Behaviour of Building with Flat Slab and Flat Slab with Drop Building With Re-Entrant Corners

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Abstract - *A flat slab is a reinforced concrete slab which is directly rested on Columns without any beams, offering flexibility in design. It provides a spacious interior without obstruction from beams, making it ideal for large open spaces. On the other hand, a flat slab with drops incorporates thicker areas, or drops, around the columns to enhance structural strength and distribute loads more efficiently. The primary objective of this investigation is to learn the valuable insights into the structural behaviour of two different flat slab types. This research endeavours to investigate the seismic performance of a multi-story residential building situated in seismic zone III having the re-entrant corners with U-shaped plan regularity, using response spectrum analysis in accordance with IS-1893:2016 standards. The study explores flat slab, and flat slab with drop. Parameters of interest include Story displacement, time period, base shear, and punching shear.*

Keywords: *Flat Slab, Flat Slab with Drop, Re-entrant corners, Story Displacement, Time Period, Punching Shear.*

1.INTRODUCTION

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1.1 Flat Slab

The current study involves the examination of a framed structure, a five-story flat slab and flat slab with drop building (G+5). For the investigation, dynamic seismic analysis, it is considered that the building is located in Mumbai with Seismic zone III and the frames are fixed within a medium soil context.

Aesthetics, functionality, and structural efficiency. These slabs also provide excellent lighting conditions, as they allow natural light to pass through, contributing to a well-lit and airy interior. Their design provides a clean and open interior space while ensuring that the building is stable and safe.

However, punching shear in flat slabs is a structural issue related to the transfer of shear forces at the edges of supporting columns. To prevent the columns from puncturing through flat slabs, structural engineers employ drop panels. These are also known as column capitals or drop caps. Drop panels involve thickening the slab directly around the column. By adding extra thickness to the slab in the immediate vicinity of the column, drop panels effectively disperse the loads from the column over a larger area of the slab.

1.2 Re-entrant Corners

Re-entrant corner irregularity exists when dimensions of projections in both of the two perpendicular directions in a building's floor plan exceed the total plan dimensions of that story of the building in the respective directions by more than 15%. This definition is crucial in the context of seismic design, as it helps identify buildings with irregular configurations that may have different seismic behavior and load distribution patterns. Buildings with re-entrant corner irregularities require additional structural analysis and reinforcement to ensure their safety under seismic forces, as specified by IS 1893:2016 and relevant building codes.

2. OBJECTIVES

1) Conduct a comparative analysis of residential buildings with Flat Slab and Flat Slab with Drop Panels under same loads and load combinations.
2) Assess and compare the structural performance of buildings located in seismic zone III with medium soil conditions using Response Spectrum Analysis.
3) Evaluate the results obtained from the analysis of Flat Slabs and Flat Slabs with Drop Panels with respect to respective parameters mentioned below.

    a) Storey-Displacement

b) Punching Shear
c) Time Period

3. MATERIALS AND METHODS

The current study involves the examination of a framed structure, a five-story flat slab and flat slab with drop building (G+5). For the investigation, dynamic seismic analysis, it is considered that the building is located in Mumbai with Seismic zone III and the frames are fixed within a medium soil context

Table -1: Material Properties

Grade of Concrete	M30
Grade of Steel	Fe500
Density of Reinforced Concrete	25 (in kN/m^3)
Density of Brick	20 (in kN/m^3)

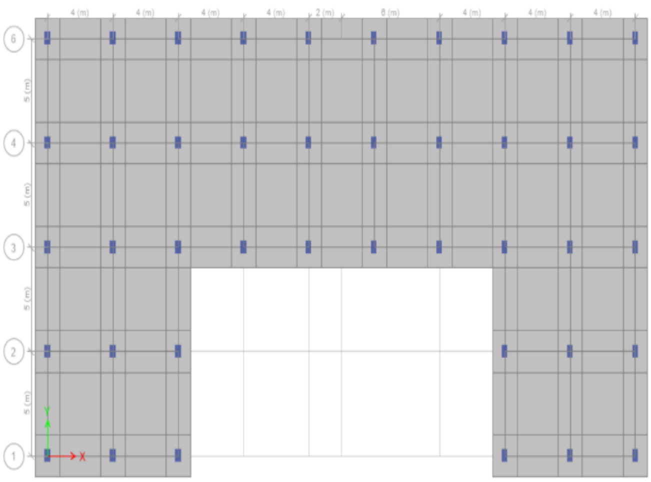

Fig -1: Plan View of Flat Slab with drop Building

Table -2: Building Parameter

Building Type	Framed Structure (G+5 Stories)
Story Height	3 meters
Column Size	350x600mm
Slab Thickness	150mm

Table 3: Description of Models

Models	Description
1	Flat Slab
2	Flat Slab with Drop

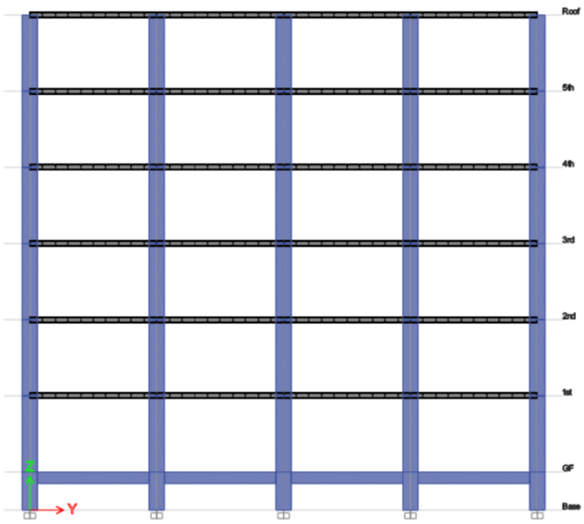

Fig -2: Elevation of Flat Slab Building

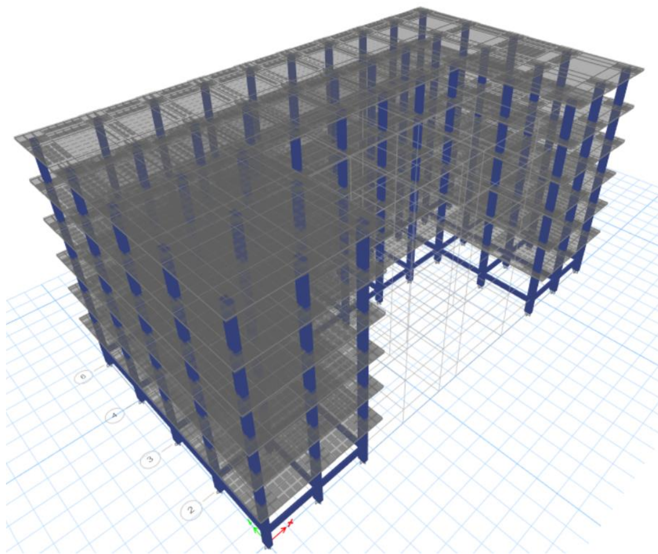

Fig -3: 3d-View of Flat Slab with Drop Building

Table 4: Seismic Parameters

Seismic Zone	III
Zone Factor	0.16
Importance Factor	1
Response Reduction	5
Soil Type	Medium Soil (Type II)
Time Period (X)	0.2925 sec
Time Period (Y)	0.3294 sec
Damping Ratio	5%
Eccentricity	5%

4. RESULTS AND DISCUSSION

The following results were obtained from ETABS software using the Response spectrum analysis of models as stated in the problem statement above. The parameters like Storey Displacement, Base Shear, Time Period, and Punching Shear were Computed for further Conclusions.

4.1 Storey Displacement

Storey displacement refers to the horizontal movement or deflection of a building's storey during an earthquake or other lateral forces. It's a critical aspect in structural design to ensure the safety and stability of a building.

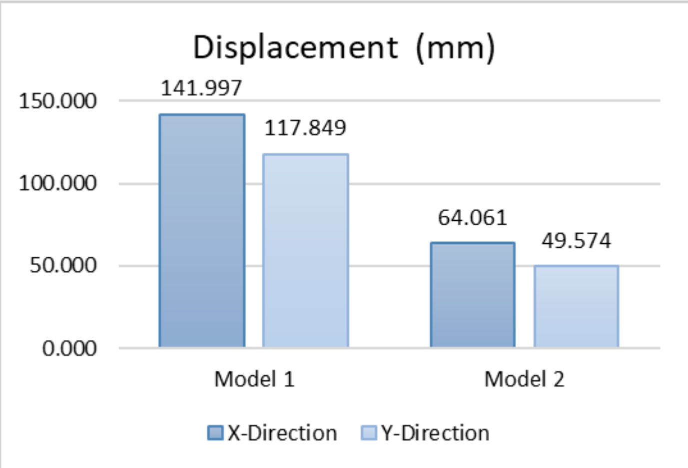

Chart -1: Storey Displacement

In comparing building models for structural performance, certain observations emerged. When Flat Slab Building (Model 1) was compared with the Flat Slab with Drop Building (Model 2), a notable decrease of 54.88% was observed.

4.2 Base Shear

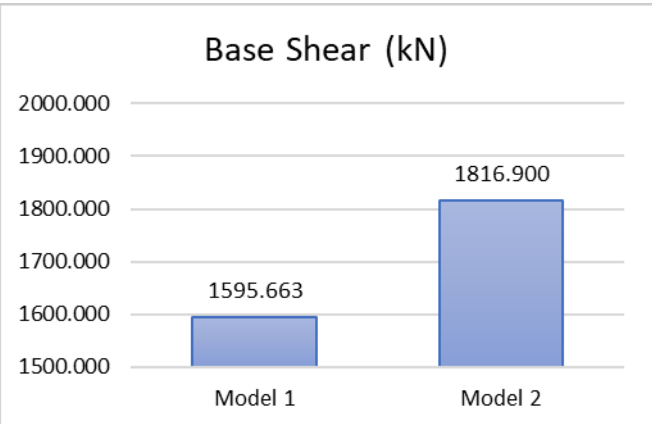

Chart -2: Base Shear

It represents the maximum horizontal force that a building's foundation must withstand during an earthquake. The magnitude of this force depends on factors such as the structure's weight, height, and the seismic conditions of the region. Codes and standards, like IS 1893:2016 in India, provide guidelines for calculating base shear.

The Flat Slab with Drop Building (Model 2) experienced a notable increase of 13.86% in displacement compared to the Flat Slab Building (Model 1).

4.3 Time Period

Time period is a fundamental concept that relates to how quickly a building or structure sways back and forth after being subjected to a force, like an earthquake. Engineers use the time period to assess a building's natural frequency of vibration, which is crucial for ensuring that it doesn't resonate or oscillate excessively when faced with external forces.

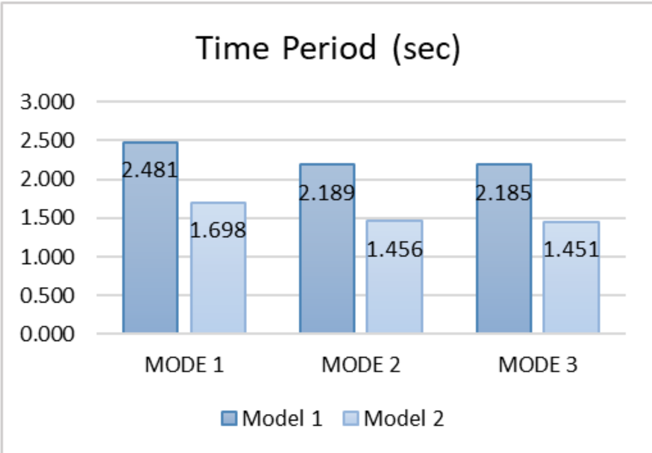

Chart -3: Time Period

4.4 Punching Shear

Punching shear refers to the downward force or stress that occurs around the columns, specifically at the slab-column connections. The Punching shear is calculated manually by referring the IS 456:2000. Here are the results obtained for flat slab and flat slab with drop buildings respectively.

4.4.1 Calculations For Flab Building

Total Factored load (V_u)= 450 kN

Nominal shear stress(τ_v) = V_u / bd = 1.675 N/mm^2

Shear strength of concrete = k_s τ_c = 1.36 N/mm^2

Therefore, $\tau_v > \tau_c$ which states that the nominal shear stress exceeds the shear strength of concrete Hence, the slab is unsafe in punching shear.

Table 5: Punching Shear (Flat Slab Building)

Load Calculation (Flat Slab)	
Description	Calculation
Load from Slab	
Self wt. of Slab	3.75 kN/m2
Floor Finish + Live Load	5 kN/m2
Total Load (kN)	175 kN
Load due to Brick walls	
Area of Wall	0.69 m2
Wall load	13.8 kN/m
Total Load (kN)	124.2 kN
Total Axial Load	299.2 kN
Total Factored Load (Vu)	
Factor of safety	1.5
Factored Load	448.6 kN

4.4.1 Calculations For Flab with Drop Building

Total Factored load (V_u)= 500 kN

Nominal shear stress(τ_v) = V_u / bd = 0.39 N/mm^2

Shear strength of concrete = k_s τ_c = 1.36 N/mm^2

Therefore, $\tau_v < \tau_c$ which states that the nominal shear stress is smaller than the shear strength of concrete Hence, the slab is safe in punching shear.

Table 6: Punching Shear (Flat Slab with Drop Building)

Load Calculation (Flat Slab with Drop)	
Description	Calculation
Load from Slab	
Self wt. of Slab	5 kN/m2
Floor Finish + Live Load	5 kN/m2
Total Load (kN)	200 kN
Load due to Brick walls	
Area of Wall	0.69 m2
Wall load	13.8 kN/m
Total Load (kN)	124.2 kN
Total Axial Load	324.2 kN
Total Factored Load (Vu)	
Factor of safety	1.5
Factored Load	486.3 kN

5. CONCLUSIONS

The findings derived from the aforementioned study can be summarized as follows:

1) The flat slab building with drop panels demonstrated significant improvements in displacement. It exhibited a 54.88% reduction in storey displacement compared to the Flat slab building.

2) The addition of a drop in the flat slab building led to a higher overall weight, resulting in a significant rise in the base shear. The Flat Slab with Drop Building (Model 2) displayed an increase of 13.86% in displacement compared to the Flat Slab Building (Model 1).

3) The flat slab building took more time to complete one oscillation compared to the flat slab building with a drop. The results shows that the addition of the drop leads to the decrease of 31.55% compared to Flat Slab building.

4) The Flat slab building showed a punching shear ratio of 1.23 which exceeds the permissible ratio of 1 whereas after the addition of drop panel punching shear ratio for flat slab with drop was reduced to 0.3.

In summary, the structural analysis of Flat Slab and Flat Slab with Drop Building has demonstrated that the Flat Slab with Drop building displayed improved results as compared to Flat Slab building in terms of Storey Displacement, Time period, and Punching Shear. Whereas the increased weight of the Flat slab with drop building leads to attracting more base shear compared to flat slab building.

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