A Review on Comparative Seismic Analysis of a High-Rise RCC Building Provided with the Shear Wall and Bracing System

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Abstract - *The seismic performance of multi-storey reinforced concrete (RC) buildings is a critical concern in earthquake-prone regions, with shear walls and bracing systems serving as primary structural elements to resist lateral seismic forces. This review paper synthesizes the findings from a diverse set of studies focused on the effectiveness, optimization, and analysis of shear walls and bracing systems in RC buildings. The research covers a broad spectrum of topics, including the impact of shear wall placement on building performance, comparative analyses of steel and concrete bracing systems, and the role of advanced simulation tools such as ETABS for dynamic analysis. Key findings from the reviewed literature indicate that shear walls significantly enhance the lateral stiffness and stability of high-rise buildings, reducing displacements and improving overall structural resilience during seismic events. In contrast, bracing systems, particularly steel braces, offer a cost-effective and flexible alternative, though their effectiveness in very tall buildings may be limited compared to shear walls. Additionally, the research explores the role of coupled shear walls, hybrid systems, and novel material innovations in further improving seismic performance.*

Key Words: RCC building, Seismic analysis, Response spectrum method, Shear wall, Bracing system, ETABS, etc.

1. INTRODUCTION

Seismic resilience is a critical consideration in the design of multi-storey reinforced concrete (RC) buildings, particularly in regions prone to high seismic activity. Earthquakes impose complex lateral forces on buildings, and without appropriate structural interventions, these forces can lead to severe damage, structural failure, or even loss of life. Among the various structural systems used to mitigate seismic forces, shear walls and bracing systems have proven to be highly effective in improving the lateral load resistance of buildings. Shear walls, typically vertical structural elements, act as a stiffening mechanism to resist horizontal forces generated by seismic events. Similarly, bracing systems, which include various configurations of steel and concrete braces, provide additional stiffness and strength to the structure, reducing deformations during an earthquake.

Over the past few decades, considerable research has been conducted to understand the behaviour of RC buildings equipped with shear walls and bracing systems under seismic loading. Numerous studies have focused on optimizing the placement, configuration, and design of these systems to improve the seismic performance of buildings. The findings from these studies highlight the significant role that shear walls and bracing systems play in enhancing the stability, safety, and overall resilience of buildings subjected to earthquake forces. Additionally, advancements in computational tools and software, such as ETABS and response spectrum analysis, have allowed engineers to conduct more accurate simulations and analyses, enabling better-informed design decisions.

1.1 Shear Wall

In structural engineering, a shear wall is a vertical component of a lateral load-resisting system designed to counteract horizontal forces such as wind and seismic loads. These walls are commonly found in tall buildings or in regions prone to strong winds or seismic activity. Shear walls are essential for resisting lateral forces generated by earthquakes, wind, or occasionally horizontal ground pressure or hydrostatic forces. They provide both lateral and vertical load support, in addition to functioning as partitions within the structure. As illustrated in Figure 1.1, shear walls extend from the foundation up to the roof level. They are particularly suitable for high-rise buildings due to their combination of strength and effective stiffness.

In buildings subject to wind or seismic forces, shear walls play a crucial role in resisting lateral loads. These walls can be either connected, non-planar assemblies or independent, planar structures. For buildings up to about 35 stories, shear walls are often more cost-effective and rigid than alternative lateral systems like rigid frames. In low to mid-rise buildings, it is typical for shear walls to carry the majority of the lateral loads, while the frame is primarily designed for vertical gravity loads. Research has shown that shear wall structures perform effectively during seismic events, with ductility being a key consideration in their design.

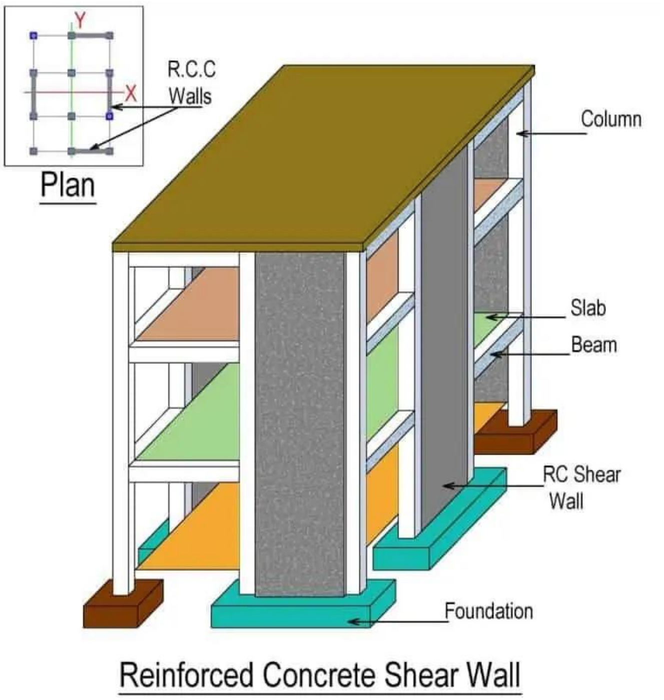

Fig.1.1 RCC building with shear wall
(https://civildigital.com/wp-content/uploads/2017/06/Shear-Wall-in-a-Building.jpg)

1.2 Bracing System

Bracing systems are a cost-effective solution for buildings of all heights, from low-rise to high-rise, due to their ability to offer substantial lateral stiffness with minimal additional material. There are two main types of bracing: concentric and eccentric. Eccentric braces do not connect directly at the beam-column intersection but are positioned at a distance, linking to the beam. Bracing systems can also be categorized based on how they transfer lateral loads: vertical or horizontal. Vertical bracing consists of diagonal braces placed between columns in vertical planes, helping transfer horizontal forces to the foundation. Horizontal bracing, installed at each floor level, helps distribute forces evenly to the vertical bracing system.

Steel bracing systems, commonly used in the seismic design of new structures, are also highly effective for the seismic retrofitting of existing reinforced concrete (RC) buildings. In these systems, columns act as the primary chords, providing lateral stability to the structure. As illustrated in Figure 1.2, diagonal bracing members, in conjunction with beams, form the web of a vertical truss. These bracing systems are particularly efficient at resisting lateral forces, as the shear forces on the structure are counteracted by the axial tensile and compressive actions within the web elements. While steel bracing is often associated with steel-frame buildings, it is now also increasingly used in reinforced concrete structures.

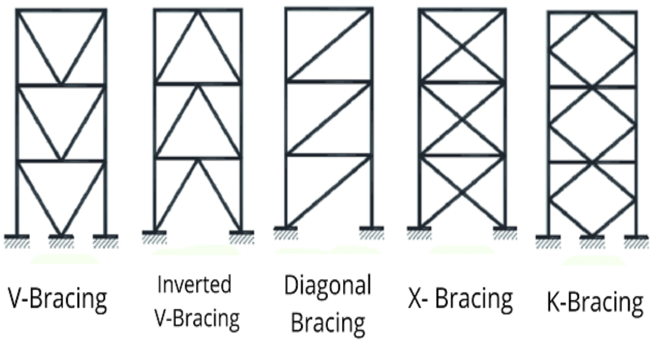

Fig. 1.2 RCC building with bracing system
(https://civilwale.com/wp-content/uploads/2020/09/Types-of-Braced-framed-structures.png)

2. LITERATURE REVIEW

Krupaben J. Patel, Dhruvkumar H. Patel (2021), “Different Types of Bracing System in Multi Story RCC Building”.

The primary objective of this study is to evaluate the structural performance of steel buildings with different bracing systems. The research also examines the structural efficiency of various bracing types. Several bracing configurations, including no bracing, X-bracing, diagonal bracing, and V-type bracing, were investigated to assess the structural strength of the steel buildings. The study involved analyzing a 10-story building with different bracing systems, such as no bracing, X-bracing, diagonal bracing, V-bracing, and inverted V-bracing, and comparing key parameters like story displacement, story drift, story stiffness, lateral load, and story shear. The analysis was carried out using ETABS software. The results indicate that steel bracing systems not only enhance the displacement capacity of reinforced concrete structures but also improve their lateral stiffness and strength by increasing shear capacity. For square-shaped buildings, the diagonal bracing system was found to be the most efficient in terms of these performance parameters.

Shaik Akhil Ahamad, K. V. Pratap (2020), "Dynamic Analysis of G + 20 Multi Storied Building by using Shear Walls in Various Locations for Different Seismic Zones by using Etabs”.

In this paper, the author observes that the maximum displacement and story drift values are significantly higher in seismic zone V across all cases compared to zones II, III, and IV. This indicates that reducing displacement is possible by designing the structure with consistent stiffness. The study further shows that the building configuration with shear walls at all four corners resulted in improved performance, with lower maximum displacement, story drift, and base shear. Consequently, the study concludes that buildings with uniform stiffness offer superior structural performance.

Vineeth Vijayan, M. Helen Santhi and Romy Mohan (2020), "Seismic Performance of High-Rise Buildings with Different Types of Shear Wall".

This paper investigates various types of shear walls, including concrete shear walls, silica fume concrete shear walls, steel plate shear walls, and steel-silica fume concrete composite shear walls, applied to lift walls in 22-story and 52-story high-rise buildings. The seismic performance of these structures is analyzed using the response spectrum method in ETABS. Key factors such as story displacement, story drift, and story shear are examined, and the results indicate a notable reduction in these parameters when compared to traditional concrete shear walls.

Prof. N. K. Meshram, Gauravi Munde (2018), "Seismic Analysis of Shear Wall at Different Location on Multi-storey RCC Building".

The primary objective of this project is to determine the optimal placement of shear walls in a multi-story building. Three different shear wall positions within the building are analyzed using STAAD Pro V8i software. The structures are evaluated based on four key parameters: joint displacement, axial force, bending moment, and base shear. The study concludes that as the mode frequency increases, the period decreases for all models. Additionally, the maximum lateral displacement increases with the building height across all models. The presence of a shear wall positioned at the center of the building results in the minimum lateral displacement, thereby improving the structure's overall performance.

Jonty Choudhary, Dr. P. G. Khare (2018), "Comparative Study and Analysis of Unbraced RCC Frame Structure with Steel Braced RCC Framed Structure using Response Spectrum Method".

The study involved analyzing a G+15 building using the response spectrum method in E-TABS (2015). The building had a plan dimension of 33x15 meters, with a floor-to-floor height of 3 meters, and was located in seismic zone V. The analysis considered several bracing configurations, including X-bracing, Double X-bracing, V-pair, Inverted V-pair, and Inverted V-alternate. The results indicated that the Double X-bracing system was the most effective in minimizing seismic parameters.

A. A. Qureshi, Tarun Magendra, Abhyuday Titiksh (2016), "Optimum Positioning of Shear Walls in Multistorey Buildings".

This paper analyzes four different shear wall placement configurations for a G+10 story building, ensuring zero eccentricity between the center of mass and the center of stiffness. The building is modeled and designed as a frame system using ETABS software. The design process includes load calculations and structural analysis, with the design approach following the Limit State Design method in accordance with the Indian Standard Code of Practice. The performance of all framing systems was studied as part of the analysis. The lateral drift/deflection ratio was evaluated, and it was concluded that a box-type shear wall positioned at the center of the building's layout is the most effective framing solution for high-rise buildings.

Rahul D. Sapkale (2016), "Seismic Response of Multi-Storey Building Equipped with Steel Bracing".

This paper investigates the seismic performance of moment-resisting reinforced concrete frames incorporating different bracing patterns. Three types of bracing systems are considered: X-bracing, V-bracing, and inverted V-bracing. A G+6 story building is modeled and designed according to the provisions of IS-1893:2002, with a linear analysis conducted in the global X direction. Among the bracing systems studied, the X-bracing system demonstrated the best performance, effectively reducing both displacement and story drift.

Anuja Walvekar, H. S. Jadhav (2015), "Parametric study of flat slab building with and without shear wall to seismic performance".

This paper applies the response spectrum method to analyze the structural behavior of a 15-story building, both with and without RC shear walls. Various shear wall placements are explored to assess the impact of their location on the building's performance. The study concludes that positioning the shear walls along the building's perimeter results in the lowest story displacement. Additionally, the story drift values for all floors remain within the allowable limits.

Krishnaraj R. Chavan, H.S.Jadhav (2014), "Seismic Response of RC Building with Different Arrangement of Steel Bracing System".

This research paper presents the seismic analysis of a seven-story reinforced concrete building (G+6) using STAAD Pro V8i software. The seismic load cases are based on the guidelines provided in IS 1893 – 2002. Several types of bracing systems are examined in the structural analysis, including X-bracing, inverted V-bracing, V-bracing, and diagonal bracing. The study concludes that the use of steel bracings does not significantly alter the overall weight of the building. Additionally, the lateral displacement is reduced by 50% to 56% with the application of the X-type steel bracing system, which also minimizes the maximum displacement of the structure.

3. SUMMARY OF LITERATURE AND GAP

A review of the literature highlights that many researchers have investigated various factors and parameters related to seismic forces on multi-story buildings. The models used in these studies are developed through different analytical tools, such as STAAD Pro and ETABS. To minimize story drift and displacement, different configurations of shear wall systems have been tested. Research on bracing systems has explored topics such as the effects of different cross-sectional shapes, comparisons of bracing types based on building geometry, and the impact of the angle between braces. The aim of the remaining analysis is to compare two lateral load-resisting systems, focusing on aspects such as their location, type, and using a specific analytical method.

Researchers have independently studied buildings with either bracing systems or shear walls to evaluate their seismic performance. Various bracing types were examined to assess their impact on the structure's seismic behavior, with many studies finding that X-bracing is more effective than other bracing configurations. Similarly, different shear wall shapes, such as I, T, or L sections, were analyzed individually to understand their influence on the seismic response of buildings. When combining shear walls and bracing, the typical approach was to place the shear walls at the building's core and the bracing systems at the corners.

4. CONCLUSIONS

The seismic performance of multi-storey RC buildings is significantly influenced by the strategic placement of shear walls and the use of bracing systems. Various studies indicate that shear walls, when optimally positioned, provide essential lateral stability and reduce the building's vulnerability to seismic forces. The location and arrangement of shear walls whether at the center or periphery of the structure can drastically impact the building's dynamic response. The consensus across the reviewed studies is that shear walls improve structural rigidity and minimize displacement under earthquake loading, thus enhancing safety and reducing damage during seismic events.

In comparison, bracing systems (both steel and concrete) are also found to be effective in improving the lateral load resistance of RC buildings. Different arrangements of bracing systems (such as X-bracing, diagonal bracing, and coupled shear walls) were explored, and while these systems also contribute to improving seismic resilience, they are less efficient in tall buildings compared to shear walls. In particular, coupled shear walls have been shown to outperform traditional shear walls in terms of reducing overall displacement and improving the building's energy dissipation capacity during earthquakes.

In conclusion, the optimal design for seismic resilience in multi-storey RC buildings involves a combination of shear walls and bracing systems, with careful consideration of their positioning, configuration, and the building's overall design. The integration of advanced modeling techniques and the application of seismic codes are essential in achieving the desired safety and performance standards for high-rise structures in seismic-prone areas.

5. FUTURE SCOPE

Advanced Material Development for Shear Walls and Bracing Systems:

While traditional concrete and steel bracing systems have been extensively studied, there is an emerging opportunity for exploring novel materials such as fiber-reinforced polymers (FRP), high-strength concrete, or smart materials that can enhance the performance of shear walls and bracing systems under dynamic seismic loads. Future research could focus on the durability, sustainability, and cost-effectiveness of these materials in the construction of high-rise buildings.

Integration of Hybrid Systems:

Many studies focus on the use of either shear walls or bracing systems independently. However, there is significant potential for exploring hybrid systems, where shear walls and bracing systems are integrated for a more optimized seismic response. Investigating the interactions and synergies between these systems can lead to better design solutions for high-rise buildings, especially in seismic-prone zones.

Seismic Performance in Different Seismic Zones:

While seismic studies on shear walls and bracing systems are available for various regions, there is still room for more in-depth analysis tailored to specific seismic zones. Understanding how shear wall and bracing performance varies across different seismic classifications, as well as the effects of soil-structure interaction, is critical. Furthermore, integrating multi-hazard analysis (including wind or fire) alongside seismic analysis could provide more holistic design guidelines.

Sustainability and Environmental Impact:

In the context of sustainable construction, future research could explore the environmental impact of shear walls and bracing systems. This includes investigating materials and construction techniques that reduce carbon footprints while maintaining structural integrity. The role of green building certifications and their influence on the design of seismic-resistant structures could also be studied.

Impact of Building Height and Number of Storeys:

As the trend towards taller buildings continues, research could focus on the effectiveness of shear walls and bracing systems in extremely tall buildings (e.g., buildings over 50 stories). These buildings experience more complex load distribution and dynamic responses that might necessitate alternative solutions or hybrid designs. Understanding how the performance of shear walls and bracing systems scales with height could inform future high-rise construction.

Post-Earthquake Damage Assessment and Repair Strategies:

Finally, research could focus on post-earthquake damage assessment of shear walls and bracing systems, exploring innovative methods for quickly identifying and assessing structural damage after an earthquake. This could include the development of automated structural health monitoring systems that provide real-time data for decision-making related to repairs, ensuring that buildings remain operational and safe after seismic events.

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