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PERFORMANCE OF REINFORCED CONCRETE SHEAR WALLS UNDER LATERAL LOADS: A REVIEW

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ABSTRACT

This paper presents a systematic review of the structural performance of reinforced concrete (RC) shear walls subjected to various types of lateral loading, including wind, earthquakes, and other dynamic forces. It thoroughly examines their load-bearing behavior, common failure modes (flexural, shear, and combined failures), and the critical parameters influencing their response, such as wall geometry, axial load ratio, reinforcement detailing, and boundary conditions. The review integrates a comprehensive synthesis of experimental studies, analytical models, and numerical simulations to evaluate the accuracy and applicability of current predictive tools. Key findings reveal that axial load ratio significantly influences shear wall strength and ductility, with higher axial loads potentially enhancing strength but reducing

Introduction:

Reinforced concrete (RC) shear walls serve as vital vertical structural components that are instrumental in resisting lateral forces and ensuring the stability of buildings during dynamic events. Commonly utilized in medium to high-rise constructions, they enhance lateral stiffness, strength, and energy dissipation capabilities (Edlebi, 2023). By effectively transferring horizontal loads such as those caused by wind, seismic events, and explosions RC shear walls play a key role in minimizing lateral movements, managing inter-story drifts, and mitigating damage to both

lateral deformation capacity. Reinforcement detailing, especially the use of superior transverse reinforcement and boundary elements, is crucial for improving ductility and seismic resilience, as well as enhancing energy dissipation. Furthermore, wall geometry dictates failure modes, with slender walls typically experiencing flexural failure and squat walls being prone to brittle shear failure. Advances in materials like high-performance concrete and fiber-reinforced polymers (FRP) show promise in enhancing shear wall capacity, though they may alter failure mechanisms. Despite significant progress in design and analysis, critical gaps remain, including limited data on ultra-high-performance and recycled materials, complexities in modeling out-of-plane behavior, and the need for real-time health monitoring in operational buildings. Addressing these challenges through future investigations focusing on innovative reinforcement methods, advanced numerical simulations, and real-time monitoring will be crucial for improving the understanding, safety, and sustainability of RC shear walls in modern structural systems.

Keywords: Reinforced Concrete Shear Walls, Lateral Loads, Seismic Performance, Structural Failure Modes and Shear Wall Reinforcement.

Structural and non-structural elements (Deepna et al., 2018). The significance of RC shear walls is particularly evident in seismically active areas, where buildings face unpredictable and often severe lateral forces that can compromise structural integrity and potentially lead to collapse (Reshma et al., 2018). When designed and detailed appropriately, shear walls function as the primary system for resisting seismic forces, absorbing and dissipating seismic energy while preventing excessive deformation (Omar & Ahmed, 2025). The efficacy of RC shear walls in reducing earthquake-related damage has been well-documented through historical seismic occurrences and experimental studies. However, the response of RC shear walls to lateral loads is complex and affected by various factors, including geometric design, reinforcement configuration, material characteristics, boundary conditions, axial load conditions, and construction methodologies (Meghdad Ghaseminia et al., 2023). Furthermore, the performance of shear walls can differ significantly based on whether they are isolated, coupled with other walls, or integrated into dual systems alongside moment-resisting frames (Service et al., 2024).

Over the years, there have been considerable improvements in the design, analysis, and retrofitting of reinforced concrete shear walls. Traditional empirical and code-based design methodologies are increasingly being enhanced or substituted with more sophisticated techniques, including performance-based design, nonlinear finite element modeling, and displacement-based assessment methods (Zameeruddin & Sangle, 2016). Additionally, contemporary advancements in materials and construction technologies such as high-performance concrete, fiber-reinforced polymers, and precast wall systems are being investigated to enhance the structural performance and sustainability of reinforced concrete shear walls. This review seeks to consolidate and synthesize the existing knowledge regarding the performance of reinforced concrete shear walls subjected to lateral loads. It offers a thorough assessment of their behavior, failure mechanisms and the key parameters that affect their response. The paper also examines experimental results, analytical and numerical modeling techniques, together with recent progress in design and retrofitting methods. By pinpointing unresolved issues, this review aids in fostering a deeper comprehension of reinforced concrete shear wall behavior and delineates pathways for future research and innovation in this crucial domain of structural engineering.

Methodology

This review paper adopts a systematic approach to gathering, evaluating, and synthesizing the literature on the performance of reinforced concrete (RC) shear walls under lateral loads. The methodology involves several key steps:

Literature Search and Selection

An extensive literature review was performed across various academic databases, including Google Scholar, Scopus, Web of Science and Engineering Village, to locate pertinent peer-reviewed articles, conference proceedings, technical reports, and books. The search utilized keywords including 'reinforced concrete shear walls,' 'lateral load resistance,' 'seismic behavior,' 'shear wall failure modes,' 'finite element modeling of shear walls,' and 'retrofitting shear walls.' The review covered the period from 2015 to 2025 to incorporate the latest research findings.

Inclusion and Exclusion Criteria

The inclusion criteria for selected studies were:

⇒ Studies focusing on RC shear walls subjected to lateral loads, including seismic, wind, and other dynamic loads.

⇒ Experimental, analytical, and numerical studies on the behavior, failure modes, and performance of RC shear walls.
⇒ Research papers that discuss reinforcement detailing, material properties, and innovative reinforcement techniques.

Exclusion criteria were:
⇒ Studies unrelated to RC shear walls or lateral load performance.
⇒ Research focusing solely on unreinforced or lightly reinforced walls.
⇒ Studies that did not provide sufficient data or methodology.

Data Extraction
Relevant data were extracted from the selected studies, including experimental results, design parameters (e.g., aspect ratio, axial load ratio, reinforcement details), and modeling techniques. Key performance indicators such as lateral load capacity, displacement, failure modes, ductility, and energy dissipation were identified and analyzed.

Synthesis and Analysis
The extracted data were organized and synthesized to identify trends, commonalities, and contradictions across the studies. The performance of RC shear walls under various lateral load scenarios was classified into different behavioral modes: flexure-dominant, shear-dominant, and coupling beam failures. The findings from both experimental and numerical models were compared to highlight the effectiveness of various reinforcement techniques and materials.

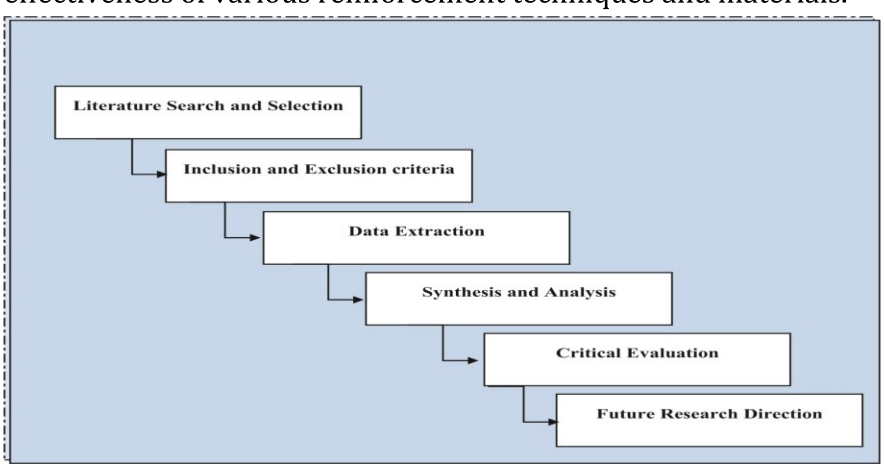

Fig 1: *Flowchart Illustrating the Methodological Approach for Reviewing RC Shear Wall Performance under Lateral Loads*

Experimental Studies on the Performance of RC Shear Walls under Lateral Loads

Reinforced concrete (RC) shear walls have undergone extensive experimental studies due to their essential function in resisting lateral forces from wind, seismic activities, and other dynamic influences. Such research offers critical insights into the intricate, nonlinear behavior of RC shear walls, especially under inelastic loading conditions that are challenging to accurately model using solely analytical or numerical approaches. These investigations assist in validating theoretical frameworks, enhancing design standards, and informing the creation of more robust structural systems. Full-scale, half-scale, and sub-assemblage tests of RC shear walls subjected to both monotonic and cyclic lateral loads have uncovered significant performance characteristics(Kim & Choi, 2015). These tests have explored various factors, including wall geometry (aspect ratio, height-to-length ratio), reinforcement detailing (boundary elements, transverse reinforcement, coupling beams), axial load levels, and the impact of construction materials. Researchers have employed testing setups such as quasi-static cyclic loading frames, shake tables, and hybrid simulation methods to replicate realistic loading scenarios and assess seismic performance(McCrum & Williams, 2016). Key outcomes from these experimental programs reveal that the failure mechanisms of RC shear walls differ markedly based on the wall's design and loading circumstances. For example, slender walls with elevated aspect ratios typically demonstrate flexural-dominated behavior with ductile failure modes, whereas squat walls are prone to brittle shear failure. Coupled shear walls, which link individual wall piers via coupling beams, exhibit enhanced energy dissipation and lateral stiffness but are sensitive to the detailing and strength of the coupling components(G. Q. Li et al., 2019).

Experimental findings have emphasized the importance of boundary element confinement, reinforcement anchorage, and axial load ratios in influencing the overall behavior of walls(Gharaei-Moghaddam et al., 2023). Adequately confined boundary elements enhance ductility and mitigate the risk of premature concrete crushing. Conversely, insufficient detailing or substandard construction practices may result in early bar buckling, shear sliding, or diagonal cracking, thereby jeopardizing the wall's integrity during seismic events(Albutainy & Galal, 2024). Additionally, research has examined the efficacy of retrofitting RC shear walls with advanced materials such as fiber-reinforced polymers (FRP), steel jackets, and engineered cementitious composites (ECC), demonstrating their potential to improve strength, ductility, and post-yield performance(Bedirhanoglu & Ilki, 2018). Experimental investigations have also assessed the performance of innovative wall systems, including precast shear walls, thin-wall systems, and shear walls made with high-performance concrete. In summary, experimental research has played a crucial role in shaping design codes and performance-based seismic design methodologies, providing vital data for the calibration of analytical models and identifying critical failure modes and vulnerabilities in conventional designs. Nevertheless, ongoing testing remains essential to tackle emerging challenges, including the performance of shear walls in tall structures, interactions with non-structural components, and behavior under multi-directional or prolonged loading conditions typical of recent significant earthquakes. This section consolidates key findings from prominent experimental studies and emphasizes prevailing trends, knowledge gaps, and practical implications for the design, construction, and retrofitting of RC shear walls subjected to lateral loading.

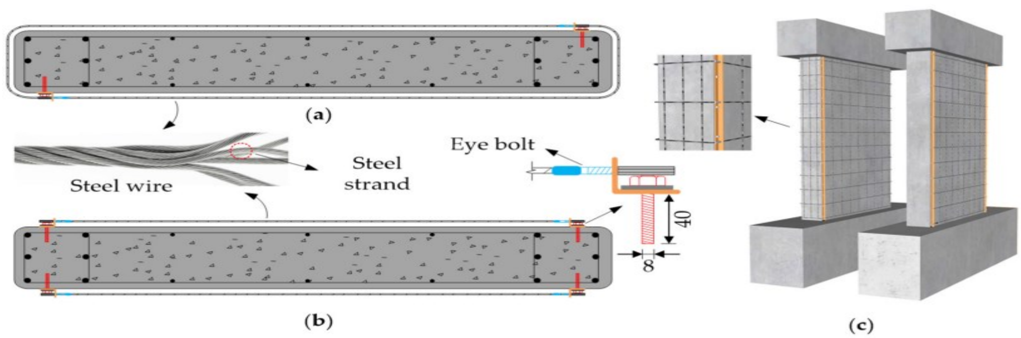

Figure 2: mesh strengthening method: (a)wrapping around surface (b wrapping only on exposed surface (c) elevation(Xie et al., 2022)*.*

Experimental Setup and Test Parameters

Most experimental studies on RC shear walls involve a series of physical tests to simulate real-world conditions(J. Li et al., 2017). These studies generally aim to assess the shear wall's strength, stiffness, ductility, energy dissipation capacity, and failure mechanisms under applied lateral loads. The experimental setups used in these studies typically include:

Table 1: Shows experimental set ups with their descriptions

Experimental set ups	Description
Wall specimens	RC shear walls are often tested as individual units, sometimes in configurations that simulate real building systems, such as single walls, coupled walls, or walls with openings.

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Experimental set ups	Description
Loading type	The majority of experimental studies subject the shear walls to lateral loads that mimic seismic or wind loads. Common loading protocols include cyclic loading (for earthquake simulations) or static monotonic loading.
Boundary conditions	The conditions at the base, top, and sides of the wall (fixed or free) are crucial in determining the wall's behavior. These conditions simulate real-world scenarios where shear walls are part of a building's lateral load-resisting system.
Material properties	Concrete mixes with varying strengths (normal strength, high-strength, and ultra-high-strength) and different types of reinforcement (conventional steel, fiber-reinforced polymer (FRP), etc.) are used in experimental studies to assess their effect on shear wall performance.

Test Parameters

⇒ Aspect ratio (height to thickness ratio)
⇒ Axial load levels (force acting along the axis of the wall)
⇒ Reinforcement detailing (layout and type of longitudinal and transverse reinforcement)

Key Experimental Findings

Experimental results from various studies reveal essential insights into the performance of RC shear walls under lateral loads. Some of the key findings include:

Strength and Stiffness of RC Shear Walls

Shear strength: Several studies have shown that the shear strength of RC shear walls increases with the axial load ratio. Higher axial loads enhance the shear wall's load-bearing capacity but can reduce its lateral deformation capacity (ductility) (Lin et al., 2022). However, excessive axial load can also lead to premature failure due to crushing or buckling.

Stiffness: The initial stiffness of the shear wall is critical in resisting lateral displacements. This is influenced by the wall's geometry (height, thickness, aspect ratio) and the quality of the concrete and reinforcement used(Mamdouh et al., 2022). Walls with higher aspect ratios typically exhibit more flexibility and are prone to flexural failure.

Failure Modes

Several failure modes have been observed in RC shear walls under lateral loads:

Flexural failure: In walls with larger aspect ratios, flexural failure is a common occurrence. This happens when the bending moments exceed the capacity of the wall, leading to the formation of cracks at the boundaries and eventual wall collapse.
Shear failure: In squat shear walls (low aspect ratios), shear failure dominates, and diagonal cracks can form. Experimental studies have shown that shear failure is more brittle than flexural failure and typically occurs when the shear stresses exceed the material strength, leading to the collapse of the wall's core.
Coupling beam failure: In coupled shear walls, the coupling beams connecting the shear wall piers are critical in transferring lateral forces. Failure in these beams can lead to a loss of the shear wall system's effectiveness in resisting lateral loads.
Buckling of longitudinal reinforcement: At high axial loads, longitudinal reinforcement can buckle, compromising the stability and strength of the wall.

Ductility and Energy Dissipation

A significant benefit of reinforced concrete shear walls, especially in seismic areas, is their capacity to absorb energy during earthquakes via inelastic deformation. Research has demonstrated that the ductility of these walls varies according to their design and reinforcement specifications(Rama Rao et al., 2016). Walls that feature evenly distributed and high-quality reinforcement generally exhibit superior performance in energy dissipation, as they can endure considerable inelastic deformation without experiencing early failure.

Influence of Wall Geometry

The geometry of the shear wall (height, thickness, and aspect ratio) plays a crucial role in its performance under lateral loads. Experimental findings have demonstrated that walls with a higher aspect ratio (slender walls) are more prone to flexural failure, whereas squat walls (low aspect ratio) typically fail due to shear(Song et al., 2024). Additionally, wall thickness has been shown to affect both the shear strength and the stiffness of the wall. Thicker walls generally perform better under lateral loads but require more material, which may increase the overall cost.

Study	Specimen Size	Reinforcement Details	Axial Load	Wall Geometry	Loading Type	Failure Mode	Key Results
Study 1	3m x 3m x 0.2m	4% longitudinal, 6mm stirrups	0.2 (low)	High aspect ratio (slender)	Cyclic lateral load	Flexural failure	High ductility, low energy dissipation
Study 2	4m x 4m x 0.3m	2% longitudinal, 8mm stirrups	0.4 (moderate)	Squat wall (low aspect ratio)	Monotonic lateral load	Shear failure	High shear strength, but brittle failure

Study	Specimen Size	Reinforcement Details	Axial Load	Wall Geometry	Loading Type	Failure Mode	Key Results
Study 3	5m x 5m x 0.25m	3.5% longitudinal, FRP wrapping	0.3 (moderate)	Medium aspect ratio	Cyclic lateral load	Mixed failure	Improved strength and ductility with FRP reinforcement
Study 4	6m x 6m x 0.2m	2.5% longitudinal, boundary elements	0.5 (high)	Slender wall (high aspect ratio)	Seismic simulation	Flexural failure	Enhanced seismic performance due to boundary reinforcement

Explanation of the Table

⇒ ***Study:*** Reference to the experimental study.

⇒ ***Specimen Size***: Dimensions of the RC shear wall specimen.

⇒ ***Reinforcement Details:*** Percentage of longitudinal reinforcement, transverse reinforcement type/spacing.

⇒ ***Axial Load:*** The axial load level applied to the wall specimen.

⇒ ***Wall Geometry:*** Description of the wall's aspect ratio or other geometric characteristics.

⇒ ***Loading Type:*** The type of lateral load applied (cyclic, monotonic, seismic simulation, etc.).

⇒ ***Failure Mode:*** The primary failure mode observed during the test (flexural, shear, mixed, etc.).

⇒ ***Key Results:*** Key findings such as strength, ductility, failure characteristics, or material performance.

Summary of Key Takeaways

The findings from the experimental studies indicate that multiple factors have a significant impact on the performance of reinforced concrete (RC) shear walls when subjected to lateral loads. The levels of axial load are particularly important, as increased axial loads can enhance the strength of RC shear walls, but may simultaneously decrease their ductility, thereby heightening the risk of brittle failure. The detailing of reinforcement, especially concerning transverse reinforcement, boundary elements, and longitudinal bars, is essential for enhancing energy dissipation and fostering ductile behavior. Additionally, the geometry of the walls influences the modes of failure, with slender walls generally facing flexural failure and squat walls being more prone to shear failure; hence, it is critical to optimize aspect ratios and wall thickness. Advances in materials, including high-strength concrete and fiber-reinforced polymer (FRP) composites, have demonstrated the potential to enhance the capacity of shear walls, although they may also change the mechanisms of failure. In summary, it is vital to comprehend and design for the primary modes of failure flexural and shear to ensure the safe and effective performance of RC shear walls under lateral forces.

Overview of Modeling Approaches

Modeling approaches for RC shear walls can broadly be categorized into macro-models and micro-models:

Macro-models: These are simplified, computationally efficient models used for global structural analysis. They often represent the wall as a series of elements such as beams, columns, or panels with concentrated plasticity zones (e.g., plastic hinges). These models are suitable for large-scale structural systems and preliminary design assessments.

Micro-models (Finite Element Models): These models capture local behavior such as cracking, crushing, and stress redistribution in detail. They discretize the wall into a fine mesh using shell or solid elements and implement material nonlinearities, making them computationally intensive but accurate for research and validation purposes.

Types of Modeling Techniques

Plastic Hinge Models

Plastic hinge models represent regions in the shear wall where plastic deformation is expected to concentrate. These models are popular in simplified seismic analysis and pushover simulations.

Advantages: Simplicity, fast computation, useful in performance-based design.

Limitations: Less accurate in predicting distributed cracking or complex failure mechanisms.

Fiber-Based Beam-Column Elements

Fiber models divide cross-sections into fibers, each assigned specific material properties. The nonlinear response is calculated by integrating the stress-strain behavior over the section.

Software: Commonly used in OpenSees and Ruaumoko.

Applications: Captures axial-flexural interaction, cyclic degradation, and material nonlinearity.

Finite Element Models (FEM)

Finite element modeling provides the most detailed approach, employing various elements (e.g., shell, solid, or layered elements) and nonlinear constitutive laws to capture:

⇒ Cracking and crushing of concrete.
⇒ Bond-slip behavior.
⇒ Shear-flexure interaction.
⇒ Strain rate effects under dynamic loading.

Notable FEM Software

Software	Features	Strengths
ABAQUS	Explicit and implicit solvers, damage plasticity for concrete	High precision, used in advanced research
OpenSees	Open-source, customizable material models	Good for seismic and performance-based design
DIANA	Advanced concrete and reinforcement modeling	Suitable for complex geometries
ATENA	Focused on RC behavior, fracture-based modeling	Excellent for cracking and post-peak behavior

Table 3: Shows the FEM Software their features and strengths

Analysis Methods

Numerical models employ a variety of analysis strategies depending on the objective:

Analysis Type	Description
Nonlinear Static (Pushover)	Used to determine load-carrying capacity and identify plastic hinge formation zones.
Nonlinear Time-History	Simulates dynamic response under earthquake ground motions.
Incremental Dynamic Analysis (IDA)	Varies earthquake intensity to assess collapse probability.
Eigenvalue/Buckling Analysis	Determines critical modes and stability under lateral loads.

Table 4: Analysis Methods

Key Modeling Challenges and Recent Advances

Despite the progress in modeling RC shear walls, several challenges persist:

Cyclic Behavior and Strength Degradation

⇒ Accurate modeling of pinching, stiffness degradation, and hysteretic energy dissipation remains complex.
⇒ Modern constitutive models such as Menegotto–Pinto and Concrete Damage Plasticity (CDP) have been developed to replicate these effects.

Flowchart of Numerical Modeling Framework

A flowchart can help visualize the step-by-step modeling process for RC shear walls.

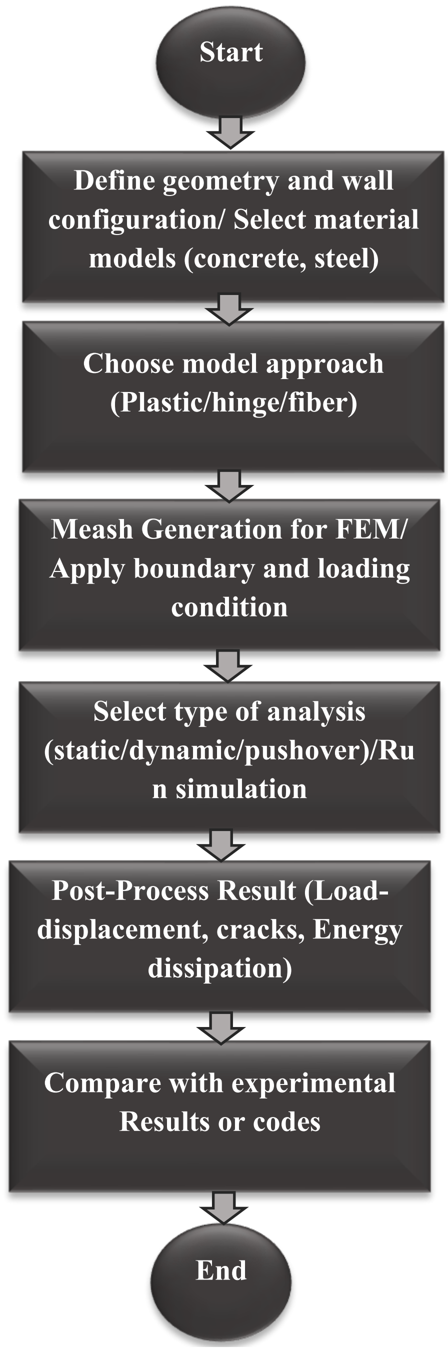


Fig 2: Flowchart of Analytical and Numerical Modeling Process

Future Directions

⇒ AI-Assisted Modeling: Integrating machine learning to predict failure or optimize design parameters.

⇒ Hybrid Modeling: Combining macro and micro approaches for efficiency and accuracy.

⇒ Open-Source Development: Expansion of OpenSees libraries to support more realistic constitutive laws.

Recent Developments and Innovations

In recent years, notable advancements have been made in the design, construction, and performance optimization of reinforced concrete (RC) shear walls, propelled by progress in materials science, digital fabrication, and structural health monitoring. These innovations focus on enhancing strength, ductility, sustainability, and the ability to monitor performance in real-time.

Advanced Retrofitting Techniques Using FRP

Fiber-Reinforced Polymer (FRP) composites have become a popular choice for retrofitting existing RC shear walls. They offer high tensile strength, corrosion resistance, and minimal weight.

⇒ ***Techniques:*** Wrapping walls with carbon or glass FRP sheets; using FRP strips in critical regions.

⇒ ***Benefits:*** Enhanced ductility, confinement, and energy dissipation under seismic loads.

⇒ ***Limitations:*** Bond failure between FRP and concrete, fire resistance concerns.

Table 6: Shows the FRP and description

FRP Type	Material	Strength-to-Weight Ratio	Typical Use
CFRP	Carbon	High	Seismic retrofit
GFRP	Glass	Moderate	Cost-effective retrofits
BFRP	Basalt	Emerging	High-temperature areas

High-Performance and Self-Compacting Concrete

High-Performance Concrete (HPC) and Self-Compacting Concrete (SCC) have been increasingly adopted in shear wall construction to ensure superior strength and workability.

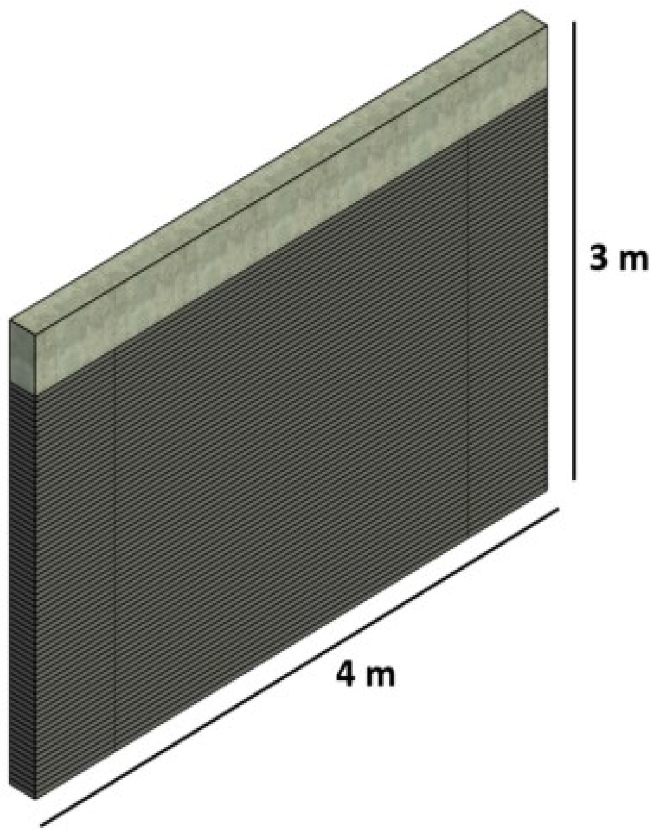
HPC provides high compressive strength (often > 80 MPa), reduced permeability, and better durability.

SCC flows under its own weight, reducing the need for vibration, which is advantageous in congested reinforcement zones.

Prefabrication and 3D Printing in Wall Construction

The adoption of prefabricated RC shear wall panels and 3D-printed formworks has significantly reduced on-site labor and improved construction speed and quality control.

Prefabricated Panels: Produced off-site with precise quality control; facilitate modular construction.



3D-Printed Formworks: Allow for complex shapes, reduced material waste, and reusable molds.

Method	Advantage	Application
Prefabricated Wall Panels	Faster assembly, consistent quality	Modular buildings, high-rises
3D-Printed Formworks	Custom shapes, reduced labor cost	Complex architectural elements

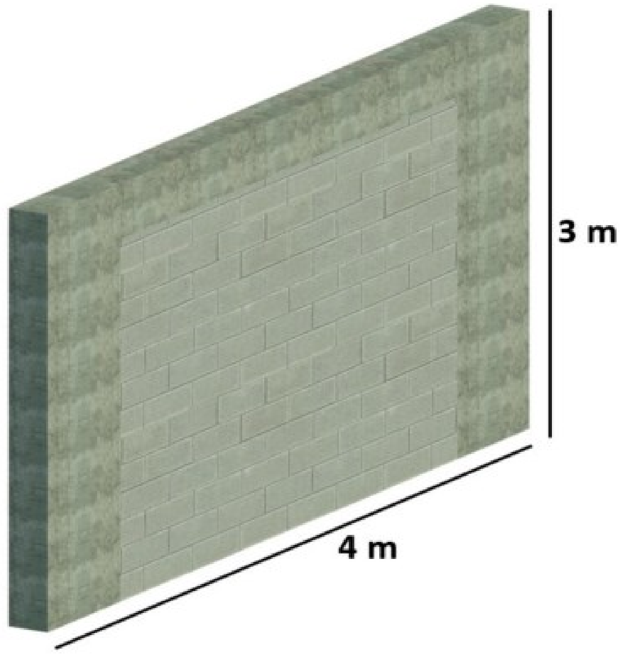
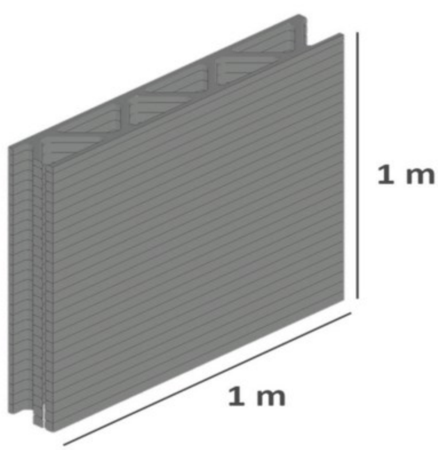


Figure 3 : Conventional construction method(Mohammad et al., 2020)*. Figure 4 : 3DCP construction method with reinforced concrete structural system*(Mohammad et al., 2020)*.*

Smart RC Shear Walls with Embedded Sensors

Smart structural systems are gaining momentum, especially in high-risk seismic regions. Embedding sensors into RC shear walls allows for real-time health monitoring.

Sensor Types: Strain gauges, fiber optic sensors, accelerometers, corrosion sensors.



Benefits: Early damage detection, performance assessment, maintenance scheduling.

Integration: Often coupled with IoT systems and digital twins for remote monitoring.

Summary of Innovations

Innovation	Impact
FRP Retrofitting	Improved ductility and seismic resilience
High-Performance/Self-Compacting Concrete	High-Performance/Self-Compacting Concrete
3D Printing and Prefabrication	Faster, cleaner, and more efficient wall construction
Smart Wall Technologies	Real-time monitoring and data-driven maintenance

Challenges and Research Gaps

Despite the significant advances in the analysis, design and construction of reinforced concrete (RC) shear walls, several critical challenges and research gaps remain that hinder their optimal performance, particularly under extreme lateral loading conditions:

⇒ Inadequate data on ultra-high-performance and recycled material use.
⇒ Limited studies on coupled shear walls in high-rise buildings.
⇒ Modeling complexities in capturing out-of-plane behavior.
⇒ Lack of real-time health monitoring in operational buildings.

Conclusion

This review highlights the critical role of reinforced concrete (RC) shear walls in resisting lateral loads and summarizes key insights from experimental, analytical and numerical studies. While significant progress has been made specifically in reinforcement detailing, modeling techniques and use of advanced materials challenges remain, including limited data on sustainable materials, out-of-plane behavior modeling, and real-time health monitoring. Tackling these gaps through innovative research and practical implementation will be essential for improving the resilience and sustainability of RC shear wall systems in future construction.

References

Albutainy, M., & Galal, K. (2024). Effect of boundary element detailing on the seismic performance of reinforced concrete masonry shear walls. *Engineering Structures*, *300*(February). https://doi.org/10.1016/j.engstruct.2023.117164

Bedirhanoglu, I., & Ilki, A. (2018). Fiber reinforced cementitious composites for retrofit of reinforced concrete members-A Review. *International Workshop on Advanced Materials and Innovative Systems in Structural Engineering: Seismic Practices*, *October*. https://core.ac.uk/download/pdf/162583485.pdf#page=130

Deepna, U., Menon, A. S., & Balamurugan, S. (2018). A comparative study on shear wall concept in accordance to its seismic behavior. *International Journal of Engineering and Technology(UAE)*, *7*(4), 182–187. https://doi.org/10.14419/ijet.v7i4.5.20041

Edlebi, G. (2023). A Review of Enhancing Performance and Sustainability of RC Shear Walls. *Steps For Civil, Constructions and Environmental Engineering*, *1*(1), 38–51. https://doi.org/10.61706/sccee120115

Gharaei-Moghaddam, N., Meghdadian, M., & Ghalehnovi, M. (2023). Innovations and advancements in concrete-encased steel shear walls: A comprehensive review. *Results in Engineering*, *19*(July), 101351. https://doi.org/10.1016/j.rineng.2023.101351

Kim, J., & Choi, H. (2015). Monotonic Loading Tests of RC Beam-Column Subassemblage Strengthened to Prevent Progressive Collapse. *International Journal of Concrete Structures and Materials*, *9*(4), 401–413. https://doi.org/10.1007/s40069-015-0119-2

Li, G. Q., Pang, M. De, Li, Y. W., Li, L. L., Sun, F. F., & Sun, J. Y. (2019). Experimental comparative study of coupled shear wall systems with steel and reinforced concrete link beams. *Structural Design of Tall and Special Buildings*, *28*(18). https://doi.org/10.1002/tal.1678

Li, J., Wang, Y., Lu, Z., & Li, J. (2017). Experimental study and numerical simulation of a laminated reinforced concrete shear wall with a vertical seam. *Applied Sciences (Switzerland)*, *7*(6). https://doi.org/10.3390/app7060629

Lin, Z., Zhang, H., Monti, G., & Castoro, C. (2022). Effects of Openings and Axial Load Ratio on the Lateral Capacity of Steel-Fiber-Reinforced Concrete Shear Walls. *Buildings*, *12*(11). https://doi.org/10.3390/buildings12112032

Mamdouh, H., Zenhom, N., Hasabo, M., Deifalla, A. F., & Salman, A. (2022). Performance of Strengthened, Reinforced Concrete Shear Walls with Opening. *Sustainability (Switzerland)*, *14*(21), 1–32. https://doi.org/10.3390/su142114366

McCrum, D. P., & Williams, M. S. (2016). An overview of seismic hybrid testing of engineering structures. *Engineering Structures*, *118*, 240–261. https://doi.org/10.1016/j.engstruct.2016.03.039

Meghdad Ghaseminia, S., Zahra, T., Thambiratnam, D. P., & Thamboo, J. (2023). Response of RC shear walls with single and double layers of reinforcements subjected to in-plane cyclic loading. *Structures*, *56*(August). https://doi.org/10.1016/j.istruc.2023.105005

Mohammad, M., Masad, E., & Al-Ghamdi, S. G. (2020). 3D Concrete Printing Sustainability : A Comparative. *Buildings*, *10*(245).

Omar, A. H., & Ahmed, G. H. (2025). *Comparative Study for Seismic Response of Various Seismic Force-Resisting Systems Employed in New Buildings in Erbil City Comparative Study for Seismic Response of Various Seismic Force-Resisting Systems Employed in New Buildings in Erbil City*. *April*. https://doi.org/10.32732/jcec.2025.14.2.41

Rama Rao, G. V., Gopalakrishnan, N., Jaya, K. P., & Dhaduk, R. J. (2016). Studies on ductility of shear walls. *Journal of Structural Engineering (India)*, *42*(6), 540–549.

Reshma, T. V, K, S. K., & Arpitha, M. (2018). *Effectiveness of Shear Wall in Seismic Performance of Rc Buildings*. *December*, 1–8.

Service, D., Pvt, C., & License, R. F. (2024). *Comparative Analysis of Different Locations of the Shear Wall in Multi-storey Rc Building on Sloping Ground With Flat Ground*.

Song, Y., Wang, J., & Du, J. (2024). Experimental Study on Seismic Performance of Partially Corroded Squat RC Shear Walls in Coastal Environment. *Buildings*, *14*(2). https://doi.org/10.3390/buildings14020404

Xie, X., Guo, Z., Basha, S. H., & Huang, Q. (2022). A Novel Shear Strengthening of Existing RC Shear Walls Using Steel Wire Mesh and Polymer Mortar. *Buildings*, *12*(2). https://doi.org/10.3390/buildings12020219

Zameeruddin, M., & Sangle, K. K. (2016). Review on Recent developments in the performance-based seismic design of reinforced concrete structures. *Structures*, *6*(February), 119–133. https://doi.org/10.1016/j.istruc.2016.03.001