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Effects of Belt Truss Integration on Flat Slab Systems with Drops Under Seismic Loading Conditions

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***Abstract:** Recent urban development trends have led to increased use of flat slabs for their aesthetic appeal and construction ease. However, their behaviour under seismic conditions remains a topic of study. The response of this system to lateral forces is influenced by various factors, including the building's height, the dimensions of the floor plate, the positioning of the shear wall core, and the spans of the flat slab, among others. The study analysed G+10-storeyed buildings with a belt truss system using ETABS 20. Dynamic analysis was conducted based on earthquake data sourced from IS 1893:2016. This research examines the seismic performance of flat slabs with drop panels, taking into account the presence of shear walls at the core and the impact of the belt truss system. Preliminary findings indicate that drop panels enhance load-bearing capacity, while shear walls reduce the period and lateral displacements during earthquakes. These results emphasise the importance of belt truss systems in enhancing seismic performance and promoting safety and resilience in earthquake-prone areas.*

***Keywords:** Belt Truss, Dynamic Analysis, Flat Slab, Lateral Displacements, period*

Abbreviations:
ETABS: Extended Three-Dimensional Analysis of Building System
SFSB: Storey Flat Slab Building
SLP: Seismic Loading Parameters

I. INTRODUCTION

Flat slabs, a critical component in modern architecture and construction, are reinforced concrete slabs that are directly supported by concrete columns, eliminating the need for beams. This design simplifies formwork and reduces construction time, making it a preferred choice for many architects and builders. However, their simplicity also brings challenges, especially in regions with seismic activity. The behaviour of flat slabs under lateral forces is a concern and requires careful consideration during the design phase. A belt truss is a structural element commonly used in building construction to provide lateral support and stability to tall or slender structures, such as skyscrapers or bridges. The primary function of a belt truss is to resist lateral forces, such as wind or seismic loads, which can cause the building to sway or deform. By connecting columns or shear walls along the The building's perimeter, the belt truss, effectively braces the structure in multi-storeyed flat slab buildings.

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II. LITERATURE REVIEW

This literature review provides a concise overview of previous studies on the analysis of flat slab structures. It focuses on the behaviour of the flat slab structure with a drop under seismic loading.

The authors conducted a study examining the impact of shear walls on the seismic performance of a 15-story flat-slab building using ETABS. Adding shear walls increased base shear by 3.08% and reduced story displacement by 48.52%. Peripheral shear walls were the most effective, reducing displacement by 29.13% and 10.06% compared to L-type and non-parallel layouts, respectively, and best-improved performance under wind and seismic loads [1]. This paper examines the optimal placement of outriggers in steel high-rise buildings to enhance seismic resilience through time history analysis. Findings show that strategically positioned outriggers enhance lateral stiffness, reduce drift, and improve stability under earthquake loads, maximizing structural performance in seismic-prone areas [2]. The study investigated different-storeyed buildings, comparing conventional designs with central cores to models with outrigger bracing systems at different heights. Placing double outriggers at both top and mid-height (0.5H and H) levels proved most effective in reducing lateral displacement and drift while slightly decreasing base shear [3]. A study analysed G+44-storey buildings with outrigger and outrigger with belt truss systems using El Centro earthquake data. Steel structures exhibited lower base shear than reinforced concrete structures, resulting in a better seismic response. Outriggers with belt truss systems were effective by placing outriggers at 0.6H, which reduced top storey drift and displacement [4].

III. OBJECTIVES

1. To analyse the flat slab structure with a drop under different loading conditions.
2. To study the effect of the belt truss in a flat slab building.
3. Comparing the results of a flat slab building with a shear wall at the core and a belt truss system.
4. To check punching shear in a flat slab building.

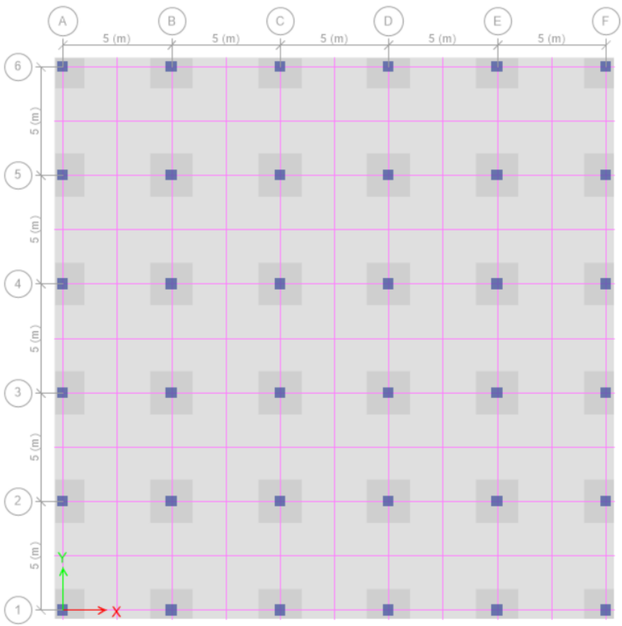
IV. METHODOLOGY

In the present study, a G+10-storey structure is selected for examination. The plan is 25 m × 25 m, and the total height of the building is 36.4 m.

The bottom storey height of 4 m and a typical storey height of 3.6 m with five bays of 5 m each along the X and Y directions is provided. The columns and slabs are designed to withstand the live and dead loads adequately. The study is carried out using ETABS 20 software. The study is conducted by IS: 1893 (Part 1): 2016 for seismic analysis.

Table I: Description of Models

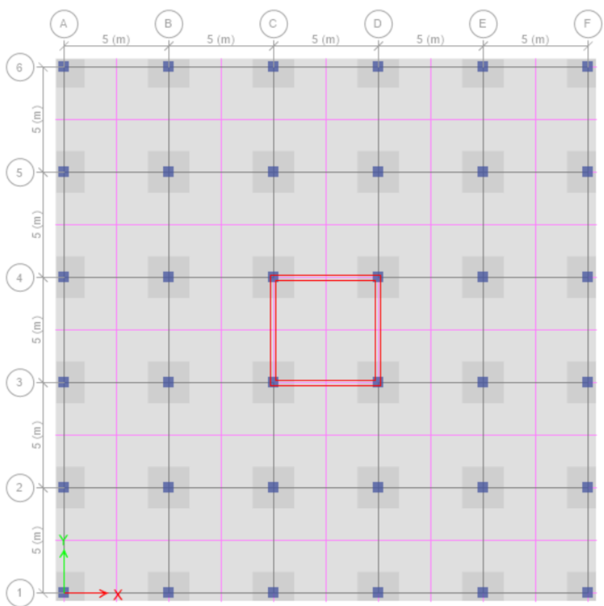
Models	Description of Models
1	Flat slab building
2	Flat slab building with shear wall at core
3	Flat slab building with shear wall at core and belt truss system



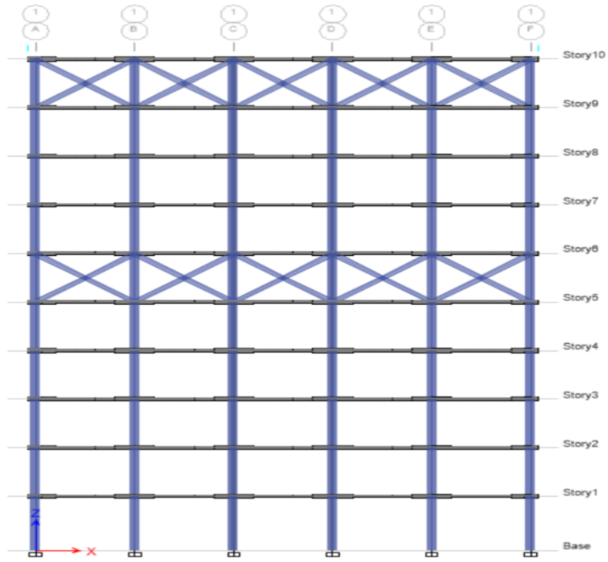
[Fig.1: Plan of Flat Slab Building (Model-1)]

Table II: Member and Material Properties

Member	Size	Materials
Thickness of flat slab	200 mm	M40
Thickness of drop	300 mm	M40
Drop width	2×2 m	M40
Column sizes	500×500 mm	M40
Shear wall thickness	250mm	M40



[Fig.2: Plan of the Flat Slab with Shear Wall at Core (Model-2)]



[Fig.3: Elevation View of G+10 Storey Flat Slab Building with Shear Wall at Core and Belt Truss System at Top and 0.5H (Model-3)]

Table III: Seismic Loading Parameters

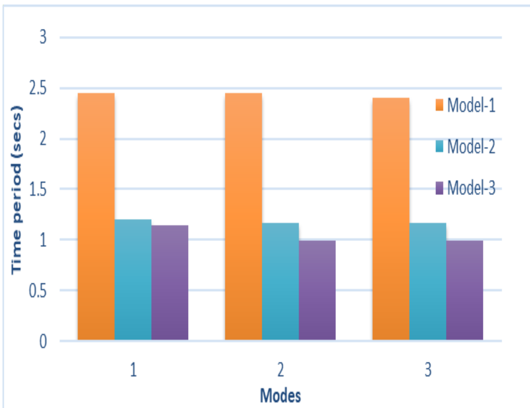
Seismic Zone	III
Zone factor	0.16
Importance factor	1.5
Type of soil	Medium (II)
Response reduction factor	5

V. RESULTS AND DISCUSSION

After conducting the seismic analysis, the parameters, such as period, base shear, storey displacement, and storey drift, for flat slab, flat slab with shear wall at the core, and flat slab with belt truss system are compared.

A. Period

The period (T) of a structure is the time taken by it to complete one full cycle of its free vibration. In simple terms, it's the time required for a structure to sway back and forth once naturally. The period of a structure gives insights into how it will respond during an earthquake or any other dynamic load.



[Fig.4: Variation of Period Vs Modes for Model-1 to Model-3]

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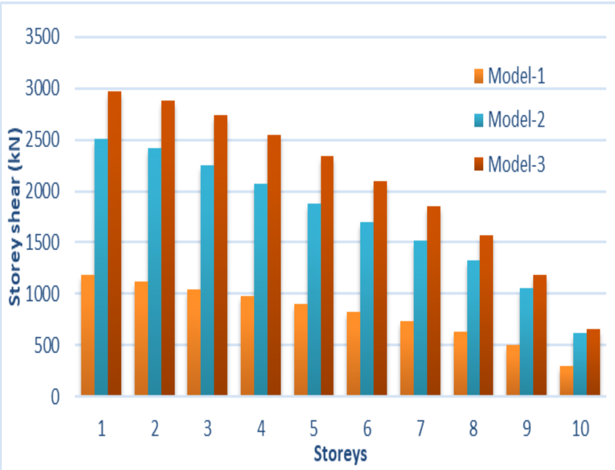
From the graph, it is observed that providing a shear wall reduces the period in a flat slab structure. The belt truss system also reduces the period in a flat slab structure.

B. Storey Shear

Base shear is the total lateral (horizontal) force or shear force that a structure is expected to experience during an earthquake. It acts at the base of the building. The base shear helps in understanding the force a building structure needs to withstand during an earthquake. It is a critical parameter that aids in the seismic design of structures.

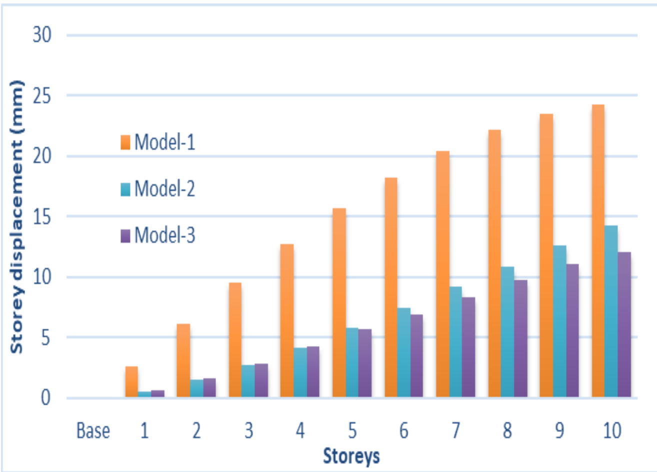


[Fig.5: Variation of Storey Shear vs Storeys for Model-1 to Model-3]

From the results, the base shear is found to be lowest for flat slab structures compared to other slabs.

C. Storey Displacement

Storey displacement refers to the lateral or sideways movement of a building's floor level relative to its original position, primarily due to lateral loads such as seismic (earthquake) forces or wind.

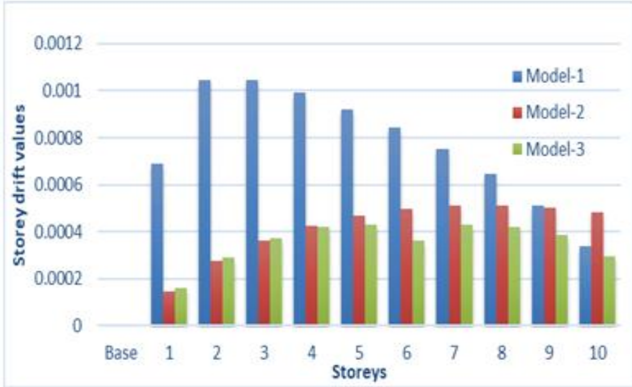


[Fig.6: Variation of Storey Displacement vs Storeys for Model-1 to Model-3]

From the results, maximum storey displacement is found in flat slabs as compared to other slabs. A flat slab with a belt truss system is 15.4% less expensive than a flat slab with a shear wall at the core.

D. Storey Drift

Storey drift is the difference in lateral displacement between two consecutive storeys of a building. As per IS 1893 (Part 1): 2016 clause 7.11.1.1, its value should not go beyond the limit of 0.004h, where (h) is the height of the building.



[Fig.7: Variation of Storey Drift vs Storeys for Model-1 to Model-3]

VI. CONCLUSION

1. The storey displacement for a flat slab with a shear wall at the core and belt truss system is 15.4% less than that of a flat slab with a shear wall at the core.
2. It is observed that for flat slab structures, the period, storey displacement and storey drift are high as compared to all other structures. Base shear is found to be the lowest in the flat slab.
3. The storey shear for a flat slab with a belt truss system is higher than that of a flat slab with a shear wall at the core.
4. Maximum storey drift was found in the flat slab, i.e. $0.00098 < 0.004$, hence OK.
5. Punching shear was found to be within the limit in a flat slab structure.

VII. FUTURE SCOPE

In this research, the belt truss was used at a height of 0.5H and 1.0H. Studies can be conducted by considering different heights, such as 0.3H or 0.7H, and so on.

DECLARATION STATEMENT

After aggregating input from all authors, I must verify the accuracy of the following information as the article's author.

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- **Funding Support:** This article has not been sponsored or funded by any organization or agency. The independence of this research is a crucial factor in affirming its impartiality, as it was conducted without any external influence.
- **Ethical Approval and Consent to Participate:** The data provided in this article is exempt from the requirement for ethical approval or participant consent.
- **Data Access Statement and Material Availability:** The adequate resources of this article are publicly accessible.
- **Author's Contributions:** The authorship of this article is

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contributed equally to all participating individuals.

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Nachiket Rokade completed his B.E. from Pillai's HOC College of Engineering and Technology in 2021. He is pursuing a Master's degree in Structural Engineering from the Saraswati College of Engineering, affiliated with Mumbai University. The current research and thesis he is working on are based on seismic analysis of flat slab buildings.

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