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Comparative Study of Seismic Behavior In G+12 Multi-Story Buildings using Flat Slabs and Conventional RC Slabs

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ABSRACT: In recent years, flat slab construction has gained popularity due to its numerous advantages over conventional reinforced concrete (RC) frame buildings. Flat slab systems offer benefits such as improved space utilization, architectural flexibility, simplified formwork, reduced construction time, and cost-effectiveness. However, the structural performance of flat slab buildings under seismic loading is a significant concern due to their vulnerability in earthquake-prone areas. Therefore, it is essential to analyze the seismic behavior of buildings to understand how conventional RC frame buildings and flat slab buildings, with shear walls, perform under earthquake forces. The analysis for this study is conducted using ETABS design software.

The study aims to evaluate the seismic performance of G+12 multi-story buildings with both conventional RC slabs and flat slabs. Key parameters considered include story drift, lateral displacement, and base shear. The results provide insights into the supplementary measures required to enhance the seismic resistance of these structures. Additionally, the performance of these buildings is analyzed under wind loading to ensure comprehensive structural safety.

Keywords: conventional reinforced concrete, G+12 multi-story buildings, RC frame buildings.

INTRODUCTION

Earthquakes are among the most devastating natural calamities known to humankind, responsible for the destruction of countless lives and infrastructure throughout recorded and unrecorded history. An earthquake is caused by a sudden release of energy in the Earth's crust, resulting in seismic waves that shake the ground. These waves can result from tectonic movements along fault lines or volcanic activity. In the context of India, a country situated in an active seismic zone, several earthquakes in the past century have highlighted the pressing need for earthquake-resistant design. Notable examples include the Bhuj earthquake (2001), Latur earthquake (1993), and Uttarkashi earthquake (1991), which collectively caused massive loss of life and infrastructure damage.

With rapid urbanization and the growth of population in Indian cities, there is an increasing demand for high-rise buildings. These vertical expansions are essential for accommodating the ever-growing residential and commercial requirements. However, such multi-story structures are significantly more susceptible to earthquake-induced damage due to their height and mass distribution. Therefore, understanding and improving their seismic performance becomes a crucial aspect of structural engineering.

Seismic design aims not only to ensure the structural integrity and safety of buildings during significant ground motion but also to minimize economic loss and ensure post-earthquake functionality. Modern seismic design philosophy incorporates ductility, redundancy, and energy dissipation as central themes, recognizing that complete avoidance of damage during a major earthquake is unrealistic. Instead, the goal is to design buildings that can absorb and dissipate seismic energy through controlled inelastic behavior, avoiding collapse.

OBJECTIVES OF THE STUDY

The main objectives of this study are to:

1. Model and analyze G+12 multi-storey RC buildings in ETABS using two structural systems: flat slab (with drop panels) and conventional beam-slab.
2. Perform response spectrum analysis to assess and compare seismic performance indicators—such as base shear, story displacement, story drift, natural period, and ductility demands.
3. Evaluate advantages vs. disadvantages in terms of structural efficiency, seismic safety, construction logistics, and economic aspects.
4. Derive recommendations on the suitability of flat slab vs conventional slab systems for tall

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buildings in seismic regions, considering current code provisions

METHODOLOGY

This chapter outlines the methodology adopted for the comparative study of seismic behavior in G+12 multi-storey buildings using flat slabs and conventional RC slabs. The methodology is structured to systematically assess and compare seismic responses including displacement, story drift, and base shear under standardized loading and design conditions. ETABS software is used for structural modeling and analysis as per IS 456:2000 and IS 1893 (Part 1): 2016.

Research Approach

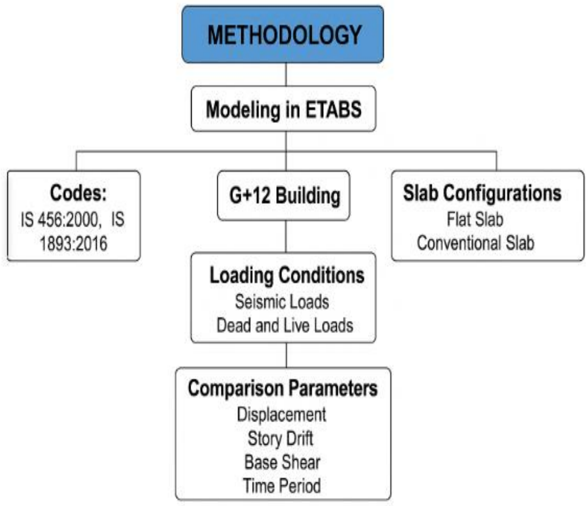

Figure 1: Flowchart of the study

PROBLEM STATEMENT

Building Description:

In this dissertation work, a G+12 storey structure is analysed by response spectrum analysis method using ETABS software for Conventional Slab and Flat Slab configurations. Plan size of building is 22.5 m X 18 m. Typical storey height is 3 m. Building description is given as per follows:

Table 1: Material Properties

Young's Modulus of concrete	25x1000 kN/m3
Density of reinforced concrete	25 kN/m3
Young's modulus of steel	2x105 kN/ m2
Density of steel	78.50 kN/m3
Density of Masonry	18 kN/m3
Density of Plaster	20 kN/m3
Poisson's Ratio	0.2

Table 2: Material Grades

Grade of concrete	M30
fck	30 N/mm2
Grade of Main reinforcement steel	HYSD 415
Grade of lateral ties or stirrups	HYSD 415

Table 3: Member Properties

Thickness of slab	150 mm
Thickness of shear wall	300 mm
Column size	600 x 600 mm
Beams size	300 x 400 mm
External wall thickness	230 mm
Internal wall thickness	150 mm
Parapet Wall height	1 m

Table 4: Loads considered

Floor finish	1kN/m2
Waterproof load	2 kN/m2
Live Load	2.5 kN/m2
Wall load: External	12. 8 kN/m
Wall load: External Parapet at top	5.81 kN/m
Wall load: Internal	8.85 kN/m

Table 5: Wind Load

Standard	IS 875 Part 3
Location	Pune
Basic wind speed	39 m/sec
Terrain Category	3
Structure Class	B
Risk coefficient(k1)	1
Topography factor	1

Table 6: Seismic Load

Standard	IS 1893 Part 1 [2016]
Location	Pune
Seismic zone	III
Zone factor, Z	0.16
Site type	Medium soil
Importance factor, I	1.2
Response reduction factor, R	5

Building Drawings:

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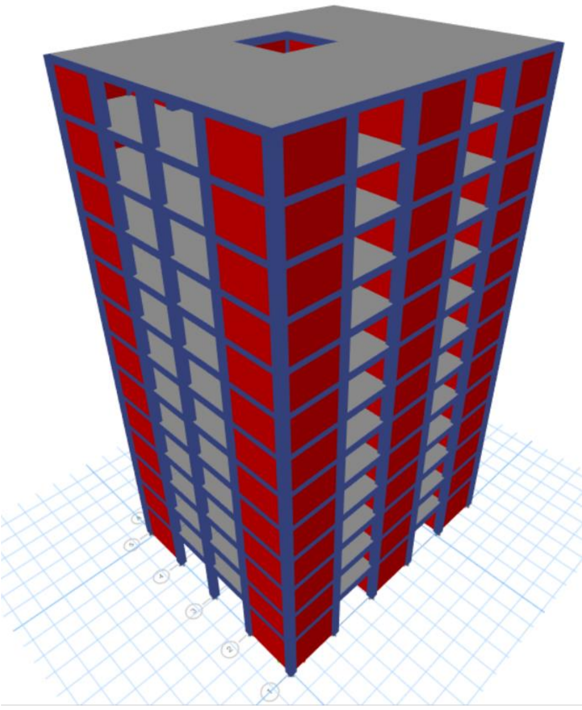

Figure 2: Elevation of Building

Loads acting on Structures:

Dead Load: External Wall

External wall load acting on structure is calculated as follows:
Dead Load calculation for external wall on typical floor:

Table 7: Dead Load calculation for external wall

Thickness of external wall	0.23 m
Height of wall	3 – 0.4 = 2.6 m
Length of wall	1 m
Density of masonry	18 kN/m3
Density of Plaster	20 kN/m3
External wall load	18*2.6*0.23 + 20*2*0.012*3 = 12.2 kN/m = 12.8 kN/m [considered]

Dead Load calculation for Parapet wall on terrace floor:

Table 8: Dead Load calculation for parapet wall

Thickness of external wall	0.23 m
Height of wall	1 m
Length of wall	1 m
Density of masonry	18 kN/m3
Density of Plaster	20 kN/m3
Parapet wall load	18*1*0.23 + 20*2*0.012*1 = 5.54 kN/m = 5.81 kN/m [Considered]

Dead Load: Internal Wall

Dead Load calculation for internal wall on typical floor:

Table 9: Dead Load calculation for internal wall

Thickness of internal wall	0.15 m
Height of wall	3 – 0.4 = 2.6 m
Length of wall	1 m
Density of masonry	18 kN/m3
Density of Plaster	20 kN/m3
Internal wall load	18*2.6*0.15 + 20*2*0.012*3 = 8.46 kN/m = 8.85 kN/m [considered]

Dead Load: Floor Finish Load
Intensity of floor finish load: 1 kN/m2

Dead Load: Waterproof Load
Waterproof load on terrace: 2 kN/m2

Dead Load: Live Load
Live load on typical floor: 2.5 kN/m2

Dead Load: Roof Live Load
Live load on terrace/roof floor: 1.5 kN/m2

Basic load cases

As mentioned above followings are basic load cases defined in software

1. Dead Load: Self Weight of members
2. Dead Load: External wall load
3. Dead Load: Internal Wall load
4. Dead Load: Floor finish load
5. Dead Load: Waterproof load
6. Live Load: Habitable floor
7. Live load: Roof live
8. Wind Load in X direction
9. Wind load in Y direction
10. Earthquake Load in X direction: EQ X [linear Static]
11. Earthquake load in Y direction: EQ Y [linear Static]
12. Earthquake load in X direction: RS X [Response spectrum]
13. Earthquake load in Y direction: RS Y [Response spectrum]

RESULTS AND DISCUSSION

Introduction

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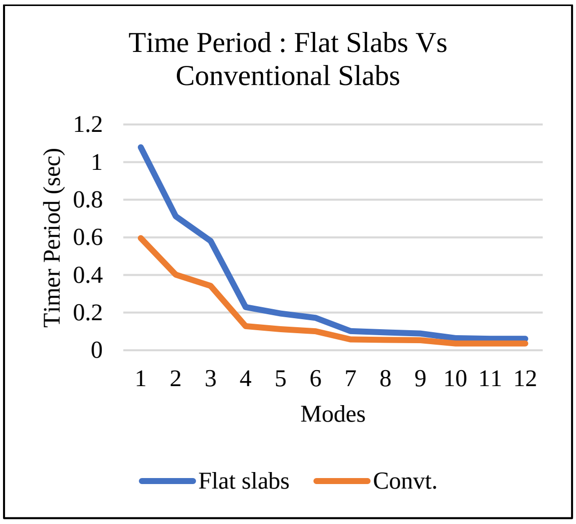
Building is subjected to Response Spectrum Analysis (RSA) for Conventional Slab [M1] and Flat slab configurations [M2].

Results: Time Period

Following table represents time period for different modes for both flat and conventional slabs.

Table 10: Time Period

Case	Time Period (Sec.)		
	Mode	Flat slabs	Convt.slabs
Modal	1	1.079	0.596
Modal	2	0.712	0.402
Modal	3	0.581	0.342
Modal	4	0.229	0.128
Modal	5	0.195	0.112
Modal	6	0.172	0.101
Modal	7	0.102	0.058
Modal	8	0.095	0.055
Modal	9	0.089	0.053
Modal	10	0.064	0.036
Modal	11	0.061	0.036
Modal	12	0.061	0.036



Graph 5.1: Time Period

1. From above graph, it is clear that time period of flat slabs is higher than conventional slabs. Flat slab structures generally exhibit a longer natural time period compared to conventional slabs due to reduced overall stiffness, as the absence of beams in flat slabs results in a more flexible structural system.
2. This increase in flexibility can lead to higher lateral displacements and lower natural frequencies, making flat slab systems potentially more vulnerable to seismic excitations if not properly detailed. Conversely, conventional slab systems, with their added beam stiffness, show shorter time periods, indicating a stiffer and more stable seismic response.
3. Therefore, while flat slabs offer architectural and construction advantages such as reduced floor height and faster construction, they must be carefully analyzed and designed with respect to lateral load resistance - especially in high-rise and seismic-prone areas. From the modal analysis, it can be concluded that conventional slab systems provide better dynamic performance, whereas flat slabs require additional structural measures (like shear walls or drop panels) to match the seismic performance of conventional designs.

Results: Base Shear

Following table shows results of base shear for flat slabs and conventional slabs for RS X load case.

Table 11: Storey Shear

	M1: Flat Slab	**M2: Conventional Slab**
Storey	**X Dir. [kN]**	**X Dir. [kN]**
13	1779.24	10542.91
12	4053.03	25234.31
11	6056.87	38316.62
10	7812.4	49844.47
9	9354.99	59955.9
8	10704.34	68797.18
7	11883.12	76507.09
6	12909.13	83165.03
5	13784.95	88850.64
4	14512.85	93570.74
3	15084.28	97245.75
2	15488.38	99795.16
1	15732.51	101243.87
Base	15732.51	101243.87

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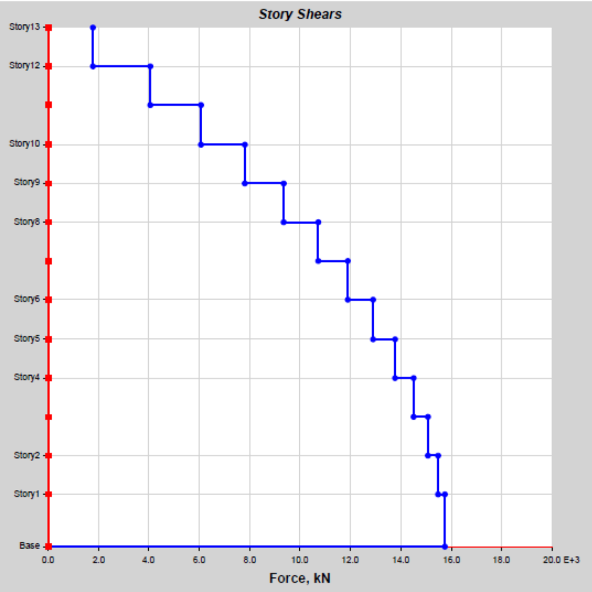
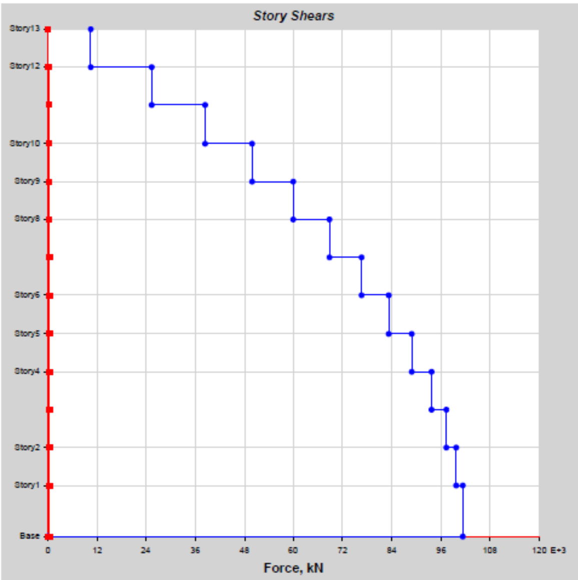


Graph 5.2: M1 - Storey shear in X direction due to RS X

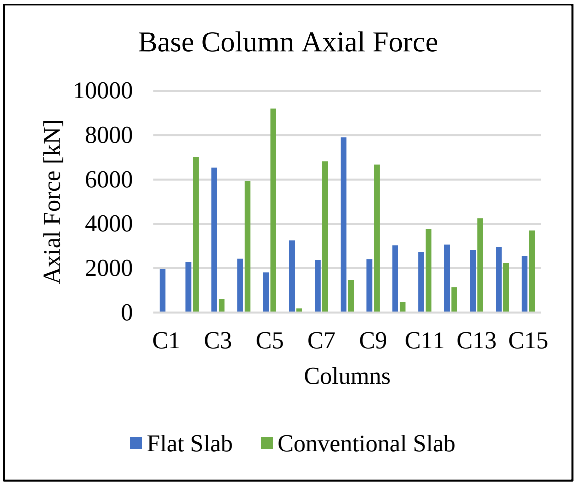


Graph 5.3: M2 - Storey shear in X direction due to RS X

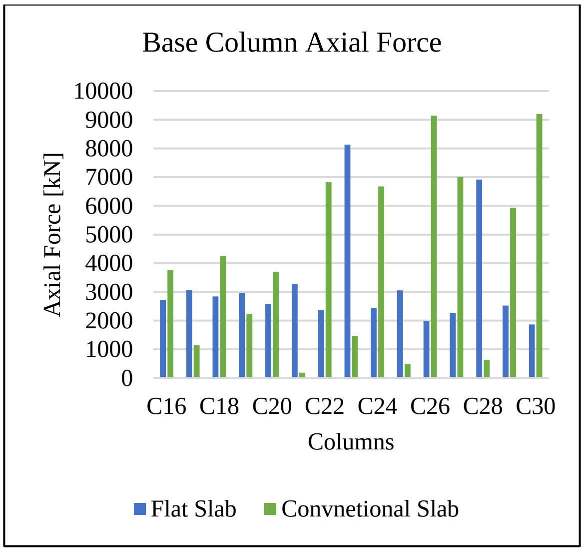
1. From above graphs, flat slabs attract less base shear as compared to conventional slabs.
2. Flat slab buildings exhibit lower base shear values compared to conventional slab systems.
3. This is primarily due to the higher flexibility and lower lateral stiffness of flat slab structures, which results in a longer fundamental time period. According to seismic design codes (such as IS 1893), a longer time period corresponds to a reduced design spectral acceleration, and hence, lower base shear. On the other hand, conventional slab buildings, with beams contributing to greater overall stiffness, show shorter time periods and consequently attract higher base shear forces.
4. While lower base shear in flat slab buildings might initially seem beneficial, it often reflects increased deformability, which can lead to greater inter-story drifts and potential non-structural damage under seismic loading. Thus:
5. Flat slab systems may require additional seismic resistance measures, such as shear walls, drop panels, or moment-resisting frames.
6. Conventional slab systems inherently provide better lateral stiffness and higher seismic demand, which contributes to better control of displacements and improved structural performance in seismic zones.

Results: Column Axial Force

Following table shows axial forces developed in base columns for flat slabs and conventional slabs.



Graph 5.4: Base column axial force (Column 1-15)



Graph 5.5: Base column axial force (Column 15-30)

1. From the above graph, it is clear that axial load in columns in conventional slab configuration is

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more than flat slab configuration. If we find out difference in magnitude of axial force in columns, then averagely 50% load is more in conventional slabs column than in flat slabs.

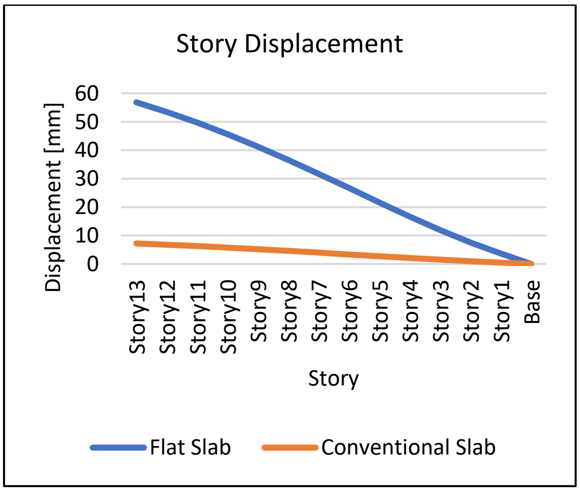
2. This is due to stiffness of structure, since flat slabs have less stiff structure as compared to conventional slabs due to lack of beams. More stiff structure attracts large axial loads in columns.

5.5 Results: Story displacement

The following tables provides results of story displacement for flat slab and conventional slab configuration building subjected to seismic load in X direction.

Total allowable displacement of top story from bottom
= H/200 = 40x1000/200
= 200 mm.

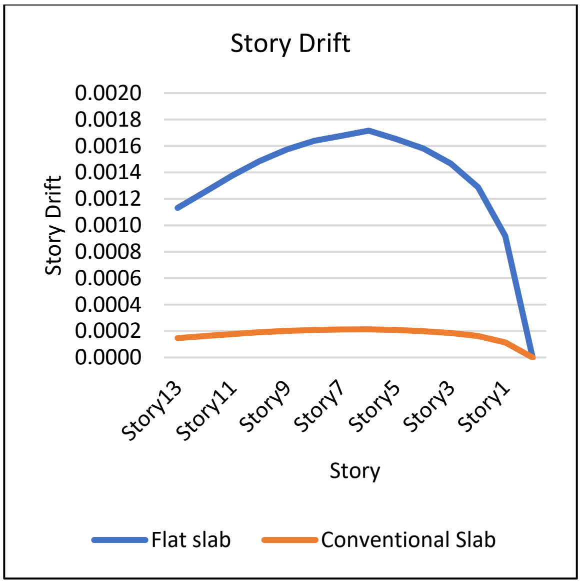
Due to use of shear walls displacement is greatly reduced within acceptable limits.
From the above table it is clear that story displacement is more for flat slabs than conventional slabs since flat slab structure is less stiff.



Graph 5.6: Story Displacement

5.6 Results: Story drift

Following table shows result of story drift when building is subjected to seismic load. Comparison between flat slab and conventional slab story drift has shown below.



Graph 5.7: Story Drift

CONCLUSION

1. Storey Drift

- **Flat Slab:** In the G+12 flat slab building, the sideways movement between floors (storey drift) is higher because there are no beams to help resist the side forces from an earthquake.
- **Conventional Slab:** In the G+12 conventional slab building, beams connect the columns and make the structure stiffer, so the drift is lower and within safe limits.

2. Storey Displacement

- **Flat Slab:** The total sideways movement at the top floor is more in the flat slab building. Less stiffness means the building sways more during earthquakes.
- **Conventional Slab:** The conventional slab building sways less because the beam-and-column arrangement is stronger against side forces.

3. Lateral Stiffness

- **Flat Slab:** This building type has lower resistance to sideways movement because the slab transfers loads directly to the columns without the extra support of beams.
- **Conventional Slab:** With beams in place, the conventional slab building is stiffer and better at resisting earthquake forces.

4. Axial Force in Columns

- **Flat Slab:** In the flat slab G+12 building, the direct load transfer from slab to column slightly reduces the vertical (axial) load on each column.

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- **Conventional Slab:** In the conventional slab building, beams send more load to the columns, so axial forces in columns are generally higher.

5. Flexibility

- **Flat Slab:** Architecturally, this type is more flexible because the flat ceiling without beams makes it easier for interiors and services. Structurally, though, it is more flexible (less stiff) and moves more during earthquakes.
- **Conventional Slab:** This type is less flexible for interiors because of the beams, but it is structurally stronger and moves less during earthquakes.

Conventional slabs are better when drift/stiffness control is critical (taller or higher-seismic buildings), while flat slabs are better for fast construction, lower floor heights, and MEP flexibility—provided a stiff lateral system handles drift.

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