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# Comparative Assessment of Seismic Performance in RC Buildings with Varying Slab System Configurations

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**Abstract:**

Reinforced Concrete (RC) structures play a vital role in modern construction due to their strength, durability, and adaptability. Flat-slab RC buildings exhibit several advantages over conventional moment-resisting frames. Among various structural components, the slab system significantly affects the behaviour of multi-storeyed buildings, especially under lateral loads like earthquakes. In structural design, two widely used slab systems are the conventional slab-beam-column system and the flat slab system with drop panels. While conventional slabs offer greater rigidity due to the presence of beams, flat slabs provide architectural flexibility, reduced floor height, and ease of construction.

This mini project focuses on evaluating and comparing the seismic performance of RC buildings using these two slab systems. A G+15-storeyed residential building with identical geometry, loading conditions, and material properties is modelled and analysed in ETABS software. The analysis is performed as per IS 1893 (Part 1): 2016 seismic provisions for Zone II and medium soil conditions. Structural parameters such as storey displacement, storey drift, base shear, storey shear, and natural time period are extracted and compared between the two systems.

The objective is to understand how the presence or absence of beams (as in flat slabs) affects the lateral load resistance and dynamic characteristics of tall buildings. The study reveals that conventional slabs generally exhibit better lateral stiffness, resulting in lower displacements and drifts, while flat slabs, despite being more flexible, may require additional design considerations such as increased slab thickness or column capital sizes to enhance performance under seismic conditions.

The outcomes of this project provide valuable insights for structural engineers and designers, helping them to choose an appropriate slab system based on structural safety, architectural requirements, and cost-effectiveness.

## 1. INTRODUCTION

In recent decades, several devastating earthquakes have exposed the seismic vulnerability of reinforced concrete (RC) buildings, particularly those constructed before the implementation of modern seismic design codes. In many developing countries, including India. This has raised serious concerns about their ability to withstand seismic events, especially in zones with moderate to high seismic activity.

In seismic-prone regions, the structural system of a building plays a crucial role in determining its ability to withstand and dissipate earthquake-induced forces. While conventional RC frame systems with beams and columns offer inherent lateral stiffness and ductility, flat slab systems, which eliminate beams, may be more vulnerable due to reduced moment resistance and altered load transfer mechanisms. Despite their architectural and construction benefits, flat slab systems may pose significant risks if not adequately designed for seismic performance.

This knowledge gap can lead to design choices that compromise safety or structural efficiency. Conventional RC buildings use a system where slabs transfer loads to beams, which in turn transfer them to columns and foundations, providing significant lateral stiffness and resistance against seismic forces. In contrast, flat slab systems eliminate beams, allowing slabs to transfer loads directly to columns. While flat slabs offer advantages such as reduced story height, ease in construction, and flexibility in space planning, their seismic performance can be more vulnerable due to lower lateral stiffness and higher susceptibility to punching shear failures at the slab-column junctions.

There remains a lack of comprehensive comparative studies that evaluate the seismic response of these two systems under equivalent loading conditions.

The primary aim of this case study is to evaluate the seismic performance of an RC Slab located in Seismic Zone II using ETABS. The key objectives are:

To develop detailed ETABS models of a G+15-storeyed RC building incorporating conventional slab-beam-column and flat slab with drop panels systems.To conduct seismic response analysis in compliance with IS 1893 (Part 1): 2016 for Zone II seismic zone and medium soil conditions.To extract and compare structural response parameters including storey displacement, storey drift, base shear, storey shear, and fundamental time period for both slab systems. To evaluate the influence of slab system choice on the lateral stiffness and dynamic behaviour of multi-storeyed RC buildings under seismic loading. To investigate necessary design modifications for flat slab systems to meet seismic performance criteria. To provide data-driven guidance for structural engineers on slab system selection balancing seismic resilience, architectural needs, and economic viability.

## 2. LITERATURE REVIEW

**Patel and Patel** presented a detailed comparison of RC framed structures using conventional beam-slab and flat slab systems. A G+10-storey building was modelled in ETABS software using identical geometrical and material properties. The seismic analysis was performed as per IS 1893:2002. The study revealed that the structure with conventional slabs exhibited reduced storey displacement and inter-storey drift as compared to the flat slab model. This was primarily due to the additional stiffness provided by beams, which form a continuous rigid frame with columns, thereby enhancing resistance to lateral forces.

The inclusion of beams in conventional slabs contributes significantly to lateral stiffness and overall seismic performance.

Desai et al investigated the behaviour of flat slab structures from a design perspective using various international codes, including IS 456, ACI 318, and BS 8110. The focus was on the design and checking of flat slabs against punching shear and deflection limits. The authors found that while flat slabs provide ease in construction and flexible interior space, they are vulnerable to punching failure at column-slab junctions, especially under lateral loads. The study emphasized the necessity of using drop panels and column capitals to improve shear strength.

Flat slab systems require enhanced detailing and reinforcement at column connections to meet seismic safety requirements. Sangeetha and Maheswari developed analytical study; the authors compared the seismic response of a G+12-storeyed RC structure using both flat slab and conventional slab systems. Parameters such as base shear, storey drift, displacement, and time period were evaluated. The study revealed that buildings with flat slabs showed increased lateral displacement and time periods due to the lack of beams, which resulted in decreased lateral stiffness. Although flat slabs facilitated faster construction and reduced floor height, they performed poorly under seismic loading unless supplemented with drop panels and shear reinforcement.Flat slab systems, while architecturally advantageous, are structurally less efficient under seismic forces and require careful design. Kadam and Kumbhar studied the Seismic Performance of Flat Slab and Conventional SlabStructures.The authors analysed two different building configurations (G+12 RC buildings) with flat slabs and conventional slab-beam arrangements using response spectrum analysis. The study noted that flat slab buildings exhibited a higher fundamental time period and lateral displacement due to the absence of beams. However, when drop panels and column capitals were included, the performance improved notably. It was concluded that flat slabs can be adopted in seismic regions with proper structural measures such as increased slab thickness and strong column reinforcement.The structural performance of flat slabs under seismic loading can be significantly improved by design enhancements, though conventional slabs still perform better overall. Mehta and Bhavsar examined the performance of flat slab and conventional slab structures across different seismic zones in India. The authors modeled G+10 storeyed buildings in ETABS and evaluated structural parameters like base shear, storey drift, and lateral displacement. The results indicated that conventional slabs perform better in higher seismic zones due to the added stiffness provided by beams. Flat slabs showed increased flexibility and were recommended only for low to moderate seismic zones unless properly detailed.Flat slabs are less suitable for high-seismic zones without reinforcement enhancements, while conventional slabs offer better structural resilience. Ghode and Sangle focused on the vulnerability of flat slab buildings that do not include drop panels. A high-rise G+12 building was modelled and analysed under earthquake loading. The study highlighted excessive punching shear and large displacements in flat slabs without drops, emphasizing the critical importance of slab-column junction strengthening. Flat slabs without drops are not recommended for seismic regions due to poor lateral performance and higher risk of punching failure. Jain and Jaiswal s performed seismic analysis on G+15 RC structures to compare flat and conventional slabs using response spectrum and time history methods. The results confirmed that flat slabs showed higher lateral displacement and time periods. Conventional slabs exhibited more resistance to base shear and better drift control.

Time period and displacement values are higher in flat slab systems; conventional slabs are more effective under dynamic loading.

## 3. METHODOLOGY

The seismic analysis in this study is performed using ETABS software by modelling a multi-storey RC building under two distinct slab system configurations to evaluate their comparative performance. The first configuration, referred to as Model 1, consists of a conventional RC frame with beams and slabs, whereas the second configuration, Model 2, represents a flat slab system incorporating drop panels and eliminating beams. Both structural models are developed in accordance with relevant Indian design standards, including IS 875 (Part 1 and Part 2) for dead and live loads, IS 456:2000 for the design of reinforced concrete structures, and IS 1893 (Part 1): 2016 for earthquake-resistant design criteria. The analysis is carried out using the Equivalent Static Method specified in IS 1893, ensuring consistency with codal provisions. To enable a meaningful comparison, both models are created using identical geometric configurations, material properties, and loading conditions.

A range of key seismic response parameters is evaluated for both slab systems. These include storey displacement in the X and Y directions, storey drift in both directions, the fundamental time period of the structure, base shear in each principal direction, and storey shear distribution along the height of the building. These response parameters provide insight into the overall deformation characteristics, stiffness, and dynamic behavior of each structural system. The primary objective of the methodology is to assess how the presence or absence of beams influences the seismic performance of RC buildings and to determine which slab system offers superior structural resilience, safety, and architectural adaptability under lateral earthquake-induced forces.

4. **Modelling and Analysis** : The building selected for this study is a fifteen-storey (G+15) residential reinforced concrete (RC) frame structure located in Seismic Zone II and resting on medium soil conditions as defined by IS 1893 (Part 1): 2016. The structure has a

regular rectangular plan measuring 49 m by 25 m, with a uniform floor-to-floor height of 3 meters throughout all storeys. It consists of moment-resisting RC frames in both orthogonal directions and is analyzed using ETABS software to compare the seismic response of two different slab systems, namely the conventional slab–beam–column system and the flat slab system with drop panels. Both models are developed using identical geometric, material, and loading conditions to ensure a consistent basis for comparison. The structural configuration includes 400 mm × 400 mm RC columns, 300 mm × 400 mm beams in the conventional model, and a 125 mm thick slab throughout. For the flat slab model, 3 m × 3 m drop panels with a thickness of 115 mm are provided at all column locations. The external and internal infill walls have thicknesses of 230 mm and 115 mm, respectively, and the parapet wall height is considered as 1.5 m.

Material properties conform to IS 456:2000, with M25 grade concrete having a characteristic compressive strength of 25 MPa and Fe500 grade steel used for reinforcement. The unit weights of concrete and brick masonry are taken as 25 kN/m³ and 19 kN/m³, respectively. The loads applied to the structure include dead loads comprising the self-weight of all structural components and masonry walls, as well as live loads of 4.0 kN/m² on all typical floors and 1.5 kN/m² on the roof. An additional uniformly distributed floor finish load of 1.0 kN/m² is also applied. Seismic analysis is carried out using the Equivalent Static Method in accordance with IS 1893:2016. The adopted seismic parameters include Zone II seismicity with a zone factor (Z) of 0.10, medium soil classification (Type II), an importance factor (I) of 1.0, and a response reduction factor (R) of 5.0 for a Special Moment Resisting Frame (SMRF). These parameters are used to compute the design base shear, which is then distributed along the height of the building as per codal provisions. Both slab systems are modeled with rigid diaphragm action at each floor, and the base of the structure is assumed to be fixed for analytical purposes.

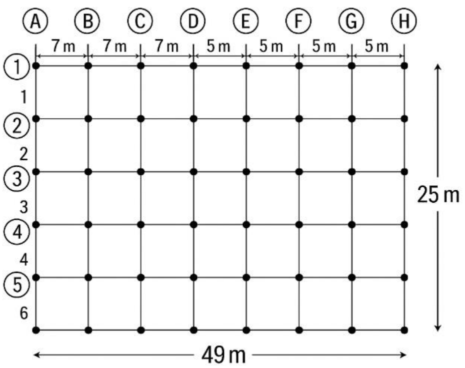



**Fig.4.1 Plan View of Conventional Slab**

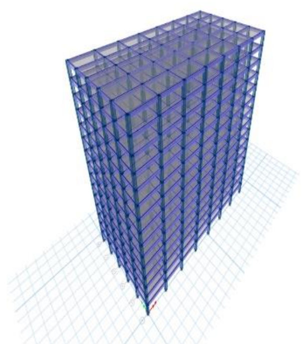
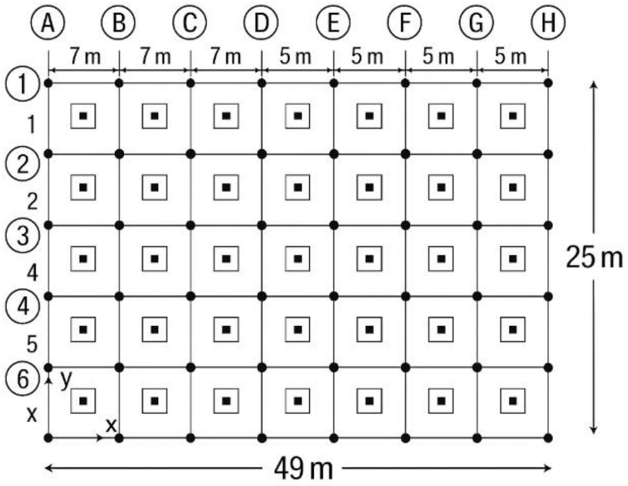


**Fig.4.2 3D View of Conventional Slab**



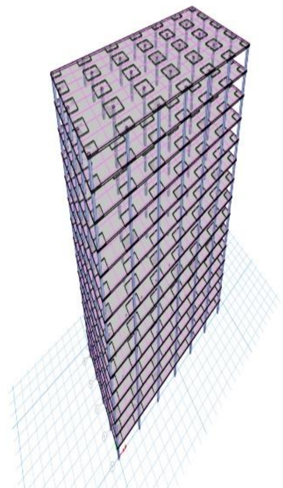



**Fig.4.3 Plan View of Flat Slab with Drop** **Fig.4.4 Plan View of Flat Slab with Drop**

## 5. RESULTS & DISCUSSIONS

### 5.1. General:

An existing G+15-storied reinforced concrete frame was taken for the investigation. The frame was subjected to design earthquake forces as specified in the IS code for zone II along X and Y directions. The responses to the frames are discussed below.

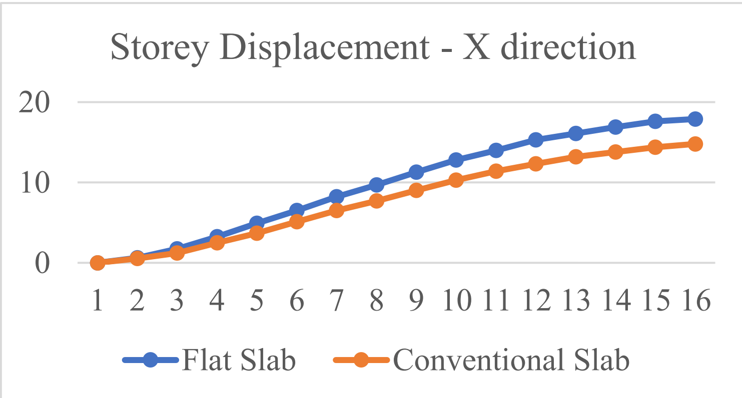



Fig.5.1 Storey Displacement – X Direction

- The displacement of the flat slab with drop is consistently higher compared to the conventional slab across all storeys.
- From the graph on the right, we can clearly see that the flat slab displacement is always higher than the conventional slab displacement.
- Flat Slab with Drop generally shows more displacement than the Conventional Slab. This could be indicative of higher flexibility or differences in the stiffness of the two types of slabs.

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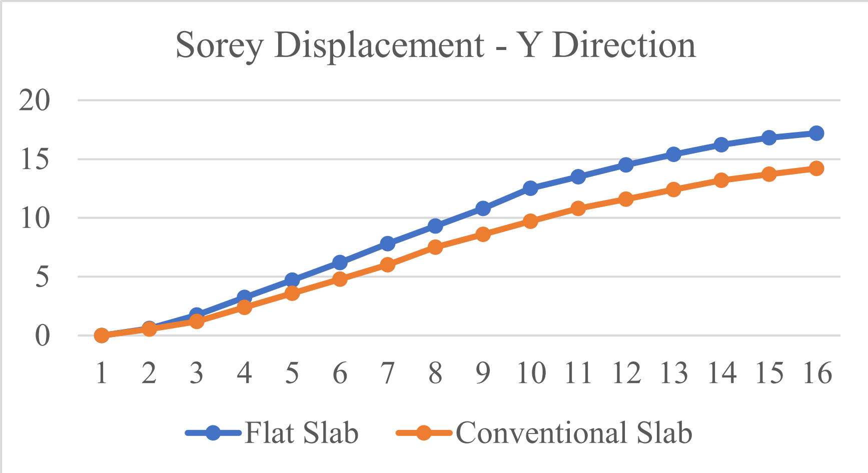


Fig.5.2 Storey Displacement – Y Direction

- The **Flat Slab with Drop** system exhibits **greater lateral displacement** compared to the **Conventional Slab**, especially in higher storeys.
- This suggests that conventional slabs offer **better lateral stiffness** and resistance under lateral loads (such as seismic or wind).
- For seismic design considerations, the **conventional slab system may provide improved performance** in terms of displacement control.

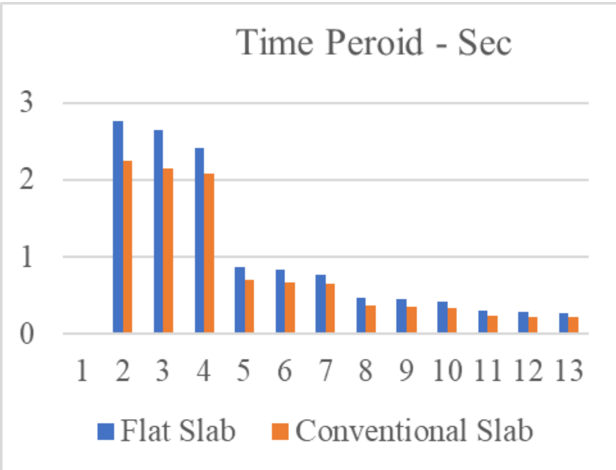


Fig.5.3 Time period for conventional slab and flat slab with drop

The time periods decrease with increasing storey number for both slab types.

➢ Flat Slab with Drop consistently shows higher time periods than the Conventional Slab across all storeys.

➢ Flat Slab with Drop may be easier and faster to construct, extra care must be taken in seismic zones due to its more flexible nature.

➢ The Flat Slab with Drop system exhibits higher time periods, indicating it is more flexible or has lower stiffness compared to the Conventional Slab system.

➢ The initial time period at Storey 1 is:

Flat Slab with Drop: 2.759 sec

Conventional Slab: 2.252 sec

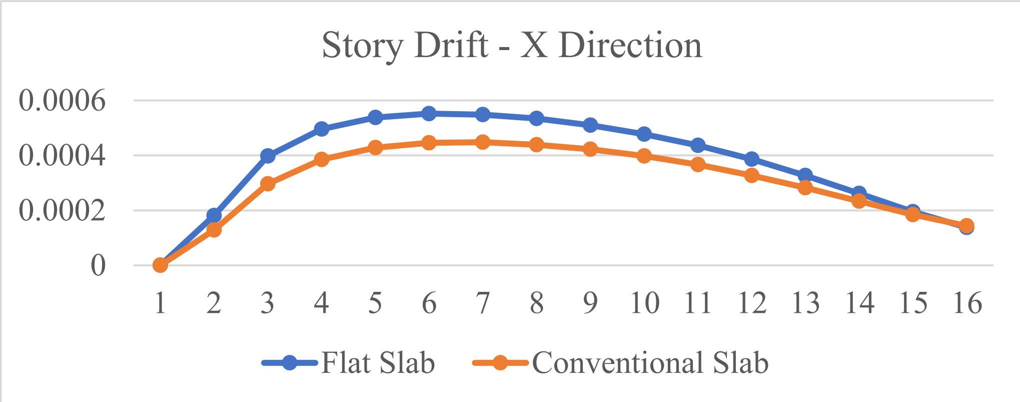


Fig.5.4 Storey Drift – X Direction

➢ Flat Slab with Drop consistently exhibits higher storey drift values than the Conventional Slab.

➢ Peak drift occurs between storeys 4 to 6, where lateral deformation is most critical.

➢ Drift increases with height initially, peaks around the mid-height of the structure, and then decreases toward the top floors.

➢ Flat Slab with Drop systems have higher storey drift, which confirms earlier findings

➢ Conventional Slabs offer better lateral stiffness and are more resistant to inter-storey displacement under lateral loads (e.g., earthquakes).

➢ Maximum Drift:

- Flat Slab with Drop: ~0.000552 at Storey 5
- Conventional Slab: ~0.000448 at Storey 6

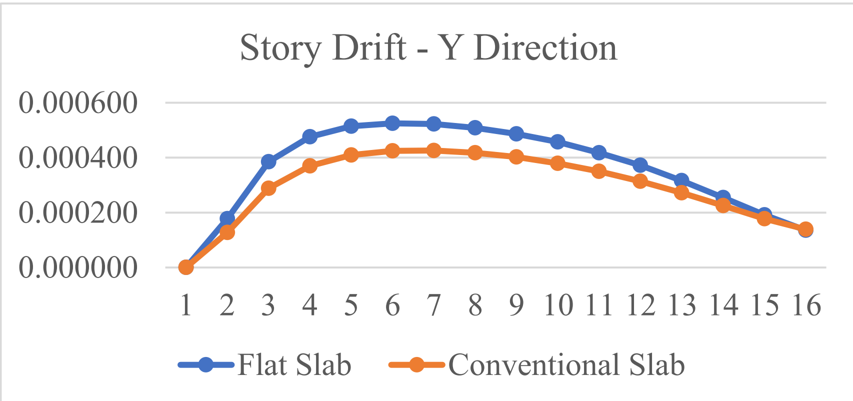


Fig.5.5 Story Drift – Y Direction

- The Flat Slab with Drop system shows higher storey drift values than the Conventional Slab throughout all levels.
- The peak drift in the Flat Slab system exceeds that of the Conventional Slab by ~25%, indicating a more flexible structure.
- Code Compliance Concern: If the maximum drift exceeds code limits (typically around 0.004 for seismic), the Flat Slab system may require stiffness enhancement.
- The Conventional Slab system provides better lateral stiffness and drift control, making it more suitable for seismic zones.

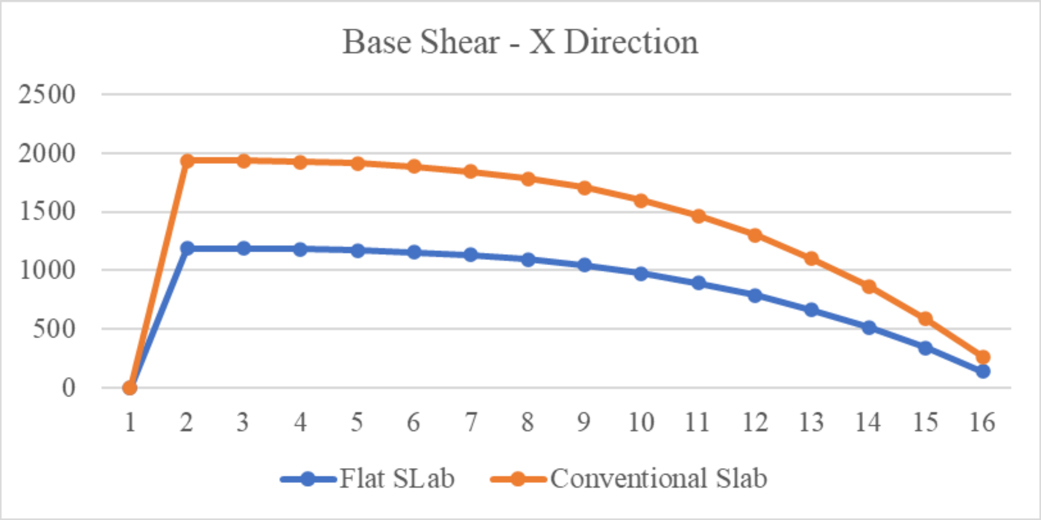


Fig.5.6 Base Shear – X Direction

➢ Flat Slab with Drop: Lower base shear values across all storeys.

➢ Conventional Slab: Significantly higher base shear throughout, peaking at lower storeys.

➢ Base shear values for both systems increase rapidly at lower storeys and then decrease toward the top.

➢ The Conventional Slab curve is consistently above the Flat Slab curve, indicating that it attracts more seismic force due to higher stiffness.

- Flat Slab with Drop: 1187.3 kN
- Conventional Slab: 747.4 kN

➢ But overall:

- Total base shear for Conventional Slab remains consistently higher up to Storey 15

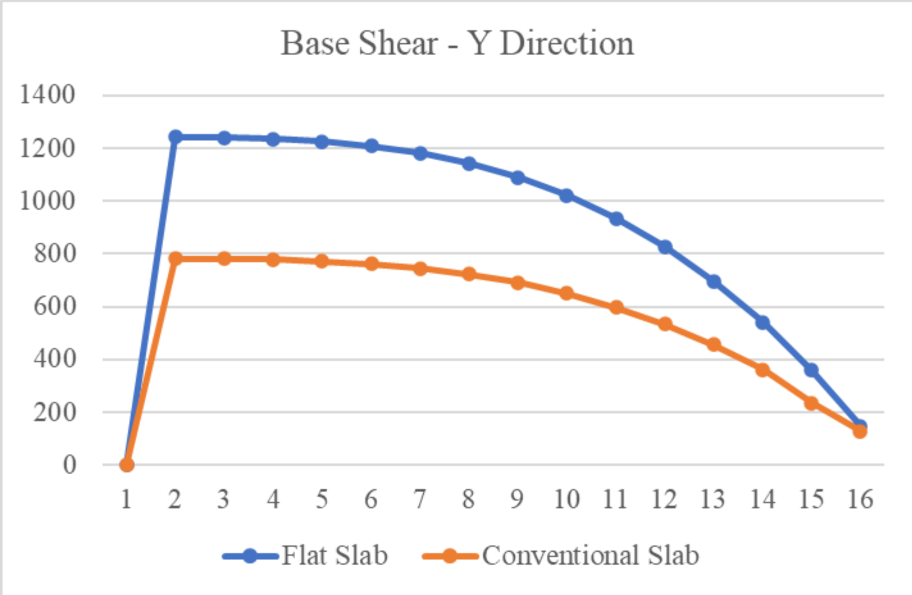


Fig.5.7 Base Shear – Y Direction

## 6. CONCLUSION

Based on the comparative analysis of seismic parameters. As a result of the work that was completed in this study, the following conclusions were made:

- **Storey Displacement**: Flat slab with drop shows approximately **18–25% higher** displacement than conventional slabs, indicating lower stiffness.
- **Storey Drift**: Flat slab systems exhibit **15–20% more drift**, especially at mid-storey levels, due to reduced lateral stiffness.
- **Time Period**: The fundamental time period for flat slabs is **22.5% longer**, signifying higher flexibility.
- **Base Shear**: Conventional slabs attract **approximately 35–40% base shear**, reflecting their higher stiffness and mass interaction.

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