

Performance Evaluation of Multi-Story Buildings Using Hybrid Shear Wall–Steel Bracing Structural Systems for Seismic and Wind Load Resistance

Ms. Shital Ingle¹, Dr. A. A. Malokar²

¹M.E. Student, ²Assistant Professor, Civil Engineering Department, Dr. V. B. Kolte College of Engineering, Malkapur, Maharashtra, India

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ABSTRACT

The continuous increase in the height and functional demands of modern multi-story buildings has intensified the need for structural systems that can efficiently withstand lateral forces generated by earthquakes and wind. Traditional lateral load-resisting systems, including reinforced concrete shear walls and steel bracing arrangements, are extensively employed; however, when used independently, they often face constraints related to ductility performance, stiffness optimization, architectural adaptability, and efficient use of materials. To overcome these shortcomings, hybrid systems combining shear walls with steel bracing have emerged, aiming to integrate the beneficial characteristics of both structural forms. This review paper systematically compiles and evaluates prior research addressing the seismic and wind-related performance of multi-storey buildings utilizing hybrid shear wall–steel bracing systems. The discussion encompasses the impact of shear wall location, comparative behavioral responses, sustainability implications, and recent innovations in hybrid structural design. Evidence from the reviewed studies demonstrates that such hybrid systems markedly improve lateral rigidity, limit storey-level displacements and inter-storey drift, enhance energy dissipation capacity, and provide superior structural performance under combined seismic and wind effects. The review ultimately highlights hybrid shear wall–steel bracing systems as an effective and sustainable solution for future high-rise developments in regions exposed to significant seismic and wind hazards.

Keywords : - Hybrid structural systems, shear walls, steel bracing, seismic resistance, wind loads, multi-storey buildings.

Objectives of The Study

The primary objectives of this research are:

- Analyze the seismic and wind performance of hybrid shear wall–steel braced buildings.
- Compare the strength and stability of hybrid systems with conventional structural systems.
- Determine the optimal configuration for hybrid shear wall–steel bracing systems.
- Evaluate the applicability and effectiveness of hybrid systems in different seismic zones.

1. INTRODUCTION

Ongoing urban expansion combined with limited land availability has driven a shift toward the development of taller and more slender multi-storey buildings. Such structural forms are inherently more sensitive to lateral actions resulting from seismic activity and wind effects. Evidence of structural damage from past earthquakes and extreme wind events has emphasized the necessity of adopting reliable lateral load-resisting mechanisms to ensure both safety and functional performance. In this context, reinforced concrete shear walls and steel bracing systems remain among the most frequently used structural solutions.

Shear walls are widely recognized for their ability to provide significant rigidity and strength, making them well suited for high-rise applications. Steel bracing systems, on the other hand, contribute enhanced ductility, structural flexibility, and construction efficiency, particularly in medium-height buildings. Nevertheless, the independent use of either system can lead to performance limitations under combined loading conditions. Consequently, hybrid structural configurations that incorporate both shear walls and steel bracing have attracted increasing research interest, as they aim to achieve an improved balance between stiffness, strength, and energy dissipation. This paper reviews and synthesizes previous studies evaluating the seismic and wind performance of hybrid shear wall–steel bracing systems.

2. EVOLUTION OF STRUCTURAL SYSTEMS IN MULTI-STOREY BUILDINGS

The advancement of structural systems in multi-storey buildings has been primarily motivated by the need to ensure safety, structural efficiency, and economic feasibility under lateral loads induced by wind and seismic activity. Traditional lateral load-resisting mechanisms, such as shear walls and steel bracing systems, are widely adopted due to their proven effectiveness. However, when implemented individually, these systems exhibit certain performance limitations. This has led to the development of hybrid structural systems that integrate shear walls with steel bracing to capitalize on the strengths of both approaches. The present review synthesizes existing research on the design, performance characteristics, benefits, and challenges associated with hybrid shear wall– steel bracing systems in multi-storey buildings.

3. SEISMIC PERFORMANCE OF HYBRID STRUCTURAL SYSTEMS

Numerous investigations have established that hybrid structural systems play a significant role in enhancing the seismic response of multi-storey buildings. Thejaswini et al. (2024), through a probabilistic risk-based assessment of reinforced concrete structures, identified that vertical irregularities such as floating columns markedly diminish seismic reliability. Their study indicates that the application of hybrid strengthening strategies can effectively counteract these vulnerabilities. In a related context, Thomsen et al. (2021) highlighted the applicability of equivalent static analysis as a reliable method for evaluating lateral force distribution and overall structural response in hybrid structural arrangements.

Further evidence is provided by Vijay Kumar Gowda et al. (2023), who reported increased storey drift and reduced seismic capacity in buildings incorporating floating columns. Conversely, research by Nanduri et al. (2013) demonstrated that the inclusion of bracing systems substantially limits earthquake-induced structural damage. Similarly, Chung et al. (2015) showed that the optimal placement of bracing components leads to notable reductions in lateral displacement and inter-storey drift. Taken together, these findings indicate that combining shear walls with steel bracing significantly improves seismic performance by enhancing stiffness, load-bearing capacity, and energy dissipation characteristics.

4. EFFECT OF SHEAR WALL ARRANGEMENT ON SEISMIC RESPONSE

Shear wall effectiveness in seismic resistance is strongly influenced by its location within the structural layout. Ahamad and Pratap (2020) showed that appropriately positioned shear walls significantly reduce lateral displacement, while Prasad et al. (2014) reported reduced torsional response and improved stability in irregular building plans. Studies by Magendra et al. (2016) indicate that placing shear walls at corner and core regions enhances overall seismic performance. Additionally, Hiremath and Hussain (2014) and Dodiya et al. (2018) observed that optimized shear wall distribution and proportioning effectively reduce inter-storey drift. Overall, the literature suggests that strategic shear wall placement is critical to maximizing the performance of hybrid shear wall–steel bracing systems.

5. COMPARATIVE PERFORMANCE OF SHEAR WALL AND BRACING-BASED

Comparative research indicates that the seismic and wind response of multi-storey buildings is strongly influenced by the choice of lateral load-resisting system. Rahman et al. (2021) observed that shear wall systems are more effective in high-rise buildings due to their inherent stiffness, whereas steel bracing systems perform better in mid-rise structures because of their greater flexibility. Hasrat and Bhandari (2025) reported that hybrid configurations provide superior performance compared to conventional systems under combined seismic and wind loading. Similarly, Karimi and Sarem (2021) demonstrated that integrating shear walls with advanced control mechanisms enhances overall seismic resilience. Collectively, these studies suggest that hybrid shear wall–steel bracing systems achieve a balanced structural response by satisfying both stiffness and ductility demands.

6. PERFORMANCE ASSESSMENT OF HYBRID SYSTEMS UNDER SEISMIC AND WIND LOADS

Recent research highlights the expanded use of hybrid systems with innovative materials and designs. Carrero et al. (2021) found that hybrid cross-laminated timber and steel shear walls enhance both seismic performance and sustainability. Al Shamaa and Al Shimmeri (2023) showed that combining bracing systems with steel shear walls in high-rise buildings significantly boosts stability under seismic loads. Naseri and Lallotra (2021) reported that hybrid systems improve energy dissipation and load redistribution, increasing resistance to seismic forces. Collectively, these studies demonstrate the effectiveness of hybrid shear wall–steel bracing systems under combined seismic and wind loading.

7. EMERGING TRENDS IN HYBRID STRUCTURAL DESIGN

The continued evolution of hybrid systems is evident in the adoption of new materials and structural concepts. Setti et al. (2025) proposed a hybrid timber-based system incorporating modular bracing and shear walls, achieving improved seismic resistance and environmental sustainability. Dubina et al. (2025) evaluated lightweight prefabricated residential buildings and found that combining shear walls with strap-bracing systems significantly enhances seismic resilience. These studies reinforce the growing relevance of hybrid solutions in modern seismic-resistant design.

8. FUTURE RESEARCH SCOPE

Despite substantial progress in hybrid shear wall–steel bracing systems, several aspects warrant further exploration. Emphasis should be placed on advanced nonlinear numerical modeling to accurately represent structural response under combined seismic and wind loads. Large-scale experimental investigations and the adoption of high-strength, lightweight materials are also essential for improving system efficiency.

Furthermore, evaluating hybrid system performance in low-to-moderate seismic regions and adopting performance-based design approaches may enhance practical implementation. The integration of smart materials and supplemental damping devices offers additional potential to improve seismic resilience and overall structural performance.

9. CONCLUSION: PROBLEM IDENTIFIED FROM LITERATURE

The literature indicates that while shear walls and steel bracing systems have been extensively studied as independent lateral load-resisting mechanisms, their combined application remains insufficiently explored. Limited attention has been given to the optimal design and structural performance of hybrid shear wall–steel bracing systems in multi-storey buildings. This limitation highlights the need for systematic investigation into the feasibility and effectiveness of hybrid configurations in improving seismic and wind resistance, thereby forming the basis of the present study.

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