



# Analysis Of Multi Storey Building With Different Slabs Having Vertical Geometric Irregularity

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**Abstract:** The distribution of stiffness, strength, and mass in both the horizontal and vertical directions determine how well a high-rise building performs during powerful earthquakes. If there is discontinuity in stiffness, strength and mass between adjoining stories of a building then such a building is known as irregular building. It is an attempt to investigate the effect of vertical geometry irregularity configuration for multi-storeyed reinforced concrete building model. The primary focus of this study is the examination of a multi-storey structures (Vertical Geometrical Irregularity Type I Building Consists of G+14 and Vertical Geometrical Irregularity Type II Building Consists of G +20) that has irregularity in elevation. Modelling of 14 storey and 21 storey RCC framed building is done in ETABS 21 ultimate software for analysis with different slabs (conventional slab, flat slab with drop panels and waffle slab). The analysis is done as per IS 456:2000 code and for seismic analysis IS 1893(Part 1): 2016 code. M30 grade of concrete and FE-550 grade of steel is adopted. There are several concerns that affect the performance of structure from which storey displacement, storey drift and Base Shear play a crucial role in findings the behaviour of structure against seismic loads. Results are conveyed in the form of tables and charts. All the models are analysed with response spectrum method for analysis. After analysis, the paper concluded that waffle slab buildings can be more effectively used for multi storey buildings. The use of waffle slab increased the stiffness, increased the weight carrying ability, as well as being safe. The use of flat slab buildings having vertical geometry irregularity in all seismic Zones are unstable and uneconomical because of less moment capacity of slab for Vertical Geometrical Irregularity Type II Building. Conventional slab buildings have moderate stiffness can be used for high rise structures and is stable and economical.

**Index Terms – ETABS, Conventional Slab, Flat Slab, Waffle Slab, Response Spectrum Method.**

## I. INTRODUCTION

Earthquake is the most destructive natural calamity. Engineers attempt to create earthquake-resistant structures since it is difficult to design earthquake-proof structures. Determining the lateral forces is crucial for analyzing earthquake-resistant structures. In accordance with IS:1893(Part 1): 2016, seismic analysis is performed using the dynamic analysis approach. Any discontinuity or irregularity in a building is the first sign of its breakdown or weakness. This discontinuity might occur in the building or structure's stiffness, geometry, or mass teams. Vertical irregularities are one of the main causes of structural failures. These structures differ from "regular" buildings in terms of their dynamic properties due to variations in stiffness and mass with height. Structural configurations that deviate from uniformity or symmetry are called as irregular building. These variations can impact how a building behaves under different loading scenarios, particularly during earthquakes. These irregularities are classified according to various aspects of the geometry, mass distribution, stiffness, or dynamic response properties of the building.

### 1.1 Vertical Geometry Irregularity

A vertical Irregular structure has one or more significant discontinuities in its configuration. Vertical geometric irregularity shall be considered to exist, when the horizontal dimensions of the lateral resisting system in any storey is more than 125 percent of the Storey below.

## 1.2 Different Types of Slabs

The slab that is resting on Beams and columns is called a conventional slab. The thickness of the slab is small whereas the depth of the beam is large and load is transferred to beams and then to columns. It requires more formwork when compared with the flat slab. The slab that is directly resting on columns is called as flat slab. Because flat slab has no longer any beams, it also known as a beam less slab. Loads are directly transferred to columns. Waffle slabs are reinforced concrete floors or roofs with deep-sided grid patterns. For an attractive view, this type of slab is typically utilized at the entrance of hotels, malls, and restaurants. When wide spans are needed (like in auditoriums and movie theatre's), it is typically utilized to prevent several columns from obstructing the available area.

## 2. METHODOLOGY AND MODELLING.

Models of Conventional slab, Flat slab with drop panels and waffle slab building are created in ETABS software for two types of Vertical irregularity buildings. Response spectrum analysis was considered for analysis in ETABS software. Lateral stability of conventional slab, flat slab with drop panels and waffle slab is assessed for lateral displacement and storey drift for all seismic Zones as per IS1893(Part 1):2016. Lateral stability of conventional slab, flat slab with drop panels and waffle slab are compared to know the suitability of structures in different seismic Zones. Review of different slab results compare with different slab arrangements in a graph and tables.

Analysis of Three-dimensional models of Vertical geometry irregularities building located in all four Zones (II, III, IV, V) has been performed in ETABS software. Response spectrum analysis is performed in all Zones of buildings. Material properties and Sectional Properties are assigned in all the models and Fixed supports at the Base. The plans are analyzed for conventional slab, flat slab and waffle slab.

### 2.1 Description of Models

This study involves six structural models to analyze the performance of different slab systems in geometrically irregular buildings. Models 1, 2, and 3 represent a Geometry Irregularity Type I building, with slab arrangements including a conventional slab, a flat slab with drop panels, and a waffle slab, respectively. Models 4, 5, and 6 correspond to a Geometry Irregularity Type II building with slab arrangements including a conventional slab, a flat slab with drop panels, and a waffle slab, respectively. For all these Models (Model 1 to Model 6) are analyzed for all seismic Zones (II, III, IV, V) as per IS 1893(Part 1):2016.

Models 1,2 and 3 of Geometry Irregularity Type I Building having a plan area of 64m X 36m and 8 No's of bays with spacing of 8m in X direction and 6 No's of bays with of 6m in Y direction are considered from plinth level to first floor. After first floor, plan area is reduced by 32m X 36m up to terrace level as shown in Fig 1. The typical floor height is considered as 3m and ground floor height as 3m from the plinth beam level. Total height of building for Type I Models is 42m. Geometric properties and material properties are shown in the Table 1. Models 4,5,6 of G+20 building with plan area of 54m X 54m and 9 No's of bays with spacing of 6m in x direction and 9 No's of bays with a spacing of 6m in y direction are considered. The typical floor height is considered as 3m and ground floor height as 3m from the plinth beam level. Total height of building Type II Models is 60m. Seismic Parameters of Building are considered for all Models are shown in the Table 3. Geometric properties and material properties of Two Vertical Geometric Irregularity Buildings are shown in the Table 1 and Table 2 Respectively.

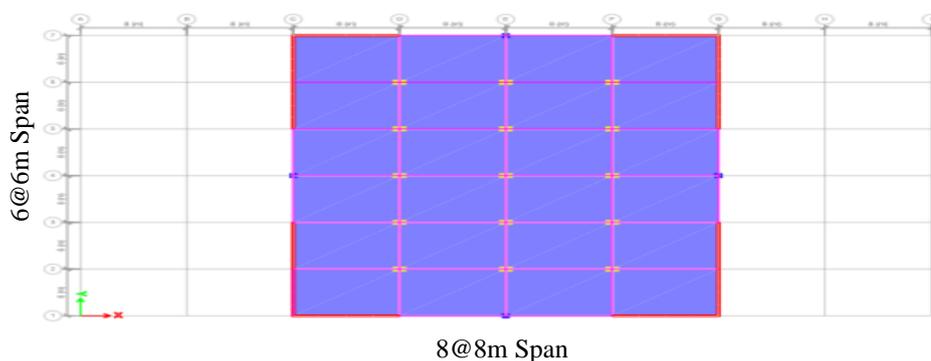
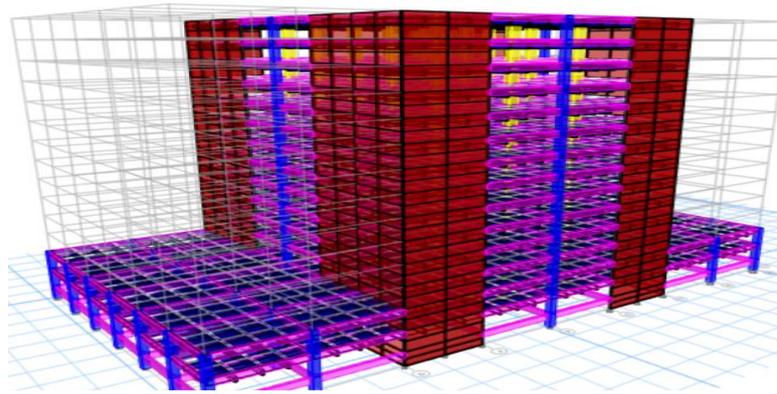


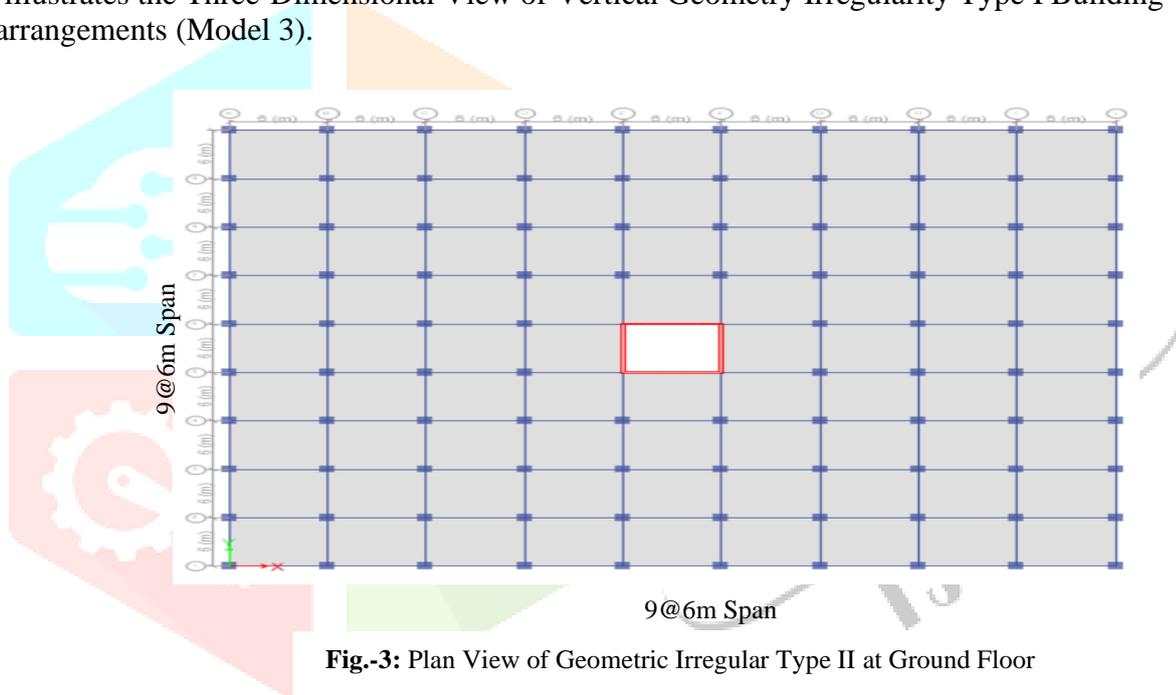
Fig.-1: Plan View of Geometry Irregularity Type I Building

Fig 1 illustrates the floor plan view of the typical floors above the first floor. The red colour highlights the locations of the shear walls in the building models of Geometry Irregularity Type I Buildings.



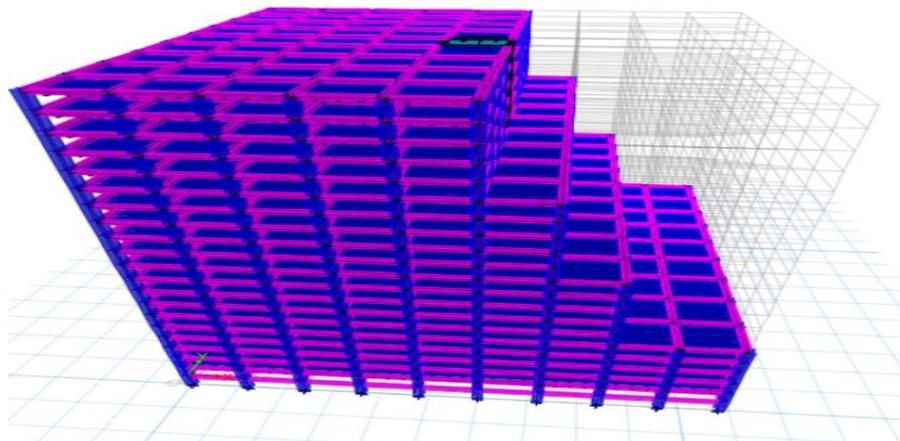
**Fig-2:** Three-Dimensional View of Geometry Irregularity Type I Building

Fig 2 illustrates the Three-Dimensional View of Vertical Geometry Irregularity Type I Building with Waffle Slab arrangements (Model 3).



**Fig.-3:** Plan View of Geometric Irregular Type II at Ground Floor

Fig 3 illustrates the floor plan view of the Vertical Geometric Irregularity Type II Building at Ground Floor with conventional Slab Arrangement (Model 4). The red colour highlights the locations of the shear walls in the Building Mod



**Fig.-4:** Three-Dimensional View Geometry Irregularity Type II Building

Fig 4 illustrates the Three-Dimensional View of Vertical Geometry Irregularity Type II Building with Waffle Slab arrangements (Model 6).

Fig-1,2,3,4 represents the models which are considered for the analysis and the results of the following models as shown in Tables and Graph.

**TABLE: 1 Geometric Properties and Material Properties for Model 1,2,3 Of Geometry Irregularity Type I Building.**

Column to Column spacing in x direction	8m
Column to Column spacing in y direction	6m
No. of bays in x direction	8 No's
No. of bays in y direction	6 No's
Floor height	3m
Ground floor height	3m
Flat slab thickness	200mm
Conventional slab thickness	150mm
Waffle slab thickness	150mm
Drop thickness	250mm
Shear wall thickness	200mm
Drop size	3m X 3m
Column sizes	C1: 600mm X 600mm
	C2: 1000mm X 600mm
Beam sizes	B: 300mm X 600mm
Grade of concrete and steel	M30 and FE 550

**TABLE: 2 Geometric Properties and Material Properties for Model 1,2,3 Of Geometry Irregularity Type II Building.**

Column to Column spacing in x direction	6m
Column to Column spacing in y direction	6m
No. of bays in x direction	9 No's
No. of bays in y direction	9 No's
Floor height	3m
Ground floor height	3m
Flat slab thickness	200mm
Conventional slab thickness	150mm
Waffle slab thickness	150mm
Drop thickness	250mm
Shear wall thickness	200mm
Drop size	3m X 3m
Column	C:900mm X 900mm
Beam sizes	B: 300mm X 600mm
Grade of concrete	M30
Grade of steel	FE 550

**Table -3: Seismic Parameters of Building are considered for all Models**

Type of Structure	SMRF
Damping Ratio	5%
Zone Factor	0.10,0.16,0.24,0.36
Importance Factor	1
Type of Soil	Type II (Medium Soil)
Reduction Factor	5

## 2.2 Loads Considered

Basic parameters of loads are affecting the design of structure. Dead load is calculated based on materials used in the structure as per IS 875(Part 3):2015. Live load is estimated based on occupancy of building as per IS 875(Part 2):2015. The seismic forces are computed as per IS 1893(Part 1):2016.

Loads considered during analysis of Multi Storey buildings:

1. Floor finish:  $1 \text{ kN/m}^2$  as per IS 875(Part 1):2015
2. Dead load (self-weight of building): automatically computed by ETABS software.
3. Live load on building:  $4 \text{ kN/m}^2$  as per IS 875(Part 2):2015.
4. Seismic load: The structural frame is considered as Special Moment Resisting Frame(SMRF) and Damping ratio of structure is 5%. Soil Type as Type II (Medium soil).

## 3. RESULTS AND DISCUSSIONS

### 3.1 Storey Displacement

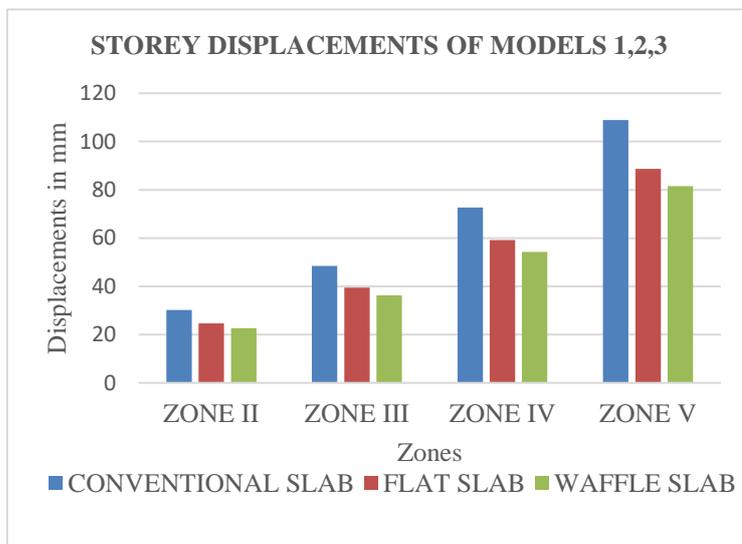


Fig.-5. Comparison of Storey Displacements for Vertical Geometrical Irregularity Type I Building.

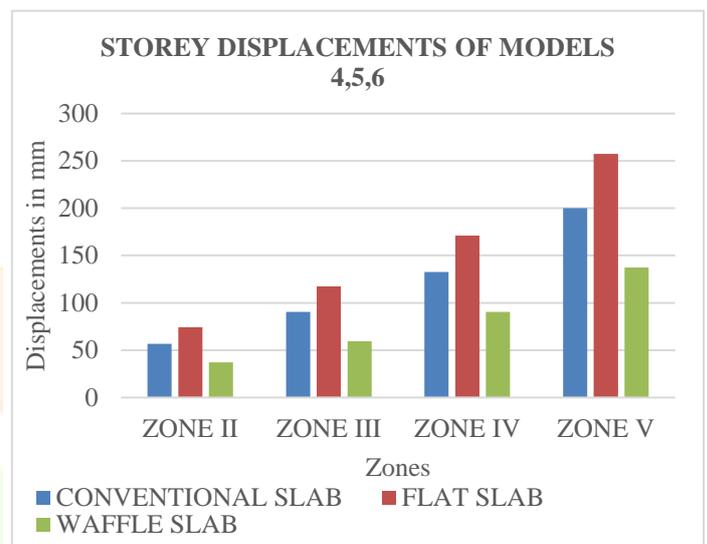


Fig.-6. Comparison of Storey Displacements for Vertical Geometrical Irregularity Type II Building.

Fig 5,6 shows the Comparison of Storey Displacements for Vertical Geometrical Irregularity Type I and Type II Buildings. Maximum Lateral displacements of the buildings as per codal provision from IS 1893(Part 1):2016 should be  $H/250$ . In this paper the total height of building for Model 1 to Model 3 is 42m. The lateral displacement results of Vertical Irregularity Type I Building with conventional slab, flat slab with drop panels, and waffle slab buildings are within the limit (168mm) for Zone II, Zone III, Zone IV, and Zone V are shown in the Fig 5. From the Fig 5, Displacements increase significantly as the seismic Zone increases, with a consistent rise of about 60% from Zone II to III and 50% for subsequent Zones. The Conventional Slab displays the highest displacement, followed by the Flat Slab, and then the Waffle Slab. The percentage difference remains consistent across all Zones, with Conventional Slab about 33.8% higher than Waffle Slab. From the Fig 6, the lateral displacement results of Vertical Irregularity Type II Building with conventional slab, flat slab with drop panels, and waffle slab buildings are within the limit (240mm) for Zone II, Zone III, and Zone IV. Flat slab buildings with drop panels are exceeding the limit in the Zone V. As Zone factor increases, storey displacements also increase. In this paper the total height of building for Model 4 to Model 6 is 60m. Maximum allowable displacements in the structure is 240mm. From the Fig 6, In Zone II, Flat Slab displacements are 24% higher than Conventional Slabs. Waffle Slabs perform significantly better, with displacements 52% lower than Conventional Slabs in Zone II and 45% to 52% lower across all Zones.

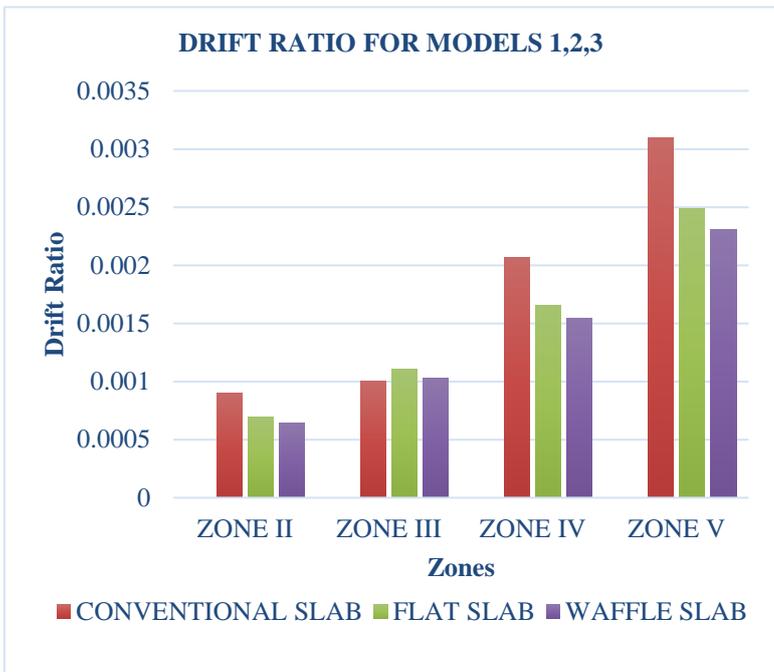


Fig.-7. Comparison of Drift Ratio for Vertical Geometrical Irregularity Type I Building.

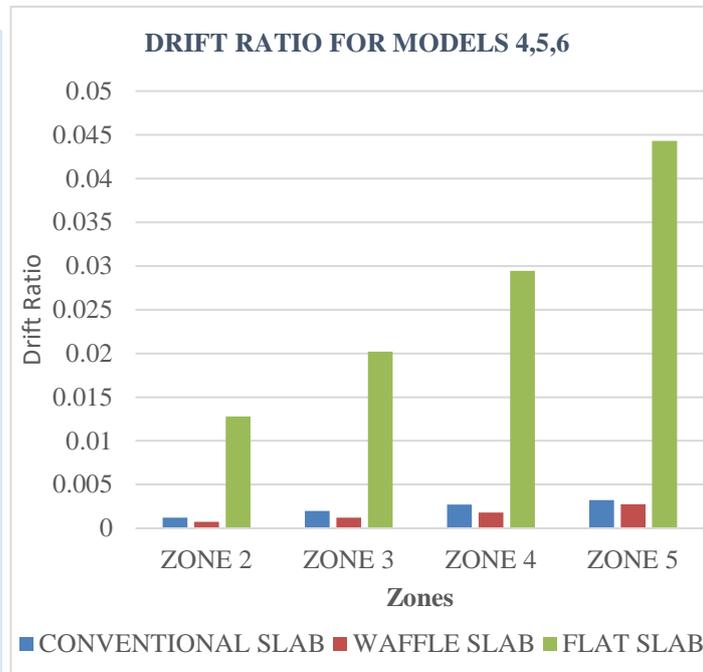


Fig.-8. Comparison of Drift Ratio for Vertical Geometrical Irregularity Type II Building.

Fig 7,8 shows the Comparison of Drift Ratio for Vertical Geometrical Irregularity Type I and Type II Buildings. The Drift Ratio results of Vertical Geometry Irregularity Type I Building with conventional slab, flat slab with drop panels, and waffle slab buildings are within the limit (0.004) for Zone II, Zone III, Zone IV, and Zone V. Drift ratios increase sharply with seismic intensity across all slab types. Drift Ratio is maximum for conventional slabs buildings for all zones. And Drift Ratio is least for waffle slabs buildings. In Zone V, conventional slab is showing higher storey drift as compared to Flat slab and Waffle Slab Arrangements.

Fig 8 shows the Storey Drift of Conventional Slab Buildings, Flat Slab Buildings with drop panels and Waffle Slab Buildings of Vertical Irregularity Type II Building are evaluated with Response spectrum analysis for all seismic Zones (II, III, IV, V) as per IS 1893(Part 1):2016 code. Flat slab buildings in all seismic Zones are experiencing maximum Drift Ratio as compared conventional slab and waffle slab buildings. The storey drift results of Vertical Irregularity Type II Building with conventional slab and waffle slab buildings are within the limit (0.004) for Zone II, Zone III, Zone IV, and Zone V. whereas flat slab buildings are not in the limit

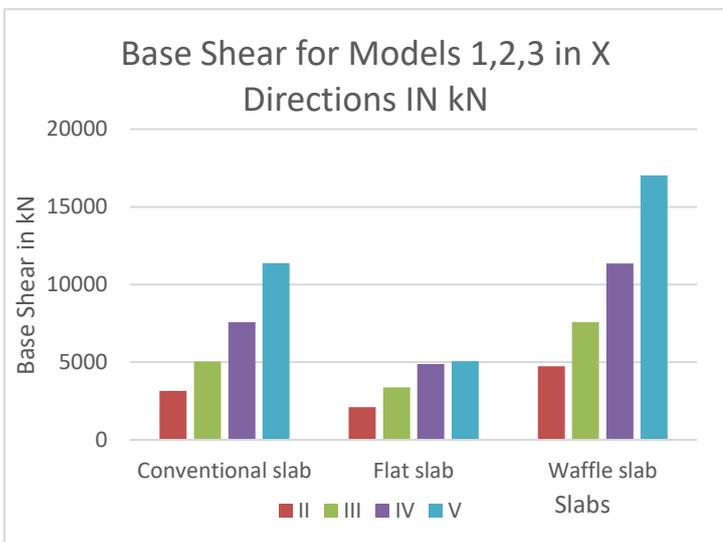


Fig.-9. Base Shear of Vertical Geometrical Irregularity Type I Building in X direction in kN.

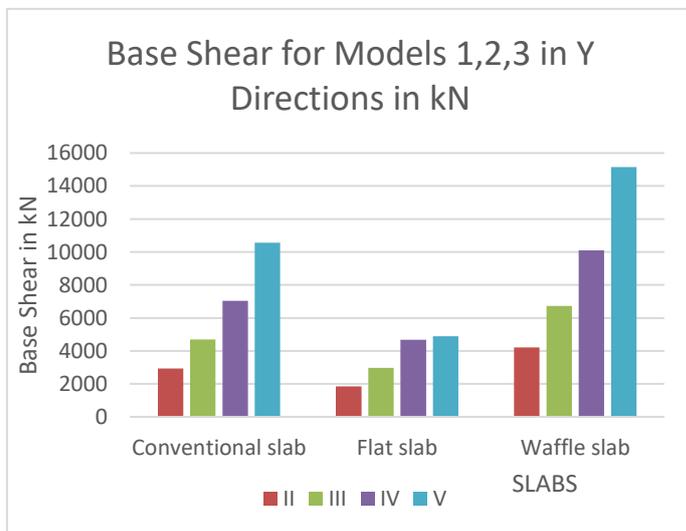
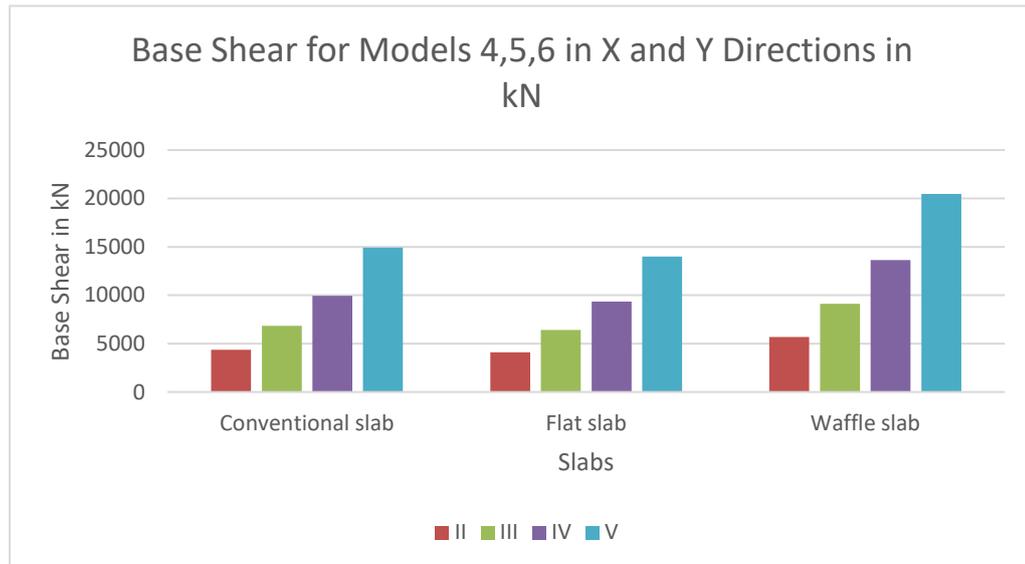


Fig.-10. Base Shear of Vertical Geometrical Irregularity Type I Building in Y direction in kN.

(0.004) for all Zones. Storey Drift is maximum for flat slabs buildings for all Zones. And storey drift is least for waffle slabs buildings.



**Fig.-11.** Base Shear of Vertical Geometrical Irregularity Type II Building in X&Y direction in kN.

Graphical representation of Maximum Base Shear is shown in Fig 9,10,11 for all Zones in X and Y directions.

In Fig 9,10 shows the Flat slabs of Vertical Geometry Irregularity Type I building have lower base shear values across all Zones when compared to conventional slabs. The flat slabs show a significant reduction in base shear values, especially in Zone V where the reduction is 55.45%.

In Fig 11 shows the Vertical Geometry Irregularity Type II Building, From Zone II to Zone III, all slab types show a 57.23% (Conventional and Flat Slabs) and 59.99% (Waffle Slab) increase. From Zone III to Zone IV, there is a moderate 45.46% to 45.47% increase for Conventional and Flat Slabs, and 50.00% for Waffle Slabs. Base reaction is maximum for waffle slab, minimum for flat slab. From above data, we can conclude that building with waffle slab is more safe compare to flat slab, when the building has vertical geometry irregularity.

## 5. CONCLUSIONS.

1. Vertical Irregularity Type I Buildings with Conventional slab, Waffle slab, and Flat slab with drop panels are suitable for all seismic Zones in terms of Lateral Displacements and Drift ratio.
2. The Vertical Irregularity Type II Building with Flat slabs and drop panels is not suitable for all seismic Zones. In contrast, conventional slab buildings and waffle slab buildings are suitable for all seismic Zones in terms of Displacement and Drift ratio.
3. Vertical Irregularity Type II Buildings with Waffle slab exhibit the highest lateral stiffness compared to conventional slab and flat slab with drop panels. After waffle slabs, conventional slab buildings have higher lateral stiffness than flat slab buildings.
4. The Vertical Geometric Irregularity of Type II Buildings configuration of the structure significantly affects the seismic response of flat slab buildings, particularly in terms of Displacement, Drift ratio, and Base Shear.

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