



Comparative Analysis Of Flat Slab, Waffle Slab, And Conventional Slab Systems In Commercial Building

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Abstract: This paper presents a comparative study on the structural performance of flat slab, waffle slab, and conventional slab systems in a multi-storey (G+5) commercial building using ETABS software. The building is modelled and analyzed under seismic zone III conditions using dynamic response spectrum methods. The comparison focuses on critical parameters such as lateral load, storey displacement, storey drift, base shear, and base reactions. The results of flat slabs exhibit higher storey drift and base shear due to increased flexibility. The findings aim to inform optimal slab system selection for commercial buildings in seismic zones.

Keywords - Flat slab, Waffle slab, Conventional slab, RCC building, Seismic analysis, ETABS, Response spectrum, Storey drift, Displacement, Base Shear.

I. INTRODUCTION

Slab systems form the critical horizontal load-resisting elements in reinforced concrete (RCC) structures. While conventional slabs dominate low-rise construction due to their simplicity, alternative systems such as flat slabs and waffle slabs are gaining traction in multi-storey buildings. With advancements in material and construction technology, multiple slab systems such as flat slabs, waffle slabs, and conventional RC slabs are adopted in commercial buildings. This study evaluates and compares the seismic performance of these slab systems under equivalent structural configurations to aid in design decision-making.

II. OBJECTIVES

The core objective of this research is to explore and emphasize the comparative benefits of waffle slabs in contrast to flat slabs. Waffle slabs present distinct advantages over flat slabs, positioning them as a favourable option in various structural applications. The aims of this study are outlined below:

- i. To conduct the analysis and structural design of flat slab, waffle slab, and traditional slab systems for a G+5 multi-storey commercial structure.
- ii. To evaluate and contrast the analytical results obtained from ETABS for the aforementioned slab types under different loading scenarios.
- iii. To investigate seismic design principles for flat, waffle, and conventional slabs in accordance with the Indian Standard Code IS:1893-2016.
- iv. To assess the structural performance, including load-bearing capacity, deflection behavior, and failure mechanisms of the three slab systems when subjected to seismic loads, using both linear static and response spectrum methods.

- v. To perform a comparative analysis of cost-effectiveness and failure characteristics using ETABS simulation results.

This research aims to assess the structural response of multi-storeyed buildings incorporating conventional RC slabs, flat slabs, and waffle slabs, particularly under seismic conditions. The evaluation centres on critical parameters such as storey drift, lateral displacements, base shear due to earthquakes, and applied lateral forces. The overarching goal is to improve the earthquake resilience of structures using these three slab systems.

III. LITERATURE REVIEW

Several research efforts have contributed to understanding the comparative behavior of flat slabs and waffle (grid) slabs, particularly under seismic loading. This brief review presents insights from recent studies that explore slab performance across different structural and seismic conditions, which closely relate to the current work.

Mohana et al. (2015) conducted a comparative seismic analysis of flat and conventional slabs in a G+5 commercial structure using ETABS. Key parameters such as base shear, axial forces, displacement, and storey drift were analyzed across various Indian seismic zones. Results indicated that flat slab systems exhibited around 5% higher storey shear and 6% more axial force than conventional slabs. Displacement differences were minor, averaging 4 mm per storey, suggesting flat slabs are a viable option without compromising seismic performance.

Harish M. K. (2017) examined the response of a G+4 building with a grid slab system using various dynamic analysis techniques, including the response spectrum method. The model incorporated all primary structural components, and results emphasized the effectiveness of grid slabs when modelled with precise geometric and loading conditions.

Thomas Navjot Kaur Bhatia (2016) assessed the seismic and wind performance of flat and grid slabs in multistorey RC structures with varied floor plans and elevations. The study demonstrated that grid and flat slabs performed better in terms of deflection control and cost-efficiency compared to conventional slabs, especially in taller buildings and higher seismic zones.

Anurag Kumar Pandey & Anjali Rai observed that buildings with grid slabs provide improved seismic response, particularly in high-risk earthquake zones. Grid slabs also offer advantages in designs requiring fewer columns per floor, enhancing architectural flexibility and space utilization.

Abhijit K. Sawwalakhe & Prabodh D. Pachpor highlighted the appropriateness of flat slabs for high-rise construction due to their simpler formwork, reduced construction height, and cost benefits. Although they carry higher bending and shear stresses, their functional and economic merits make them suitable for large-scale projects. Conversely, conventional slabs are preferred in residential settings, while grid slabs suit larger spans requiring rigidity.

Lalit Balhar & Dr. J.N. Vyas (2017) emphasized the benefits of flat slabs, such as reduced construction time and formwork complexity. However, they also stressed the need for thorough seismic analysis, as flat slab buildings may underperform under earthquake loading. Their STAAD Pro. based study showed that incorporating shear walls or other design modifications can enhance the seismic performance of flat slab systems.

IV. METHODOLOGY

A G+5 commercial RC building was modelled using ETABS. Three models were created based on the slab systems:

- Model 1: Flat Slab with drop
- Model 2: Waffle Slab
- Model 3: Conventional Slab with beams

The same building layout, material properties (M25 concrete, Fe550 steel), and loading conditions were used across all models. Analysis was carried out using: Response Spectrum Method (Dynamic Analysis).

V. ACKNOWLEDGMENT

All three models share the following properties:

- Plan dimensions: 19.6m × 21.9m
- Height: 24.6m
- Seismic Zone: III (Z = 0.16)
- Importance Factor (I): 1.0
- Response Reduction Factor (R): 5
- Soil Type: Medium

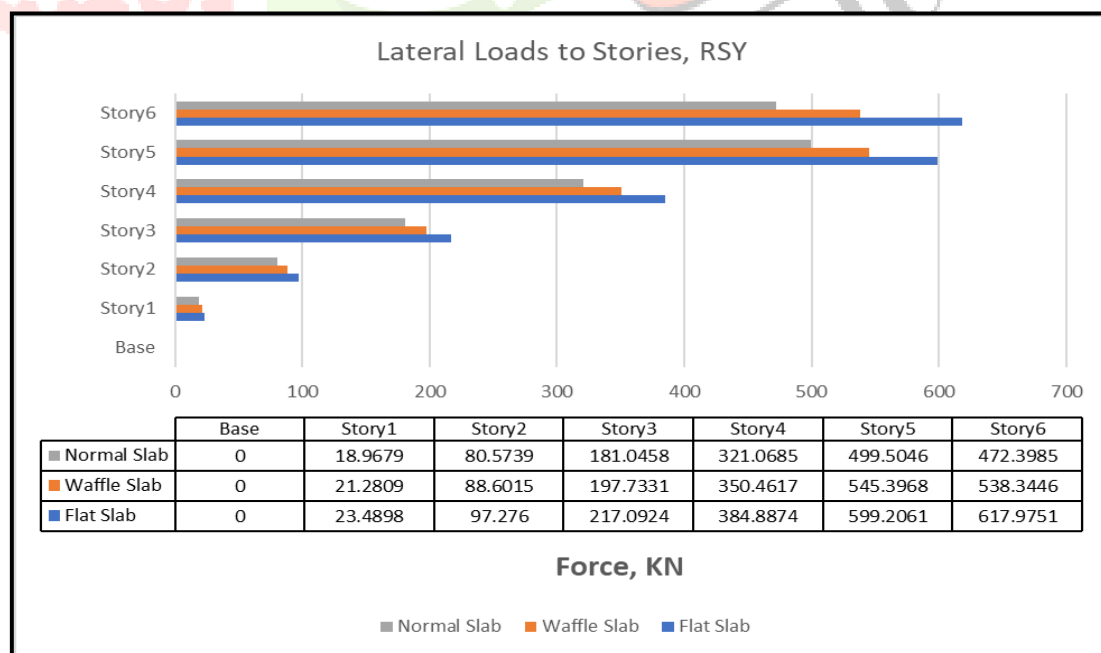
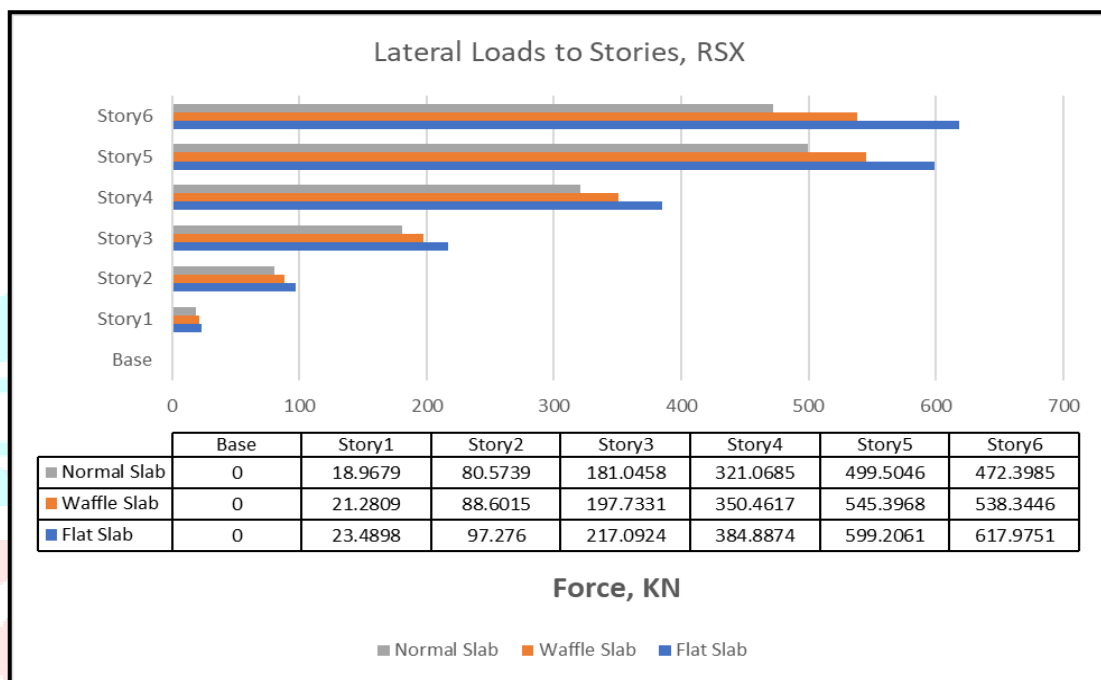
Sl. No.	Specification	Different Types of Slab System		
		Flat Slab	Waffle Slab	Conventional Slab
1	Plan Dimensions	19.6m X 21.90m	19.6m X 21.90m	19.6m X 21.90m
2	Length In X Direction	19.6m	19.6m	19.6m
3	Length In Y Direction	21.9m	21.9m	21.9m
4	Storey Height	24.6m	24.6m	24.6m
5	No. Of Storey	6 + Stair Room	6 + Stair Room	6 + Stair Room
6	Slab Thickness	200mm	100mm	125mm
7	Beam Size	-	250X450 mm	250X500 mm
8	Grid Spacing	-	0.9m	-
9	Grid Beam Size	-	200X250 mm	-
10	Drop Depth.	250mm	-	-
11	Maximum Spacing of Grid	4.1m	4.1m	4.1m
12	Maximum Height of Floor	3.65m	3.65m	3.65m

Wind and seismic loads were calculated as per IS 875 Part 3 and IS 1893:2016. The models were analyzed for base shear, storey drift, and displacements in both X and Y directions.

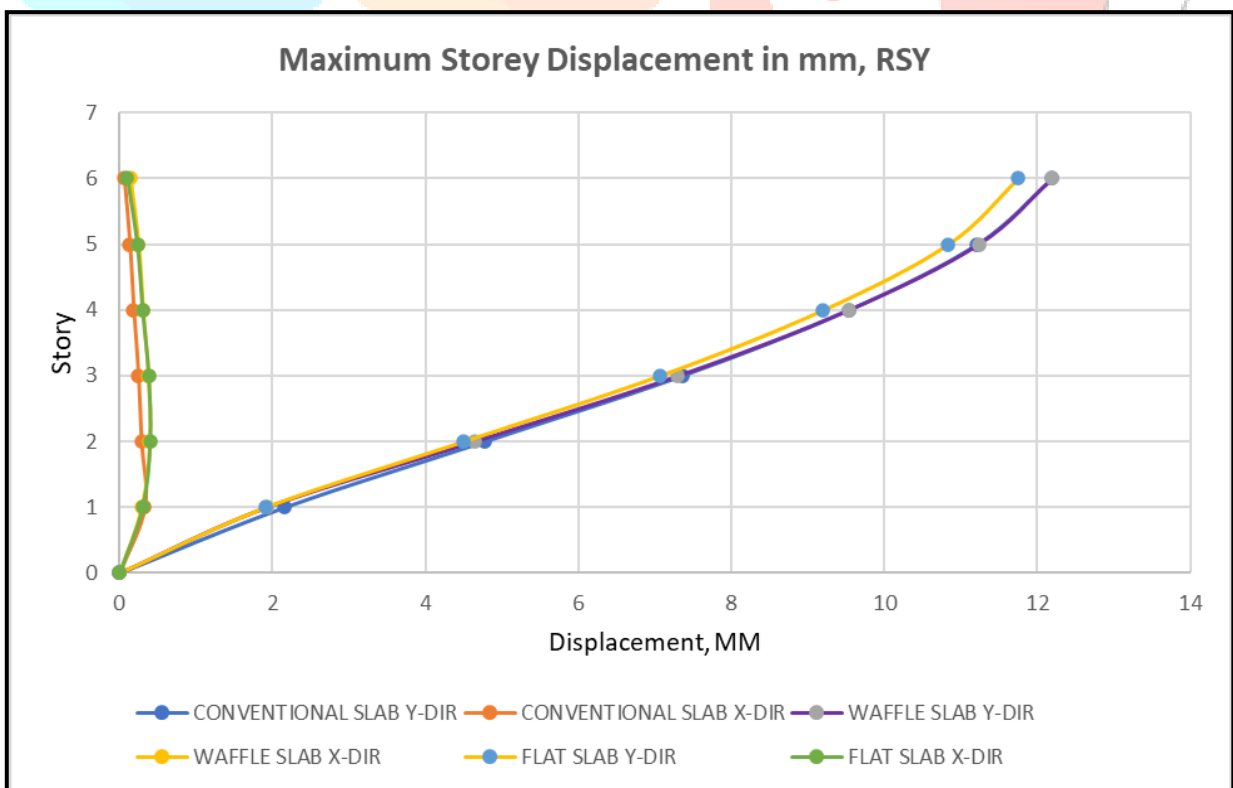
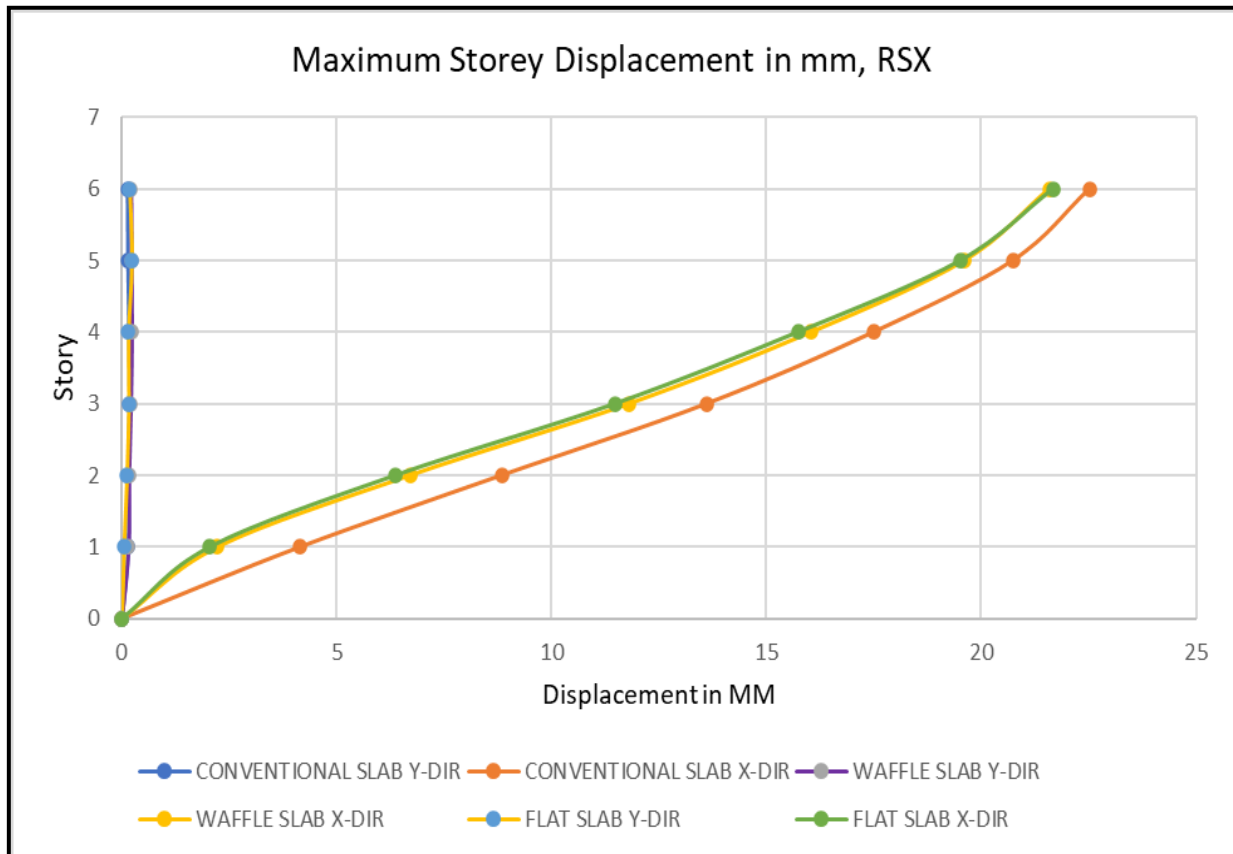
VI. RESULTS AND DISCUSSION

The structural analysis of the G+5 commercial building was carried out using the Response Spectrum Method in ETABS. This dynamic analysis approach evaluates how a structure behaves under seismic activity. It involves applying a standard response spectrum curve, derived from applicable seismic design codes, to determine key structural responses such as lateral displacements, base shear forces, and storey-level accelerations. This technique effectively captures the building's dynamic properties, including natural frequencies and modal contributions. It is particularly well-suited for mid-rise buildings like G+5 constructions, providing a more reliable assessment of seismic performance than traditional static analysis methods.

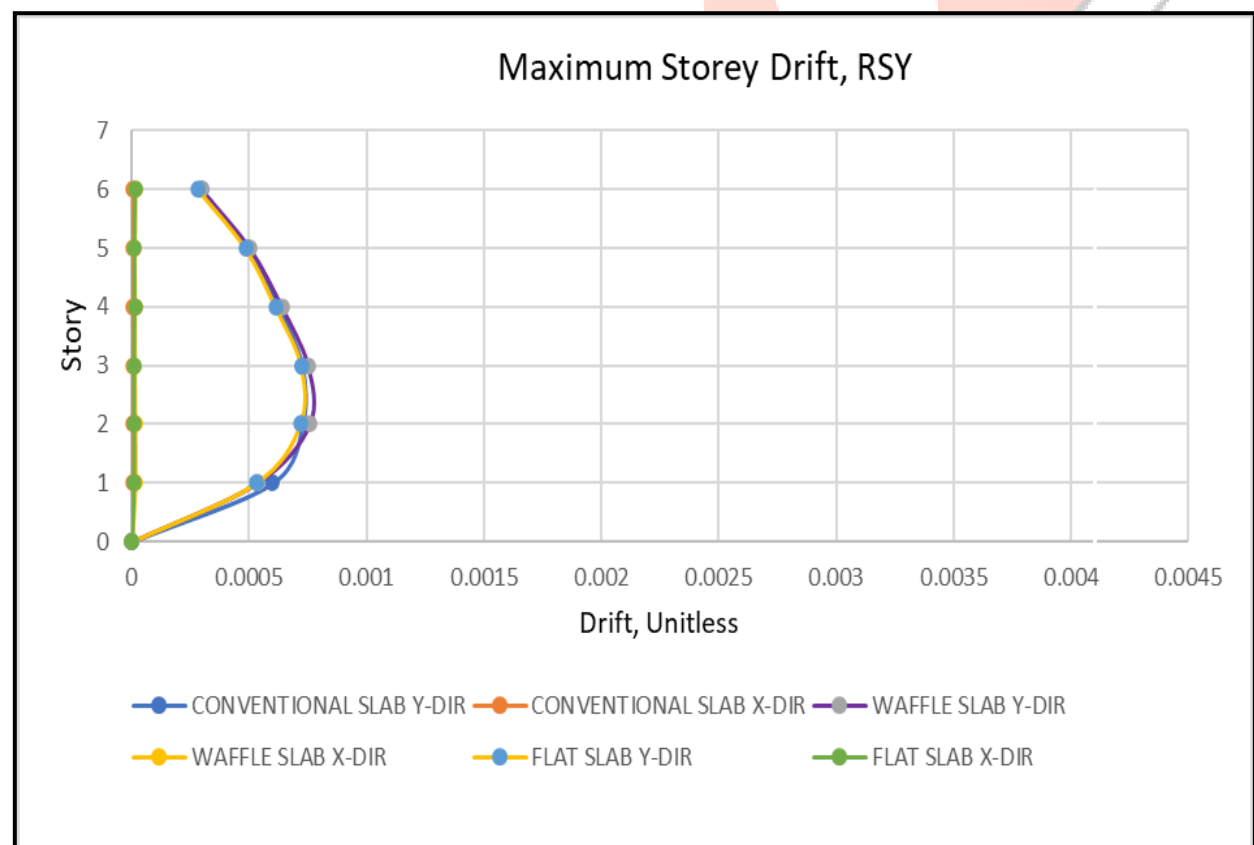
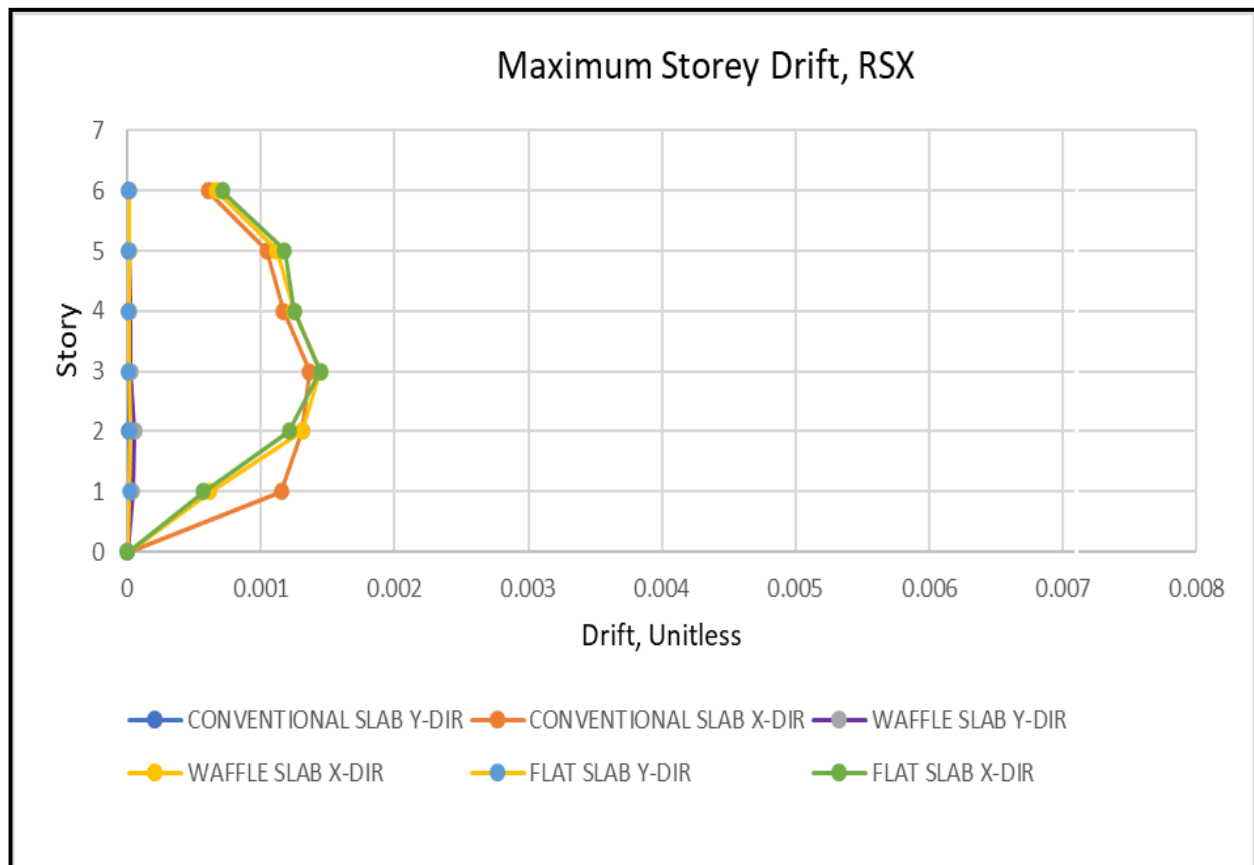
i. Comparison of Lateral Loads to Stories



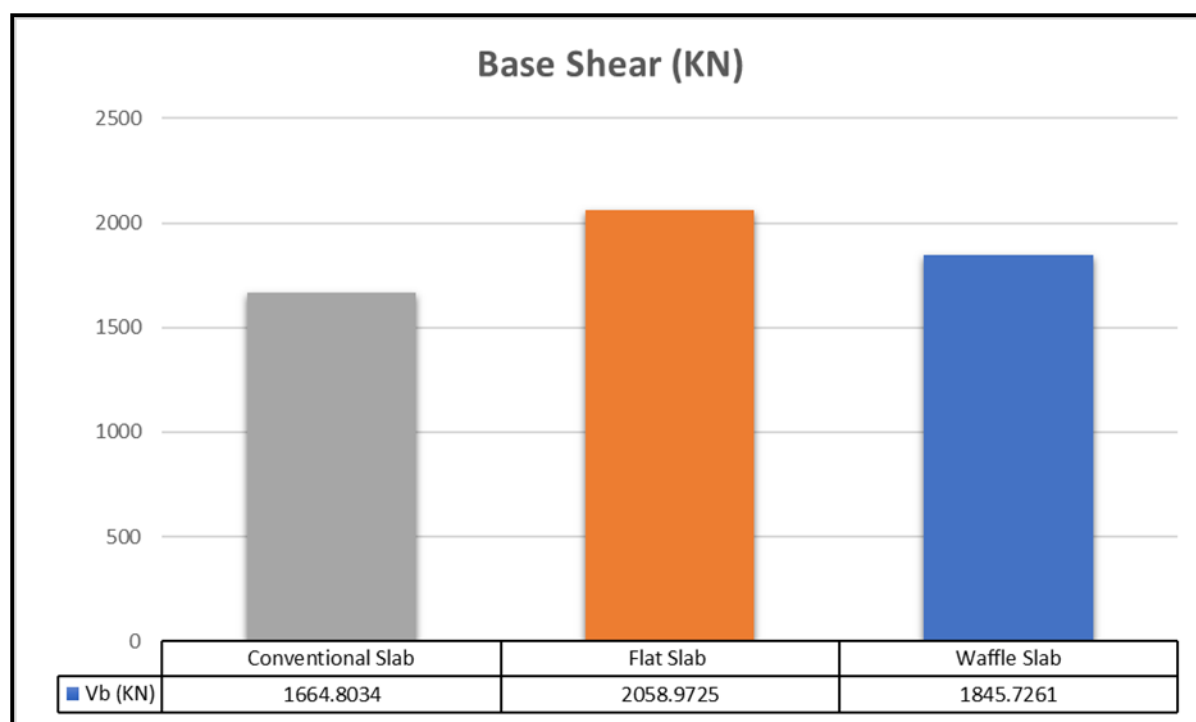
ii. Comparison of Maximum Storey Displacement



iii. Comparison of Storey Drift



iv. Comparison of Base Shear



VII. CONCLUSIONS

Flat slab systems are advantageous in terms of architectural versatility and simplified utility layout; however, they tend to attract greater seismic forces. Waffle slabs provide an effective compromise between structural flexibility and rigidity, making them particularly well-suited for earthquake-prone regions.

i. Storey displacement is observed to be maximum at the top floor and minimal at the ground level of the structure. As the height of the building increases, the displacement also rises accordingly.

ii. Flat slabs are typically designed with drop panels to effectively manage high shear forces and counteract negative bending moments.

iii. In the case of grid slabs and irregular building configurations, the storey drift values in both X and Y directions are generally lower for structures with grid slabs compared to those with flat slabs. From the perspective of lateral displacement, grid slab systems tend to perform better than flat slab systems.

v. ETABS proves to be a highly valuable software for structural analysis, offering rapid and precise output, making it efficient for evaluating complex building systems.

VIII. CONCLUSIONS

Although this study has drawn significant conclusions, several potential areas warrant further exploration:

i. **Advanced Seismic Analysis:** Incorporating nonlinear time history methods could offer more refined insights, especially for irregular or high-rise structures.

ii. **Experimental Studies:** Future research could involve scaled physical models and lab testing to corroborate the analytical findings.

iii. **Economic Evaluation:** A comprehensive comparison of material costs, labor requirements, and construction time would support more practical design decisions.

iv. Tensioned Slab Systems: Investigating pre-tensioned and post-tensioned versions of flat and waffle slabs may reveal additional structural and economic benefits.

v. Environmental Assessment: Comparing the ecological impact and carbon emissions of different slab systems can promote sustainable design.

vi. BIM Integration: Implementing Building Information Modelling could enhance accuracy in cost forecasting, construction planning, and project execution.

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