Grenze International Journal of Engineering and Technology, June Issue

Enhancing Seismic Performance of Reinforced Concrete Structures: A Comprehensive Review of Shear Wall Configurations and Filler Slabs

Janvi Sarode[1], Amruta A. Yadav[2], Sneha G. Hirekhan[3], Nikhil Gaikwad[4] and Sameer Mendhe[5]
[1,2]Department of Civil Engineering, Yeshwantrao Chavan College of Engineering Nagpur, India
Email: janvirs13@gmail.com
[3]Regency Homes Nagpur, MH, India
[4,5]Faculty of Engineering and Technology, Datta Meghe Institute of Higher Education & Research Wardha

***Abstract*—Reinforced concrete (RC) structures, popular designs in construction, boast strength and durability. Consideration of their seismic performance becomes critical in earthquake-prone regions. This article discusses the seismic behavior of these structures, with a focus on shear wall configurations and filler slabs. The intention is to deeply understand their roles, benefits, and possible improvements that enhance seismic resilience. Shear walls provide significant increases in stiffness through lifter strength and produce lower levels of lateral displacements. In this regard, they dissipate the seismic energy through inelastic deformations. Filler slabs reduce the weight of the overall structures, thus less seismic forces acting on them, and induce an improved energy dissipation. Several advances have occurred in relating advanced materials like ultra-high-performance concrete (UHPC) and fiber-reinforced polymers (FRPs) in increasing performance through improvements in the design of these elements. Some of these improved quality controls and reduction of several construction cycles are prefabricated modular construction. The most important aspects of evidence are that the two factors, shear walls, and filler slabs, work best for optimum performance against earthquakes. Research findings provide further direction into newer avenues for research, including smart materials and sensor technologies; performance-based design adoption; and sustainability in seismic design. These improvements are paramount in creating safe and resilient RC structures against damage due to seismic events.**

***Index Terms*—earthquake resilience, filler slabs, prefabrication, reinforced concrete, seismic performance, shear walls.**

I. Introduction

The use of reinforced concrete (RC) structures and applications were so much in demand in construction owing to their strength, versatility, and affordability. Components of such structures consist of concrete reinforced with steel bars or meshes, thus providing excellent compressive strength and enhancing tensile strength. However, their performance during seismic loads causes critical concern for most structures located in an earthquake-prone region. Another critical issue concerning most researchers on the seismic performance of RC structures is the energy absorption and dissipation by the structures caused by seismic waves and, subsequently, the avoidance of catastrophic failure and the occupancy protection.

Grenze ID: 01.GIJET.11.2.245_20

Dynamically induced loads by earthquakes produce shaking, with large amounts of horizontal and vertical forces acting on buildings. Ground shaking should be considered for the structural design of RC structures, depending on appropriate detailing, material selection, and structural configuration. Important parameters affecting the seismic performance of RC structures are stiffness, ductility, and energy dissipation capacity of the building.

Combinations of the fundamental principles that govern a seismic design-including appropriate reinforcement detailing, concrete confinement, and structural elements, such as shear walls and filler slabs-would improve such structures' ability to resist seismic loads.

A. Importance of Shear Walls and Filler Slabs in Enhancing Seismic Resistance

The effects of shear walls and filler slabs are inevitable in the seismic design of any RC structure. Definitely, a shear wall is a vertical structural element that gives lateral stiffness and enhances strength, thus improving the capacity of a building to resist the action of horizontal seismic forces.

Shear walls behave like vertical cantilevers, connecting the superstructure and foundation by transferring seismic input forces downwards, minimizing overall lateral displacements and increasing stability. Shear walls can be classified into coupled, cantilever, and core walls, each of which suits a specific advantage depending on design and seismic requirement for the building. Coupled shear walls consist of two or more walls connected together by coupling beams or slabs to enhance ductility and energy dissipation.

Cantilever walls are simply continuous extending from the foundation to the top of the building, having considerable lateral stiffness and strength. Core walls constitute parts of most buildings, situated generally against elevators or stairwells, which serve as the structural core for increasing torsional resistance. Filler slabs are horizontal structural elements forming floor and roof systems for RC buildings.

These slabs comprise concrete plus lightweight filler material such as hollow blocks, polystyrene, or cellular concrete. This clearly reduces the total weight of the building and therefore seismic forces acting upon it. Furthermore, this improves thermal insulation and acoustic insulation in the building, making it energy efficient and occupant friendly.

In seismic design, the filler slabs distribute the seismic forces through the building system, further constraining the probabilities of occurrence of partial failure. With this additional reduced weight, it makes the demands on the structural elements, such as beams and columns, very much less in volume, which in turn makes them perform better during a seismic event. Thus, with strategic placement of shear walls in associations with filler slabs in RC structures, it is possible to achieve balanced and effective seismic design overall.

B. Objectives of the Review

The primary target of this review is to give a holistic appraisal of the seismic response of RC structures, with emphasis specifically on that of different shear wall configurations together with their filler slabs. The review, therefore, synthesizes existing research and empirical data to:

- Summarize the current state of understanding regarding the contribution of shear walls and filler slabs to the seismic performance of RC structures.
- Compare different configurations of shear walls and filler slabs, highlighting the advantages and disadvantages, if any, under various seismic conditions.
- Highlight critical design considerations and best practices for the incorporation of shear walls and filler slabs into RC buildings to improve their seismic performance.
- Present and discuss some of the recent advances and innovations in the field of seismic design, particularly with respect to shear walls and filler slabs.
- Elaborate future research and development challenges and opportunities for the improvement of seismic performance of RC structures.

Seismic Response of RC Structures

II. LITERATURE REVIEW

A lot has been researched about the performance of reinforced concrete (RC) structures under an earthquake to finally point the way for making them resilient to earthquakes.

The major evaluation has been in seismic behavior of structural components and configurations like shear walls, filler slabs, and different types of bracing.

Experimental and numerically dynamic response and failure mechanisms studies have been directed towards these within seismic loading conditions. The central aim focuses on making more efficient and safer design strategies capable of bearing that forces induced therein.

A. Summary of Key Findings from Previous Studies

Precasting Composite Walls with Reinforced Concrete braces: Huang et al. (2024) numerically investigated the seismic behavior precast composite wall types with different forms of reinforced concrete braces [1]. They found that different bracing configurations such as horizontal, oblique, and V-shape ones had greatly influenced the mechanical properties of PCWs. Among all configurations, horizontal cross-braced walls showed good deformation capacity, oblique cross-braced walls provided the most loading capacity and stiffness, and V-shaped braced walls displayed superior energy dissipation capacity.

Retrofitting Core Shear Wall Systems: Meghdadian and Ghalehnovi (2022) presented a case of retrofitting core RC shear wall systems with openings by including steel plates and FRP sheets [2]. They showed that both methods significantly improved the seismic performance of areas around spandrels acting as seismic fuses. The case study established that augmenting with steel plates was more economical than that utilizing FRP sheets.

Reinforced Masonry Core Walls with Boundary Elements: Mahrous et al. (2022) introduced reinforced masonry core walls with boundary elements (RMCW+BEs) as seismic force resisting systems (SFRS) [3]. Their results of nonlinear history analysis further revealed that RMBCW+BEs effectively controlled the seismic demand upon mid and high-rise buildings. But, they become a challenge to taller structures due to the higher modes of vibration; this necessitates dual plastic hinge design approach to mitigate shear demand and improve seismic performance.

Shaking Table Test of Prefabricated Shear Wall Structures: Zhang et al. (2022) conducted shaking table tests on prefabricated concrete shear wall structures [4]. The specific failure modes included bending-shear composite failure and horizontal interface penetration under strong seismic excitations developed by the structures. The findings necessitate detailed seismic design specific to prefabricated components to avoid collapse.

Seismic and Structural Behavior of Reinforced Rib-Double Steel Plate Shear Walls: Zhou et al. (2024) studied seismic performance of reinforced rib-double steel plate concrete composite shear walls (SCSWs) using finite element analysis [5]. The study established that stiffened ribs improve shear capacity dramatically, ductility, and energy dissipation of SCSWs, thus indicating that this form configuration is appropriate for nuclear power plants and consequently for high-rise buildings.

Effect of Masonry Infill Panels on RC Frame Structures: Panels of masonry infill were subjected to a seismic response examination with regard to RC frame structures. Pushover analysis on in-fills was discovered likely to increase the rigidity and strength given to frames and also demonstrate 503 nonlinear behavior. The images portrayed changes brought by these infills into the seismic response in a manner further emphasizing the need for well consideration in the design.

UHPC tall buildings with ductile coupled shear walls: AlHamaydeh and co-workers (2022) compared the seismic performance of ultra-high-performance concrete with that of conventional high-strength concrete in tall buildings [6]. The use of UHPC specifically improved the seismic behavior and lowered early construction costs, desirable as seismic applications in tall buildings.

Steel Plate Shear Walls for Self-Centering: What a mixed dual lateral force-resisting system formulated by Xie et al. (2023) with regard to incorporation of high-strength moment resisting frames in combination with self-centering steel plate shear walls [7]. An experimental evaluation showed that the system had a stable hysteretic response combined with repairability, feasible in the context of seismic design.

Curved RC Shear Walls: Abdoos-Khaloo (2024) checks out the seismic behavior of the curved RC shear walls (CRCSWs) subjected to cycled loadings [8]. In their experimental research, CRCSWs present along with stable hysteretic responses and no premature failure, indicating theirs being fit for seismic applications, albeit it lacks specific provisions in current codes for such design considerations.

Yan et al. (2024): Seismic Performance of Fabricated Shear Wall Structures Defective by Design: The sleeve grouting defects were the main focus in the study by Yan et al. (2024) on how these defects will affect the seismic performance of prefabricated shear wall types with these faults [9]. Numerical simulations conducted showed that these defects could greatly incur poor seismic responses, thus underlining the need for quality control during construction.

C. Identification of Research Gaps and Areas Needing Further Investigation

The current understanding of the seismic response of RC structures reveals several gaps that require further exploration. While advanced materials such as UHPC show promise, their long-term performance and cost-effectiveness in seismic applications need more investigation. Hybrid systems that integrate different shear wall configurations and damping mechanisms still lack an optimized seismic design, necessitating further research. Additionally, limited studies exist on the behavior of RC structures under severe seismic events and multiple seismic cycles, despite their importance for enhancing resilience and safety [10].

Another critical gap lies in the absence of design code provisions for novel configurations like curved RC shear walls (CRCSWs) and self-centering systems. Over time, comprehensive guidelines should be developed based on extensive experimental and numerical research. Lastly, greater attention must be given to the impact of construction quality on seismic performance, particularly for prefabricated and fabricated components, to ensure the reliability of seismic designs.

III. COMPARATIVE ANALYSIS

A. Comparative Assessment of Shear Walls and Filler Slabs in Terms of Seismic Performance

Shear walls and filler slabs are structural elements that are essentially required in the design of reinforced concrete (RC) structures, more so in regions with severe seismic activity. The structural seismic action is resisted by vertical few elements termed as shear walls, providing the large lateral stiffness and strength necessary for this purpose. The resultant effectiveness is to minimize lateral displacements and avoid structural failure [11]. On the contrary, fillers are applicable as lighter filler material that occupies the tension zone of slabs to lessen the overall seismic forces acting on the structure because it brings down weight.

The seismic performance of shear walls has proved to be one of the most effective ways of improving the lateral load-resisting design of RC structures. Their primary responsibility would be to act as vertical cantilevers resisting lateral forces through their stiffness and strength. The performance of shear walls in earthquake conditions is characterized by high stiffness reducing lateral displacement, and also the shear walls absorb and dissipate the seismic energy released during an earthquake by inelastic deformation that increases the ductile performance [12].

Additionally, Shear walls are connected to the roof slab to resist horizontal forces caused by lateral seismic events with the foundation, thereby providing a continuous load path from roof to foundation in terms of overall structural stability. On their own, filler slabs, when incorporated into the design, would give added reduction to the structure weight, and so would result in a reduction in seismic forces as generated during an earthquake [13, 14].

B. Advantages and Limitations of Each Approach

These walls could deliver certain benefits: their high lateral strength and stiffness significantly improve resistance to lateral load of a building. As they undergo severe inelastic deflections, high ductility and energy dissipation features come along with this. Direct tensions and transmissions offer great energy dissipation and absorption through them in case of an earthquake. Thus, shear walls ensure structural stability by providing continuous load paths to the foundations, often ensuring that seismic forces are transferred efficiently onto the base [15]. However, shear walls also have some drawbacks. They may raise construction costs, due to the procurement of additional materials and labor, and they might impose certain constraints on architecture as well: One cannot use this solution very freely in the flexibility of design for placement of the openings [16].

Now from the same, filler slabs provide base advantages: First, they cause a reduction in a weight of a structure as a whole. Of course, this lessens the forces by earthquake, affecting the building. Less concrete and steel are used in filler slabs, which makes the construction's total material costs lower. Occupants will find an increase in thermal and acoustic insulation standards over solid slabs due to the employment of a hollow structural system [17].

TABLE I. COMPARATIVE ASSESSMENT OF SHEAR WALLS AND FILLER SLABS

Aspect	Shear Walls	Filler Slabs
Seismic Resistance	High lateral stiffness and strength	Reduces seismic forces through weight reduction
Energy Dissipation	High due to inelastic deformations	Moderate, distributed cracking
Structural Stability	Provides continuous load path	Limited contribution to lateral stiffness
Cost	Higher due to additional materials	Lower due to reduced concrete and steel
Architectural Flexibility	Limited due to placement constraints	Higher flexibility in design

IV. CONCLUSION

The effects of shear walls and filler slabs on seismic performance have been appreciated in this review as critical components of the RC structures. Therefore, shear walls are available with great stiffness and lateral resistance to red outcome lateral displacement and absorb seismic energy in inelastic deformation. The filler slab lessens

the total weight of the structural system, thus reducing the seismic forces acting on buildings and promoting better energy dissipation. Most importantly, it shows that shear walls made of these advanced materials such as ultra-high-performance concrete (UHPC) and fiber-reinforced polymers (FRPs) can even further improve the performance of the filler slabs. Modular construction and prefabrication methods have also been linked with better quality control and shorter time of construction coupled with superior seismic performance.
Future Development and Practice will recommend research on the use of smart materials and sensor technologies towards the realization of adaptive and self-monitoring RC structures. The incorporation of performance-based design principles in advancing green seismic design would, moreover, foster more secure and resilient structures. It will also embrace their wider acceptance to ensure the future survivability of RC structures in seismic events. This would result in better safety, efficiency and sustainability for such infrastructures.

REFERENCES

[1] Huang, W., An, Y., Miao, X., Quan, W., & Wang, M. (2024, March). Research on seismic behavior and shear strength of precast composite walls with different reinforced concrete braces. In Structures (Vol. 61, p. 106067). Elsevier.

[2] Meghdadian, M., & Ghalehnovi, M. (2022). Retrofitting of core reinforced concrete shear wall system with opening using steel plates and FRP sheets, A case study. International Journal of Steel Structures, 22(4), 920-939.

[3] Mahrous, A., AbdelRahman, B., & Galal, K. (2022). Seismic response analysis of reinforced masonry core walls with boundary elements. Engineering Structures, 270, 114882.

[4] Zhang, Z. W., Bai, G. L., Qin, C. G., Li, J. R., & Liu, H. Q. (2022, September). Shaking table test of fabricated concrete shear wall structure and study on damage mechanism of strong earthquake. In Structures (Vol. 43, pp. 645-656). Elsevier.

[5] Zhou, L., Li, X., & Li, X. (2024). Numerical investigation on seismic performance of reinforced rib-double steel plate concrete combination shear wall. Nuclear Engineering and Technology, 56(1), 78-91.

[6] Zine, A., Kadid, A., & Zatar, A. (2021). Effect of masonry infill panels on the seismic response of reinforced concrete frame structures. Civil Engineering Journal (Iran), 7(11).

[7] AlHamaydeh, M., Elkafrawy, M., & Banu, S. (2022). Seismic performance and cost analysis of UHPC tall buildings in UAE with ductile coupled shear walls. Materials, 15(8), 2888.

[8] Xie, C., Wang, X., & Vasdravellis, G. (2023). Mechanical behaviour and experimental evaluation of self-centring steel plate shear walls considering frame-expansion effects. Journal of Building Engineering, 72, 106636.

[9] Abdoos, H., & Khaloo, A. R. (2024). Failure mechanism of a curved RC shear wall subjected to cyclic loading: Experimental findings. Engineering Structures, 304, 117703.

[10] Yan, H., Song, B., & Yin, H. (2024). Seismic performance of fabricated shear wall structures with design defects. Journal of Vibroengineering, 26(1), 98-111.

[11] Dang, N., Xu, C., Yu, D., Tu, J., Zhu, W., Wang, J., ... & Zhao, W. (2025). Highly deformable self-sensing cementitious composites enabled by monomer polymerization for full-scale shear wall seismic monitoring. Composites Part B: Engineering, 289, 111948.

[12] Çiçek, O., & Baytaş, A. C. (2024). Seismic Collapse Risk Assessment and Fragility Analysis of Reinforced Masonry Core Walls with Boundary Elements Using the FEMA P695 Methodology. Journal of Building Engineering, 111227.

[13] Ding, J. Y., Feng, D. C., & Galasso, C. (2024). Seismic Fragility Assessment of Regional Building Portfolios Using Machine Learning and Poisson Binomial Distribution. International Journal of Disaster Risk Reduction, 105044.

[14] Zhou, T., Wang, Z. X., Liu, H. B., Yuan, H. Z., Shu, Z. T., & Guo, J. L. (2024). Seismic behavior of a new fabricated concrete grating composite wall structure in rural residences: Shaking table test and finite element analysis. Journal of Building Engineering, 82, 108254.

[15] Zhang, J., Guo, X., Tang, X., & Lata, A. (2024, November). Experimental and numerical simulation of seismic behavior of reinforced concrete frames infilled with refractory straw blocks. In Structures (Vol. 69, p. 107475). Elsevier.

[16] Monical, J., & Pujol, S. (2024, May). A study of the response of reinforced concrete frames with and without masonry infill walls to earthquake motions. In Structures (Vol. 63, p. 106345). Elsevier.

[17] Ebadi-Jamkhaneh, M., Kontoni, D. P. N., & Homaioon Ebrahimi, A. (2024). Assessment of different methods for enhancing progressive collapse resistance of irregular reinforced concrete buildings using pushdown analysis. Arabian Journal for Science and Engineering, 1-23.