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Comparative Study of Flat Slabs and Waffle Slabs Structures Using E-Tabs on Different Earthquake Zones in India

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Abstract

This study looks at the seismic performance of flat slab and waffle slab structures in various earthquake zones in India, utilizing ETABS for structural analysis. Flat slabs are often used in modern construction due to their advantages in weight reduction, construction speed, and cost-effectiveness, whereas waffle slabs provide flexibility, rapid construction, good vibration control, fire resistance, increased load-carrying capacity, and safety. The study works on a G+6 commercial building, analyzing variables such as base shear, storey drift, axial force, and displacement to assess the structural behaviour, performance, and seismic resistance of both slab systems. The study seeks to provide a thorough understanding of the seismic problems and performance of flat and waffle slabs in India's various earthquake zones.

Introduction

Flat slabs and waffle slabs are two separate structural systems commonly used in building construction, each with its own set of benefits and qualities that cater to diverse architectural and engineering requirements.

Flat slabs

Flat slabs are defined by their uniform thickness and the absence of beams, which allows for greater architectural freedom and space management. Flat slabs are concrete slabs supported directly by columns, eliminating the need

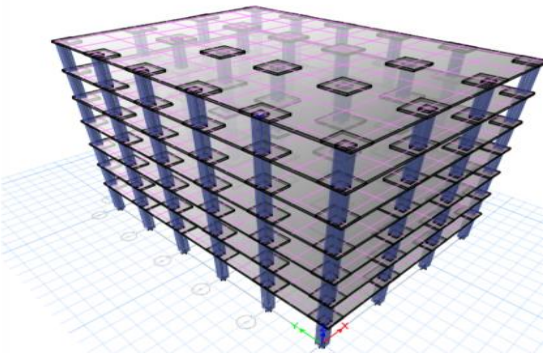

Fig:1-flat slab structure

for beams. This results in a flat ceiling, which is suitable for structures that require an unobstructed underside, allowing for more flexible space planning and easier mechanical and electrical service installation. The simplicity of flat slab construction also results in shorter building periods and lower costs due to less formwork and manpower. There are four types of flat slabs:

- Simple/Typical flat slab
- Flat slab containing drop panels

- Flat slab containing column heads
- Flat slab containing both drop panels and column heads

Fig:1-flat slab structure

WAFFLE SLABS

A waffle slab is a reinforced concrete flooring system with a ribbed grid structure that supports heavy loads while minimizing material use.

There are two types of waffle slab system:

- One way waffle slab system
- Two-way waffle slab system

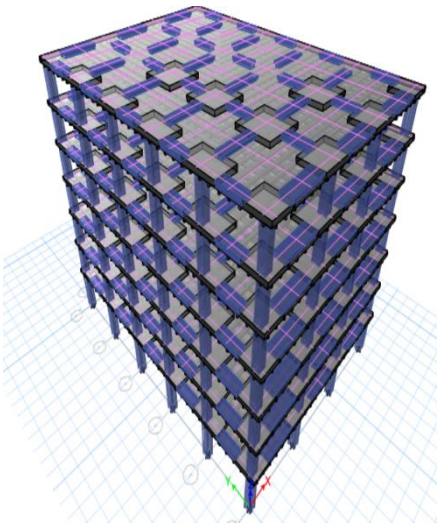

Fig:2 waffle slab structure

Literature Review

- **Maulin Patel, Abbas Jamani**: Flat slabs offer significant architectural flexibility and cost savings by reducing building height and simplifying construction. However, they have greater storey displacement and drift—20% and 23% more, respectively—than standard slabs, rendering them unsuitable for seismic zones. Conventional slabs, with their beam-supported architecture, are more resistant to lateral stresses, making them safer for residential and small-scale structures. Waffle slabs are great for large-scale buildings such as malls and auditoriums because of their material economy and visual appeal, but their seismic performance must also be carefully considered.
- **Abhijit K Sawwalakhe, Prabodh D Pachpor:** Flat slabs are appropriate for high-rise constructions because of their versatility, simplicity of construction, and cost savings from lower building height. Although they are heavier and subjected to higher bending moments and shear stresses than conventional and grid slabs, the benefits outweigh the downsides in bigger projects. Conventional slabs are excellent for residential and small-span constructions, whereas grid slabs are best for wider spans that require additional rigidity. Slab type should be chosen based on construction needs such as span, height, aesthetics, and cost.
- **Anurag kumar pandey ,Anjali rai** :when two structures with different slab arrangements were compared, it was found that the building with a grid slab had a safer seismic response in the higher zone factor area. Additionally, grid slabs are advised in situations where fewer columns are needed, as in this case, where there are fewer than two columns per storey.
- **Monika D. Pethe , Amey Khedikar:**The waffle slab design, while needing extra reinforcement at the top, may provide improved stiffness and less displacement in one direction (depending on the pattern), but may increase displacement in the perpendicular direction. Flat slabs, because to their greater flexibility, display larger modal displacements and storey drifts, particularly in the X direction, implying that they may be less suited for seismically active places unless reinforced or modified. Conventional slabs appear to offer balanced performance,

with mild displacements and drifts in both directions. Understanding these characteristics can aid in determining the best slab type for a project depending on its individual requirements, especially in areas prone to dynamic stresses such as earthquakes.

Objective

- To analyse G+6 flat slabs and waffle slabs across different zones.
- To compare how flat slab and waffle slab structures withstand earthquakes in different seismic zones in India.
- Explore how these two types of slabs transmit building loads, particularly during an earthquake.
- Compare the sway and movement of structures with flat and waffle slabs during an earthquake.
- Determine which slab type might bend or stretch without breaking during an earthquake.

Methodology

- Create a new model using E-tabs built-in options.
- Define concrete and steel materials.
- Define frame sections such as beams and columns.
- Define slab and drop panels.
- Define static load situations.
- Automatically generate the load combination.
- Assign the loads.
- Verify the model and do the analysis.
- Examine the distorted shape.

DETAILS OF MODEL:

Number of storeys	G+6
Grade of concrete	M30
Grade of reinforcement steel	HYSD Fe450
Dimensions of beam	900×600
Dimension of column	900×900
Slab thickness	200mm
Size of Drop panel	2m
Height of the bottom storey	4m
Height of the remaining storey	3m
Density of concrete	25KN/m
Live load	5KN/M
Floor load	1.5KN/m
Seismic zones	Zone 2,3,4,5
Importance factor	1.5
Response reduction factor	5
Site type	II

Result

Axial force:

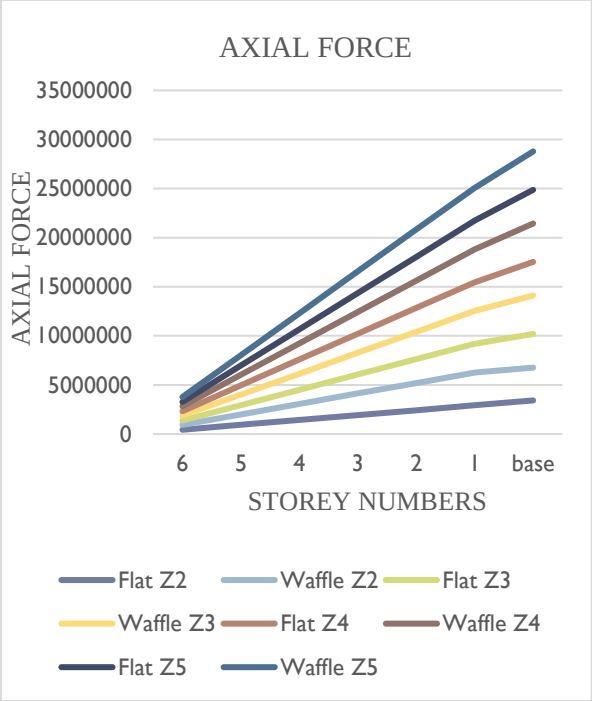

Fig:3 Axial force of the structure

As the storey level rises from the foundation to the sixth floor, the axial forces normally decrease. This pattern is similar for both flat and waffle slabs throughout all zones (Z2 through Z5). Waffle slabs have larger axial force values than flat slabs at each storey level. This shows that waffle slabs may bear greater weight or have different structural qualities.

DISPLACEMENTS:(X-DIRECTION)

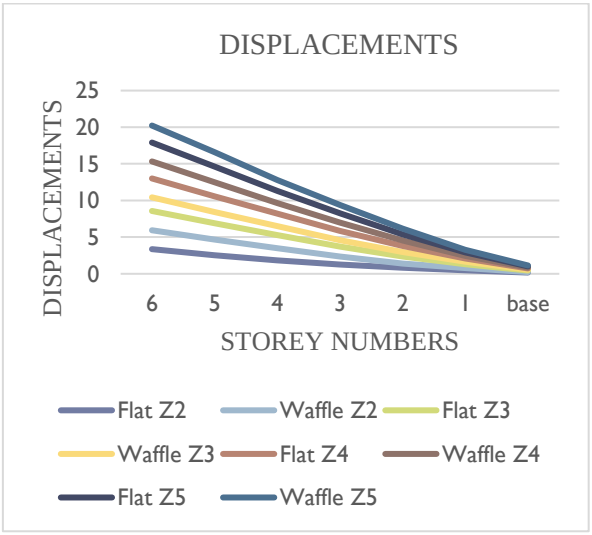

Fig:4 Displacements in X-Direction

AT Y-DIRECTION:

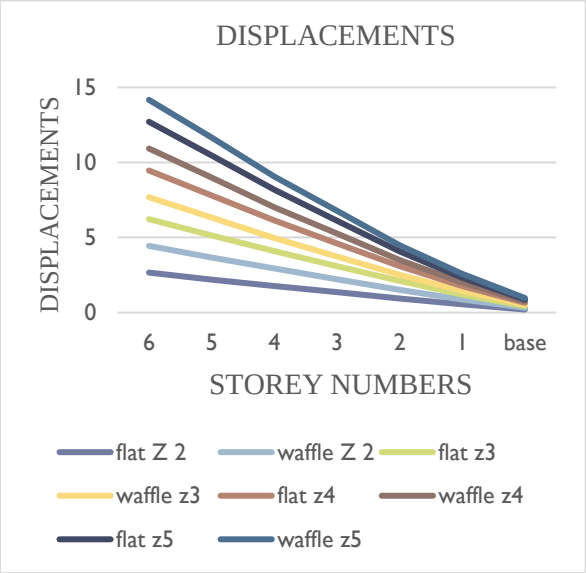

Fig:5 Displacements in Y-Direction

Displacement values decrease as you descend from the sixth storey to the base. This pattern holds true for both flat and waffle slabs throughout all zones in both directions. Waffle slabs have larger displacement values than flat slabs at the same stories and zones, which might suggest more flexibility or different structural behavior under load.

STOREY DRIFT:(X-DIRECTION)

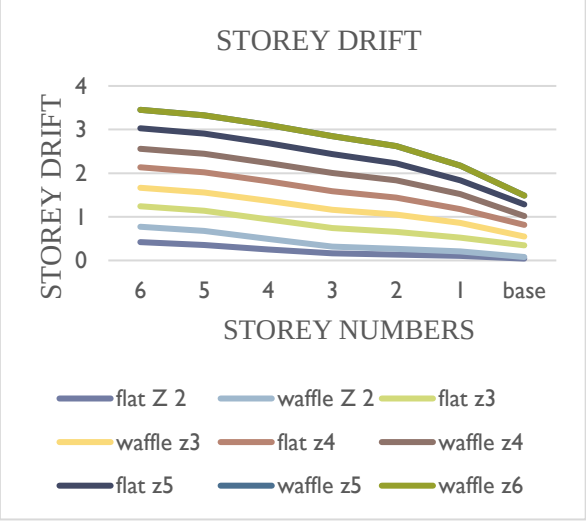

Fig:6 Storey drift in X-Direction

AT Y-DIRECTION

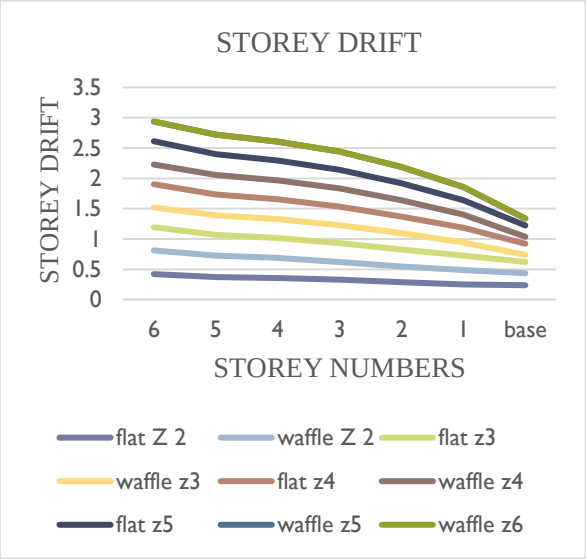

Fig:7 Storey drift in Y-Direction

The storey drift increases with building height and is smaller in waffle slabs than in flat slabs, indicating improved rigidity and performance. Waffle slabs are better at limiting lateral movement, making them ideal for high-seismic or windy settings. Differences across zones indicate that structural changes might further enhance stability.

BASE SHEAR:

AT X-DIRECTION:

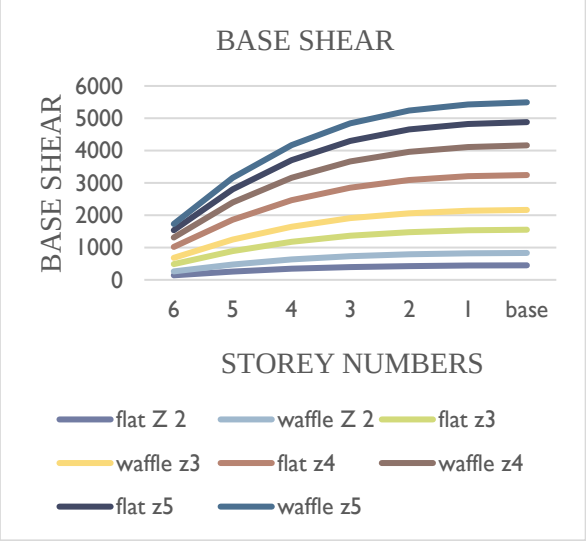

Fig:8 Base shear in X-Direction

AT Y-DIRECTION

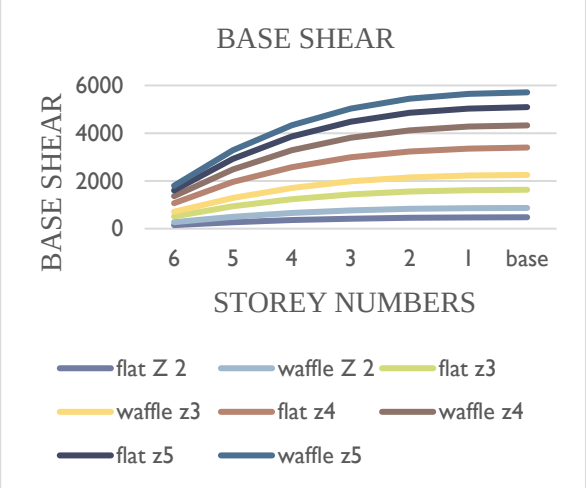

Fig:9 Base shear in Y-Direction

The base shear, which represents lateral stresses from seismic loads, rises from the top to the bottom of a structure. Waffle slabs have lower base shear values than flat slabs, indicating better load distribution and rigidity. Higher base shear values in zones Z3–Z5 indicate increased lateral resistance owing to stiffness. This data demonstrates the usefulness of waffle slabs and adjusted zoning in increasing structural stability.

Conclusion

The study concluded Waffle slabs are usually more structurally stable than flat slabs, with reduced storey drift and base shear, which means they can withstand lateral stresses like as seismic and wind loads better. This performance varies by zone, implying that adjusting design and material stiffness can enhance a structure's response to these stresses. Thus, employing waffle slabs and properly planning for distinct zones is critical for improving building safety and resilience.

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