following load combinations is specified. The basic load combinations given by the code as per clause 6.3.4.1 are as follows:

1. 1.5 (D.L. + L.L.)
2. 2 (D.L. + L.L. ± EQ x )
3. 1.2 (D.L. + L.L. ± EQ y )
4. 1.5 ( D.L. ± EQ x )
5. 1.5 ( D.L. ± EQ y )
6. 0.9 (D.L.) ± 1.5 (EQ x )
7. 1 (D.L. + L.L. ± EQ x )
8. 1 ( D.L. + L.L. ± EQ y )
9. 1 ( D.L. ± EQ x )
10. 1 ( D.L. ± EQ y )

Direction and Eccentricity

Direction = Multiple

Eccentricity Ratio = 5% for all diaphragms

*Structural Period*

Period Calculation Method = Program Calculated

Factors and Coefficients

Response Reduction Factor, R[IS Table 7]:: R=5

Importance Factor, I [IS Table 6] :: I=1

Site Type [IS Table 1] = III

Seismic Response

Spectral Aeleration Coefficient, $\frac{Sa}{g} = \mathbf{0.34}$

Seismic Coefficient, Ah= $\frac{ZI\frac{Sa}{g}}{2R}$

**VI. ANALYSIS OF RESULTS**

*A. General:*

A G+6storied RCC building in zone III is modeled using Etabs software and the results are computed. The configurations of the model are discussed in the previous chapter. A mode law was prepared based on a different configuration, for Flat Slab and Grid Slab.

- Model- Frame Structure with Flat Slab from ground to 3rd floor and Grid slab from 4th to 6th floor.

The above types of Slab are analyzed for zone III by a conventional fixed base, Limit State Design Method. So a model was prepared for analysis.

The model is analyzed and designed as per the specifications of Indian Standard codes IS 1893:2002 IS and IS 456:2000. The response spectrum method had been used to find the design lateral length of the story in the X and Z direction of the building.

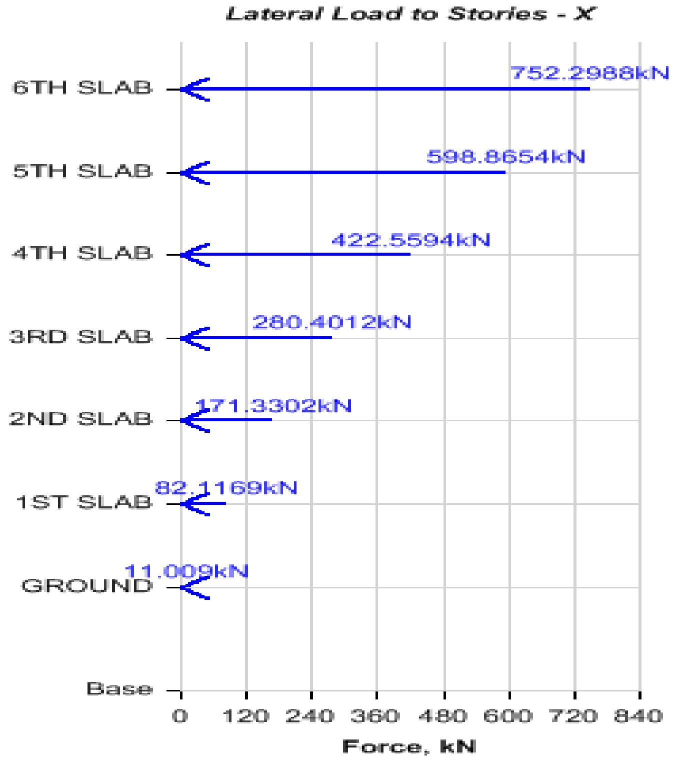


Fig. 1 Graph of Base shear (kN) in the X direction for Flat Slab and Grid Slab

Fig 1 shows the graph of the maximum base shear comparison of Flat Slab and Grid Slab in the X direction for RCC Frame by conventional fixed base, Response Spectrum Method. It shows that base shear values are maximum for Flat Slab and also base shear is minimum for Grid Slab. But the base shear value for a base for flat slab structure and grid slab structure is zero. As the elevation level increases the base shear value increases. As per the graph grid slab has a slightly minimum base shear as compared to a flat slab.

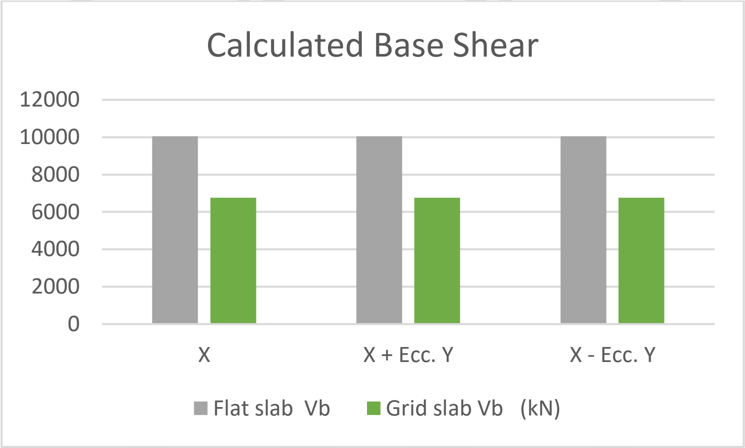


Fig. 2 Graph Calculated shear (kN) in the X direction for RCC Frame with Flat Slab and Grid Slab

Fig 2 shows the graph of the maximum base shear comparison of Flat Slab and Grid Slab in the X direction for RCC Frame by conventional fixed base, Response Spectrum Method. It shows that. Calculated based shear values are maximum for Flat Slab and Also base shear is minimum for Grid Slab.

## CALCULATED BASE SHEAR

Table: Calculated shear (kN) in the X direction for RCC Frame with Flat Slab and Grid Slab

| Direction | Period Used (sec) | W (kN) | $V_b$ (kN) |
|---|---|---|---|
| X | 1 | 461695.46 | 10046.493 |
| X + Ecc. Y | 1 | 461695.46 | 10046.493 |
| X - Ecc. Y | 1 | 461695.46 | 10046.493 |

| Direction | Period Used (sec) | W (kN) | $V_b$ (kN) |
|---|---|---|---|
| X | 1 | 311089.11 | 6769.2991 |
| X + Ecc. Y | 1 | 311089.11 | 6769.2991 |
| X - Ecc. Y | 1 | 311089.11 | 6769.2991 |

The table shows the maximum base shear comparison of Flat Slab and Grid Slab in the X direction for RCC Frame by conventional fixed base, Response Spectrum Method. It shows that base shear values are maximum for flat slabs and Also base shear is minimum for Grid Slab. This calculation presents the automatically generated lateral seismic loads for load pattern EQX according to IS1893 2002, as calculated by ETABS

**BASE REACTION**

**FORCES**

Base Reaction Force comparison of Flat Slab and Grid Slab in all directions for RCC Frame by conventional fixed base, Response Spectrum Method.

| Maximum Force | Fx max | Fy max | Fz max |
|---|---|---|---|
| **Flat Slab** | 31942.821 | 31942.821 | 221385.92 |
| **Grid Slab** | 31942.821 | 31942.821 | 31942.821 |
| **Minimum Force** | **Fx min** | **Fy min** | **Fz min** |
| **Flat Slab** | -355962 | 31942.821 | 117032.81 |
| **Grid Slab** | -355962 | -355962 | 6748.0068 |

The table shows maximum base Reaction Force comparison of Flat Slab and Grid Slab in all directions for RCC Frame by conventional fixed base, Response Spectrum Method. It shows that base reaction force values are maximum for Flat Slabin Z-direction and Also base Reaction is minimum for Grid Slab. This calculation presents the automatically generated lateral seismic loads for load patterns EQX, EQY, and EQZ according to IS1893 2002, as calculated by ETABS.

## VII. CONCLUSION & SUGGESTED FURTHER WORK

A 6-storied RCC building in zone II is modeled using Etabs software and the results are computed. The configurations of all the models are discussed in the previous chapter.

Model - Frame Structure with Flat and Grid Slab.

The above types of Slab are analyzed for zone III by the conventional fixed base, Limit State Design Method. These models are analyzed and designed as per the specifications of Indian Standard codes IS 1893:2016 IS and IS 456: 2000. The response spectrum method had been used to find the design lateral forces, drift, base shear, and base reaction along with the story in the X and Z direction of the building.

Storey shear:- It is the lateral force acting on a story, due to the forces such as seismic force. It is calculated for each story and changes from maximum at the bottom to minimum at the top of the building. As per analysis Storey shear is maximum for flat slab and minimum for grid slab.

Shear Force:-As per the observation, the shear force value is the same for the grid slab and flat slab in the directions X & Y. But for direction Z Shear Force value is Maximum for the grid slab and minimum for the flat slab. So basically shear force value is the maximum for the Grid slab. Shear force value is minimum for the flat slab.

Bending Moments:- As per the observation, the bending moment value is greater for a flat slab in the direction X. For direction Y Bending Moment, the value is maximum for the grid slab as well for direction Z bending Moment value is Maximum for the flat slab. So overall bending Moment value is maximum for flat slab and the bending Moment value is minimum for grid slab.

Story displacement**:-** It is the total displacement of the story concerning ground and there is a maximum permissible limit prescribed in IS codes for buildings. Story displacement is the same in all directions.

Storey drift:-Storey drift is the drift of one level of a multi-story building relative to the level below. The drift of inter-story is the difference between the floor displacements and roof of any given story as the building sways during the earthquake and is normalized by the story height. Story drift is the same for grid slab and flat slab.

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