

DYNAMIC EVALUATION OF LATERAL FORCE RESISTING SYSTEMS FOR TALL BUILDINGS UNDER SEISMIC LOADING

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Abstract

The rapid growth of urban infrastructure has resulted in an increased demand for tall buildings, which are highly vulnerable to lateral loads induced by earthquakes and wind. Unlike gravity loads, lateral forces significantly influence the overall stability and performance of such structures. Therefore, the selection of an appropriate lateral force resisting system becomes a critical aspect of structural design. This study presents a dynamic evaluation of various lateral force resisting systems, including rigid frames, braced frames, reinforced concrete shear walls, and steel plate shear wall systems. Special emphasis is given to the comparative performance of normal (unstiffened) and braced (stiffened) steel plate shear walls. Dynamic analysis is performed to evaluate parameters such as natural time period, storey displacement, storey drift, and base shear. The results indicate that steel plate shear wall systems offer superior seismic performance, with braced configurations providing enhanced stiffness and reduced lateral deformation. The findings of this study contribute to the efficient selection of lateral load resisting systems for tall buildings located in seismic-prone regions.

Keywords: Lateral Load, Dynamic Analysis, Steel Plate Shear Wall, Seismic Performance, Tall Buildings.

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1. Introduction

Urbanization and limited availability of land have compelled engineers to design taller and slender structures. These structures are subjected to significant lateral loads due to seismic activity and wind forces. In seismic regions, lateral loads often govern the design criteria rather than gravity loads. Inadequate resistance to such forces can result in excessive deformation, structural damage, or collapse.

To ensure safety and serviceability, various lateral force resisting systems have been developed and implemented in tall building design. Conventional systems such as rigid frames and braced frames are commonly used; however, their effectiveness decreases as building height increases. In recent years, steel plate shear wall systems have emerged as an efficient alternative due to their high ductility, energy dissipation capacity, and ease of construction.

This research focuses on the dynamic behavior of different lateral force resisting systems with particular emphasis on the performance comparison between normal and braced steel plate shear wall systems.

2. Literature Review

Several researchers have investigated the seismic behavior of tall buildings using different lateral force resisting mechanisms. Past earthquake events, such as the Bhuj earthquake in India and the Chi-Chi earthquake in Taiwan, have highlighted the vulnerability of inadequately designed structures and emphasized the importance of effective lateral systems.

Studies have shown that shear wall systems significantly enhance stiffness and reduce lateral displacement. Braced frame systems have also been reported to provide improved seismic resistance by controlling drift. More recent research has demonstrated that steel plate shear walls exhibit excellent post-buckling behavior through tension field action, resulting in high energy dissipation and ductility. However, limited studies have focused on the comparative dynamic performance of unstiffened and stiffened steel plate shear walls, which forms the basis of the present study.

3. Methodology

A three-dimensional analytical model of a multi-storey tall building is developed to investigate the seismic response of different lateral force resisting systems. The structure is assumed to be located in a seismic-prone region and is analyzed using dynamic analysis procedures in accordance with relevant provisions of Indian Standard codes such as IS 1893 (Part 1): 2016 and IS 16700: 2017. The building is modelled as a regular plan configuration with uniform storey height, and all structural members are assumed to be rigidly connected. The analysis is carried out using response spectrum analysis to capture the dynamic characteristics of the structure under earthquake loading. Appropriate load combinations, damping ratio (5%), and soil conditions are considered as per code recommendations.

Four different lateral force resisting systems are incorporated into the structural model for comparative evaluation:

- Moment resisting frame (rigid frame system)
- Braced frame system
- Reinforced concrete shear wall system
- Steel plate shear wall (SPSW) system

The steel plate shear wall system is further modelled in two configurations, namely unstiffened (normal) and stiffened (braced). In the unstiffened configuration, thin steel infill plates are used without additional stiffeners, allowing tension field action after buckling. In the stiffened configuration, diagonal bracing elements are introduced to enhance stiffness and delay plate buckling, thereby improving overall seismic performance.

The structural response is evaluated in terms of key dynamic parameters such as natural time period, base shear, storey displacement, and inter-storey drift. These parameters are extracted for all models and compared to assess the effectiveness of each lateral force resisting system in controlling seismic response

Sectional Properties: The member sizes adopted for the structural model are varied along the building height to account for the reduction in axial forces and bending moments. Larger sections are provided at lower storeys, while relatively smaller sections are used at higher levels for structural efficiency and economy.

- Columns are designed as box sections with sizes ranging from 1200 mm × 1200 mm at lower storeys to 600 mm × 600 mm at upper storeys.
- Exterior beams are modeled as built-up I-sections of size 800 mm × 300 mm × 32 mm.
- Interior beams are considered as standard rolled sections (ISMB 500).

This variation in member size ensures adequate stiffness and strength distribution throughout the height of the building.

Table 1. Sectional Properties

Member	Size in mm.
Columns	
st th 1 to 25 (outer tube)	1200 x 1200
st th 1 to 25 (inner)	1000 x 1000
th th 25 to 50 (outer tube)	1000 x 1000
th th 25 to 50 (inner)	800 x 800
th th 50 to 75 (outer tube)	800 x 800
th th 50 to 75 (inner)	600 X 600
Exterior Beams (I Section)	800X300X32
Interior Beams (I Section)	ISMB 500

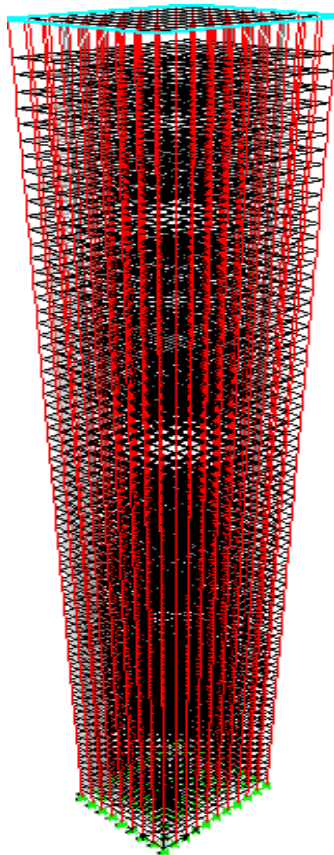


Fig.1. Building model 3D view

4. Results and Discussion

The dynamic analysis results reveal that the lateral response of the structure varies significantly with the type of resisting system employed. Structures with rigid frames exhibit higher flexibility, resulting in increased storey displacement and drift. The introduction of bracing systems improves stiffness and reduces lateral deformation.

Steel plate shear wall systems demonstrate superior seismic performance compared to conventional systems. In the normal steel plate shear wall configuration, early buckling of the plate occurs; however, the post-buckling tension field action contributes to effective energy dissipation. The braced steel plate shear wall system exhibits enhanced stiffness, delayed buckling, and improved control over lateral displacement and drift.

Overall, braced steel plate shear walls provide better performance in terms of seismic safety and serviceability, making them suitable for tall buildings in high seismic zones.

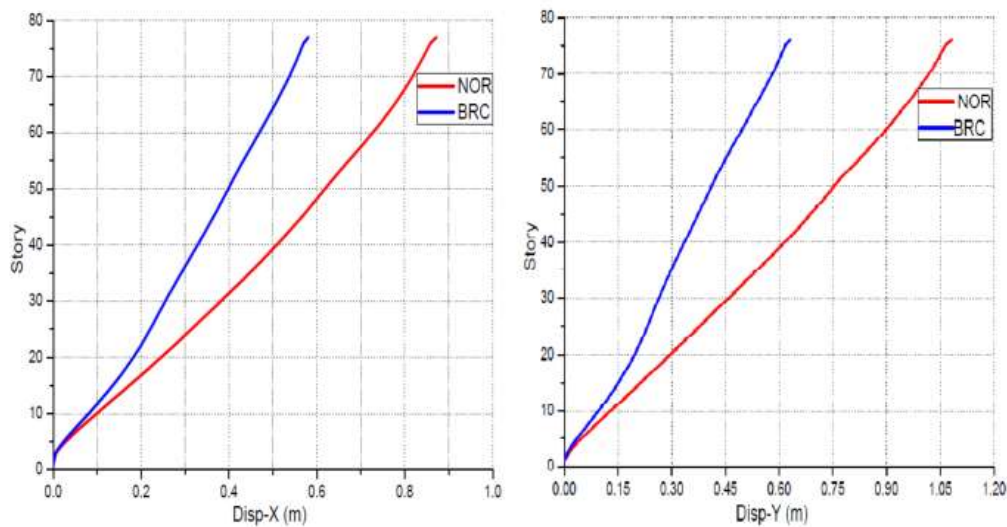


fig. 2.a X and Y displacements of normal and braced building

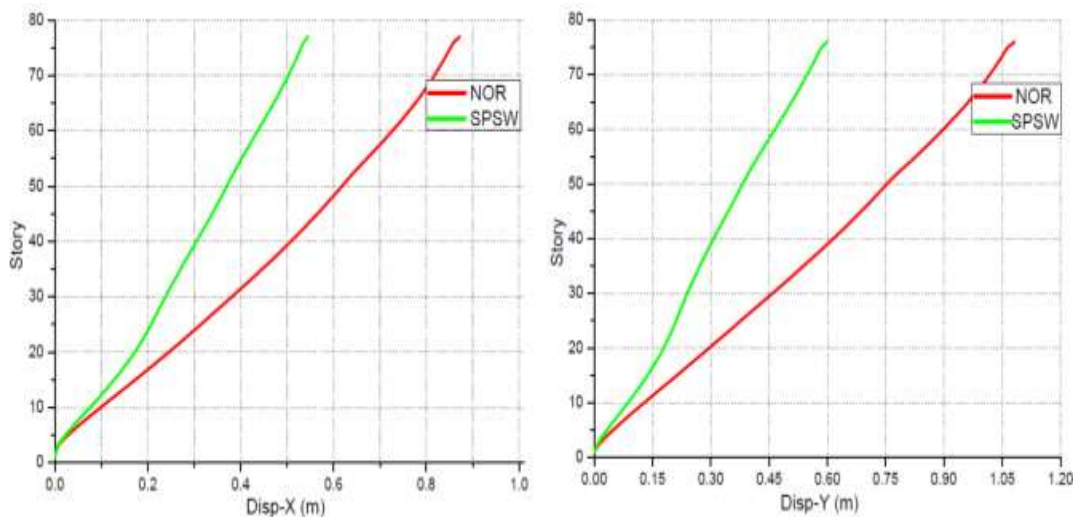


fig. 2.b X and Y displacements of normal building and after application of SPSW

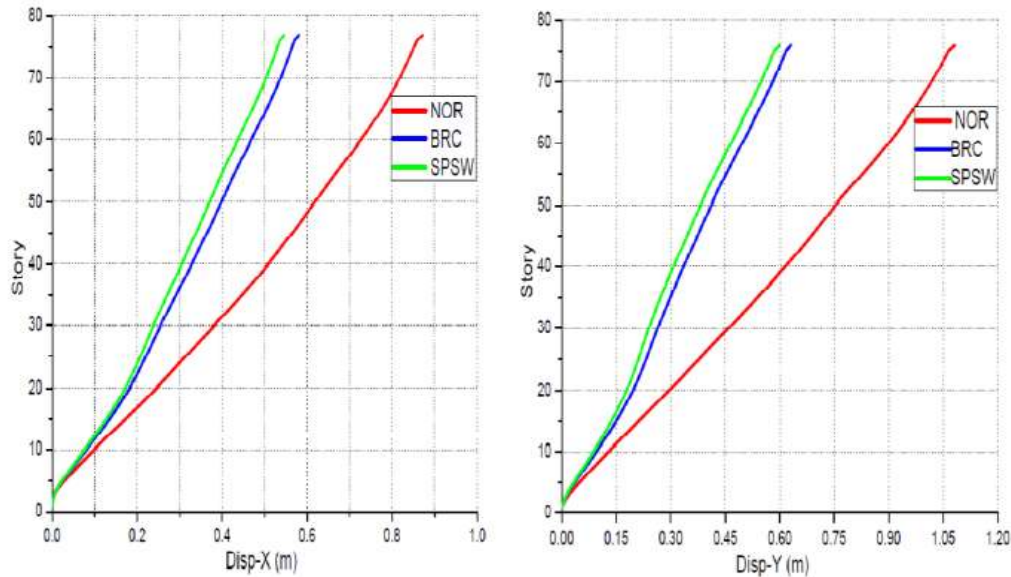


fig. 2.c X and Y displacements of normal building and after application of bracing system and SPSW

5. Conclusion

The present study highlights the importance of selecting an efficient lateral force resisting system for tall buildings subjected to dynamic loads. Based on the dynamic evaluation, steel plate shear wall systems are found to be more effective than conventional systems such as rigid frames and braced frames.

Normal steel plate shear walls offer economical and ductile behavior, while braced steel plate shear walls provide superior stiffness and reduced deformation. The choice between the two configurations should be based on building height, seismic intensity, and performance requirements. The findings of this study can assist structural engineers in designing safer and more efficient tall buildings in seismic-prone regions.

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