Wind Load Effects on the Behavior of Composite Shear Wall Systems in High Rise Buildings

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Abstract—**The rapid growth of high-rise and slender buildings in urban areas has increased the demand for lateral load-resisting systems capable of efficiently resisting wind forces, which often govern design in moderately seismic regions. Conventional reinforced concrete (RC) shear walls, while effective, require increased thickness and reinforcement to meet drift and stiffness limits under wind loading, resulting in higher material use and construction challenges. Composite shear walls, combining RC with structural steel components, offer an efficient alternative by enhancing stiffness, strength, ductility, and crack control. This composite action reduces wind-induced lateral displacements and inter-storey drifts, improving serviceability and occupant comfort. This study employs finite element method (FEM) analysis to evaluate the behavior of composite shear walls under wind loads as per IS 875 (Part 3): 2015. Models incorporate material nonlinearity, interface interactions, and realistic boundary conditions to assess lateral displacement, stress distribution, and stiffness degradation. Results demonstrate superior performance of composite walls over conventional RC systems, providing guidance for safer, efficient, and economical wind-resistant design in high-rise buildings in India.**

Index Terms—**Composite shear walls, Wind loads, Lateral displacement, Inter-storey drift, High-rise buildings, Finite Element Method (FEM), Structural performance.**

I. INTRODUCTION

The rapid expansion of high-rise and slender buildings in urban areas has greatly heightened the need for structural systems that can effectively resist lateral loads. Among these, wind forces frequently dictate the design of tall structures, especially in regions with moderate seismic activity. Excessive wind-induced effects can lead to serviceability issues, including large lateral displacements, increased inter-storey drifts, occupant discomfort from acceleration, and long-term fatigue-related damage. As a result, ensuring adequate wind resistance in lateral load-resisting systems has become a crucial consideration in contemporary structural engineering practice.

Shear walls are widely adopted as primary lateral load resisting elements in high-rise buildings due to their effectiveness in controlling lateral deformation. However, conventional reinforced concrete shear walls often require increased wall thickness and reinforcement to satisfy stiffness and drift limits under wind loading, which may lead to higher material consumption and construction challenges. In this context, composite shear walls have emerged as an efficient alternative, combining reinforced concrete with structural steel components such as steel plates, steel sections, or encased steel elements. The composite interaction between steel and concrete enables superior utilization of material properties, resulting in enhanced stiffness, strength, crack control, and overall structural efficiency compared to traditional reinforced concrete systems.

Under wind loading, the behaviour of composite shear walls is governed by complex interactions between flexural stiffness, shear resistance, and axial forces. The presence of steel components improves load transfer mechanisms, delays crack initiation, and enhances post-elastic behaviour, thereby reducing wind-induced lateral displacements and improving serviceability performance. Additional advantages of composite shear walls include reduced wall thickness, improved ductility, faster construction, and better

control over long-term deformation, making them particularly suitable for wind governed high rise structures.

The increasing height and slenderness of modern buildings necessitate accurate prediction of wind-induced structural response. Advanced numerical techniques are required to capture composite action, material nonlinearity, interface behaviour, and complex load–deformation characteristics. Finite Element Method (FEM) based analysis has therefore become an indispensable tool for evaluating the performance of composite shear walls under wind loading.

FEM enables detailed assessment of key response parameters such as lateral displacement, inter-storey drift, stress concentration, cracking patterns, and stiffness degradation. Numerical models employing shell or solid elements for concrete in combination with plate or beam elements for steel components allow realistic simulation of composite behaviour under varying wind load intensities.

In the Indian context, wind loads play a dominant role in the design of tall and slender structures, particularly in coastal, urban, and cyclonic regions. As per IS 875 (Part 3): 2015 – Design Loads (Other Than Earthquake) for Buildings and Structures, wind-induced forces significantly influence both structural safety and serviceability. The code highlights the importance of parameters such as basic wind speed, terrain category, topography, height factor, and dynamic response characteristics, especially for buildings exceeding 50 m in height. Serviceability criteria prescribed by IS 875 (Part 3), including limits on lateral deflection and inter-storey drift, frequently govern the overall structural configuration of tall buildings.

Although composite shear walls offer enhanced stiffness and improved control of wind-induced response, Indian design codes provide limited explicit guidance for their analysis and design under wind loading. This limitation necessitates detailed numerical investigations to evaluate their performance and to supplement existing code provisions. Finite element modelling, when combined with wind load calculations based on IS 875 (Part 3), provides a robust framework for simulating realistic structural behaviour by incorporating appropriate material properties, composite interaction, and boundary conditions.

Despite extensive research on the seismic behaviour of composite shear walls, studies focusing specifically on their wind-induced response using high fidelity FEM models remain limited. Addressing this gap, the present study investigates the structural behaviour of composite shear walls subjected to wind loads defined in accordance with IS 875 (Part 3) using finite element analysis. The study focuses on evaluating lateral displacement, stress distribution, and stiffness characteristics, with particular emphasis on serviceability performance. The findings aim to enhance understanding of composite shear wall behaviour under wind loading and contribute to the development of safer, more efficient, and economical wind-resistant design strategies for high rise buildings in India.

Composite shear walls are structural systems that combine steel plates, reinforced concrete, steel sections, and reinforcement to create a hybrid lateral load-resisting element. There are various types of composite shear walls, and their hybrid nature effectively addresses the limitations associated with conventional reinforced concrete (RC) shear walls and steel plate shear walls, offering improved strength, stiffness, and ductility. A critical aspect of composite shear wall technology is the use of shear connectors, which link the steel components to the concrete, ensuring full composite action and efficient load transfer between materials. Boundary columns, located along the edges of the wall, primarily resist gravity loads while also counteracting overturning moments caused by lateral forces. Similarly, boundary beams at the top and bottom of the wall serve as anchors for the tension field action of the steel plates and act as compression-bearing elements. The connection of the steel shear wall to these boundary elements is achieved through bolted or welded joints, which maintain structural integrity and ensure coordinated interaction between the steel and concrete components.

II. REVIEW OF LITERATURE

Composite shear walls, particularly steel plate–reinforced concrete (SPRC) systems, have gained significant attention as efficient lateral load-resisting elements for high-rise buildings, combining the advantages of reinforced concrete and steel plates. Several studies have demonstrated their superior

performance in resisting lateral loads and seismic forces compared to conventional reinforced concrete (RC) shear walls.

Praseedha and Bhavya (2019) investigated the seismic performance of steel plate–concrete composite shear walls, highlighting the interaction between steel plates and concrete infill as a critical factor in enhancing lateral stiffness, load-carrying capacity, and ductility. Their study showed that composite action improves confinement of the concrete core, delays cracking, and results in stable hysteretic behavior with enhanced energy dissipation under seismic loading. Proper connection and bonding between steel plates and concrete were found essential to mobilize full composite action and ensure uniform stress distribution.

Dastfan and Driver (2016) conducted experimental studies on modular steel plate shear walls (SPSWs) integrated with partially encased composite columns. Results indicated high lateral strength, stable post-yield behavior, and improved ductility, with the infill steel plates resisting shear forces via tension field action and the encased columns providing additional confinement and stiffness. The modular configuration also demonstrated advantages in constructability and repairability under cyclic loading.

Hargunani and Rasal (2023) provide a comprehensive review of advancements in composite walling and shear wall design aimed at enhancing seismic resilience in high-rise buildings. Their study synthesizes a wide range of research covering the behavior, performance, and benefits of composite and hybrid shear wall systems under lateral and seismic loads. The review highlights how composite walling systems such as those combining profiled steel sheeting with infilled concrete offer improved lateral resistance, stiffness, ductility, and energy dissipation compared with conventional reinforced concrete shear walls, making them increasingly suitable for tall structures in seismic regions. The study also discuss diverse structural configurations, material combinations, and analytical approaches used to optimize seismic performance and identify current design methodologies and gaps in research, emphasizing the need for further investigation into advanced composite materials and refined modeling techniques to better predict real-world seismic behavior. This review contributes to a deeper understanding of the state of the art in seismic shear wall technology and informs future developments in high-rise seismic design.

Earlier research on SPRC shear walls (Paulay & Priestley, 1992; Wang, Jiang, & Lu, 2017) established their effectiveness in enhancing seismic resilience through improved energy dissipation, delayed cracking, and favorable failure modes. Studies by Song et al. (2015) and Lee et al. (2016) emphasized the influence of steel plate placement, boundary detailing, and reinforcement layout on lateral stiffness, ductility, and energy dissipation. Complementary numerical analyses (Zhang & Li, 2014; Wang et al., 2017) further explored nonlinear behavior under seismic loads, enabling parametric studies that are difficult to capture experimentally.

Recent research by Haridas and Rasal (2021) provides a comprehensive overview of the seismic behavior of composite shear walls, highlighting their effectiveness as lateral load resisting systems for high rise buildings. The study emphasizes how the integration of steel and concrete in composite shear walls enhances stiffness, strength, and ductility, making them particularly suitable for structures subjected to significant lateral forces. Building on this, Hargunani and Rasal (2023) conducted a comparative analysis of composite shear walls and conventional reinforced concrete systems, demonstrating that composite configurations offer superior lateral load resistance, improved energy dissipation, and greater serviceability. Both studies underline the importance of composite action between steel and concrete in optimizing structural performance under seismic and lateral loading conditions. Collectively, these investigations contribute to a growing body of evidence supporting the adoption of composite shear walls in high-rise construction, offering a more efficient, robust, and resilient alternative to traditional reinforced concrete systems. Haridas and Rasal (2022) studied the seismic behavior of high-rise buildings with various composite shear wall configurations, including steel plate encased and double-skin walls. Using analytical modeling, they showed that composite shear walls provide higher stiffness, reduced lateral displacements, and lower inter-storey drift compared to conventional RC walls. The study highlights the importance of composite action between steel and

concrete, demonstrating that optimal design and detailing of these walls can significantly enhance seismic performance while allowing thinner wall sections and more efficient material use.

Despite extensive research on composite shear walls and SPRC systems, several important gaps remain. Most studies have primarily focused on regular wall geometries subjected to uni-directional seismic loading, leaving the performance of irregular or asymmetric configurations under multi-directional forces largely unexplored. The influence of soil structure interaction (SSI), particularly in soft or layered soils, has received limited attention, even though it can significantly affect the seismic response of high-rise buildings. Additionally, while experimental and numerical studies have evaluated material combinations, boundary detailing, and steel-concrete interaction, there is a lack of comprehensive investigation into advanced composite materials, prefabricated systems, and optimized wall configurations for practical construction. Further research is also needed to refine analytical and numerical modeling techniques to more accurately predict real world seismic behavior and serviceability performance. Addressing these gaps is critical to improving design guidelines, structural safety, and the efficient application of composite shear walls in earthquake-prone high rise construction.

III. OBJECTIVES OF THE STUDY

The aim of this study is to investigate and evaluate the behavior of multistory buildings subjected to wind loads, with particular emphasis on the comparative performance of buildings incorporating composite shear walls and conventional reinforced concrete (RCC) shear walls. The study focuses on understanding how different shear wall systems influence the overall structural response under wind-induced forces.

To achieve this aim, the dynamic behavior of multistory buildings under wind gust loading is examined in detail. A comparative assessment is carried out to evaluate joint deflections in buildings with composite shear walls and RCC shear walls. The study further analyzes and compares the story drift response of buildings equipped with these two shear wall systems to assess serviceability performance.

IV. METHOD OF ANALYSIS

The numerical problem considered in this thesis involves the analysis of a rectangular-shaped multistory building having a length-to-breadth (l/b) ratio of 5 and a total plan area of 1125 m². The building is modeled as a 75 m tall structure to represent a typical high-rise residential building. The materials adopted for the study include M30 grade concrete and Fe 500 grade reinforcement steel, while the steel plates used in composite shear walls are of Fe 250 grade. These material properties are selected in accordance with relevant Indian Standard specifications to ensure realistic and code-compliant structural behavior.

The modelling and analysis of the building are carried out using ETABS software. The buildings considered for the study are residential in nature, and all loadings are applied in accordance with IS 875 (Part 1) and IS 1893:2002.

Loads are assigned using uniform load sets in ETABS. Typical floor finish loads of 1.5 kN/m² and live loads of 2 kN/m² are considered for residential floors, resulting in a total load of 3.5 kN/m². For toilet areas, finish and live loads of 2.5 kN/m² and 2 kN/m² respectively are applied, giving a total load of 4.5 kN/m².

Chajjas are assigned a finish load of 0.75 kN/m² and a live load of 1 kN/m², resulting in a total load of 1.75 kN/m². Lobby areas are modeled with finish and live loads of 1.5 kN/m² and 3 kN/m² respectively, giving a total load of 4.5 kN/m².

Staircases are assigned higher loads of 5 kN/m² as finishes and 3 kN/m² as live loads, resulting in a total load of 8 kN/m². For the terrace, finish and live loads of 4 kN/m² and 2 kN/m² respectively are considered, giving a total load of 6 kN/m², while service slabs are assigned finish and live loads of 1 kN/m² and 2 kN/m² respectively, resulting in a total load of 3 kN/m².

The self-weight of all structural members is not explicitly defined, as ETABS automatically accounts for the dead load when the self-weight multiplier is set to 1. For all other load patterns, the self-weight multiplier is maintained as zero to avoid double counting of dead loads

V. STRUCTURAL MODELLING

For the analysis of wind effects on the building, wind load parameters are selected in accordance with

relevant provisions of IS 875 (Part 3). The terrain category considered is Category 3, representing built-up areas with closely spaced obstructions. The basic wind speed adopted for the study is 44 m/s. An importance factor of 1.0 and a risk coefficient of 1.0 are used, indicating a standard residential building with normal design life and importance. The terrain, height, and structure size factor (K_2) is taken as 1.0, while the topography factor (K_3) is also assumed as 1.0, considering flat terrain without significant topographical features. The external pressure coefficients (C_p) are taken as 0.8 for the windward face and 0.5 for the leeward face, which are applied to evaluate the wind pressure acting on the building surfaces.
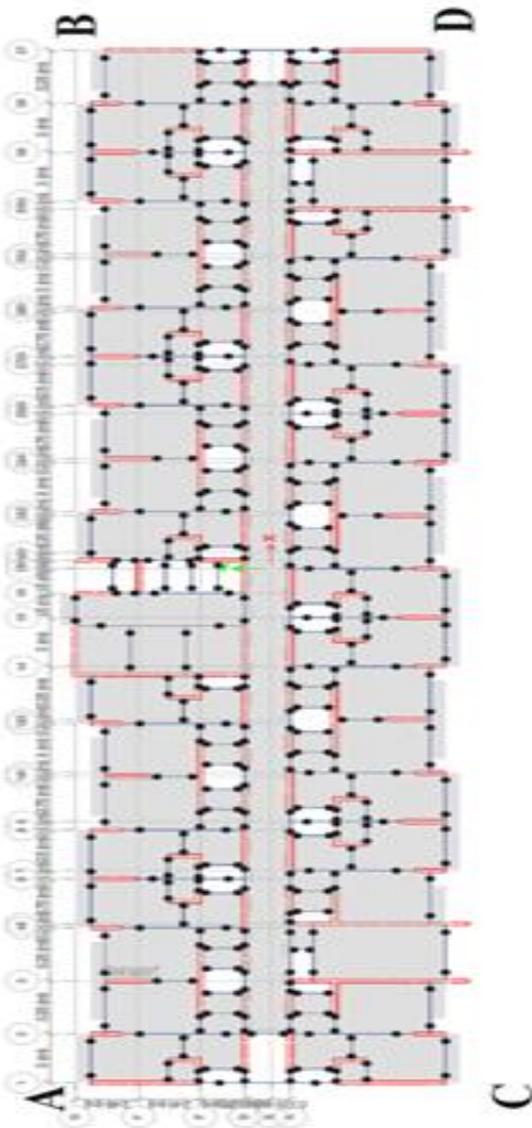

Fig. 1: Plan Layout

The plan shows a typical multistory building layout with composite shear walls. It illustrates:
• Shear wall locations (both perimeter and internal),
• Column layout,
• Nodes where responses are evaluated (A, B, C, D),
• Span dimensions for analysis,
• Reinforcement/steel plate indications (red lines) for composite walls.

Diaphragms are horizontal structural elements that play a crucial role in resisting and transmitting various types of loads and in firmly tying the vertical structural elements together. In ETABS, diaphragms are primarily classified into two types: rigid and semi-rigid. A rigid diaphragm is assumed when the in-plane stiffness is sufficiently large such that no relative movement occurs between any two nodes within the diaphragm. In this case, ETABS constrains all nodes within the diaphragm extent to move together with the center of rigidity, assuming infinite in-plane stiffness. In contrast, a semi-rigid diaphragm accounts for the actual in-plane stiffness of the floor slab and its interaction with the vertical lateral load-resisting system, resulting in a more accurate and realistic representation of structural behavior. Therefore, in the present study, semi-rigid diaphragms are modeled in ETABS to capture the combined action of the floor system and vertical elements under wind loading.

VI. RESULT AND DISCUSSION

1. Displacement

The graphical representation of the two load cases, WY-X and WY+X, clearly illustrates the displacement behavior of the RCC and composite shear wall systems at the four corners (A, B, C, and D) in the Y-direction. For the WY-X load case, RCC exhibits the highest displacements of 79.257 mm at A, 98.765 mm at B, 79.265 mm at C, and 97.765 mm at D. COMPOSITE-I reduces these displacements to 70.260 mm at A, 97.450 mm at B, 70.240 mm at C, and 97.452 mm at D, representing moderate improvements. COMPOSITE-II further lowers the displacements to 62.077 mm at A, 86.647 mm at B, 62.087 mm at C, and 86.647 mm at D, while COMPOSITE-III shows very similar values of 62.151 mm at A, 86.423 mm at B, 62.758 mm at C, and 86.422 mm at D.
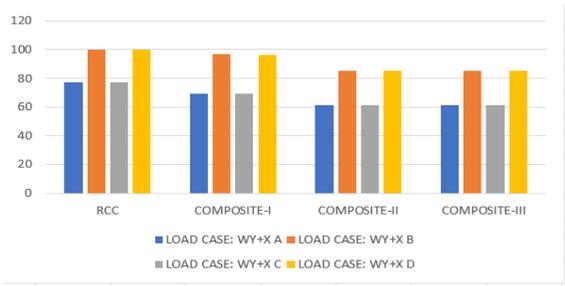
Fig. 2: Displacement behavior of the RCC and composite shear wall systems at the four corners (A, B, C, and D) for load case WX+Y

For the WY+X load case, RCC displacements are 77.307 mm at A, 99.853 mm at B, 77.100 mm at C, and 99.872 mm at D. COMPOSITE-I reduces these to 69.251 mm at A, 96.751 mm at B, 69.251 mm at C, and 96.452 mm at D, while COMPOSITE-II further decreases the values to 61.242 mm at A, 85.243 mm at B, 61.322 mm at C, and 85.322 mm at D. COMPOSITE-III shows almost identical performance with 61.321 mm at A, 85.330 mm at B, 61.322 mm at C, and 85.324 mm at D.

In both load cases, corners B and D consistently exhibit higher displacements than corners A and C, indicating asymmetric lateral deformation. Overall, the graphs reinforce the trend observed in the graphs: RCC > Composite-I > Composite-II ≈ Composite-III, highlighting that COMPOSITE-II and COMPOSITE-III are the most effective in reducing lateral displacements and improving structural stiffness under both positive and negative X-direction lateral loads.

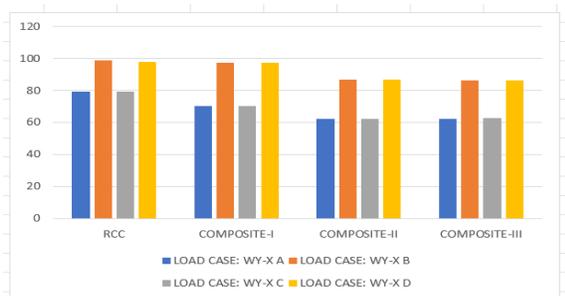The graphical representation of these two cases is shown below

Fig. 3: Displacement behavior of the RCC and composite shear wall systems at the four corners (A, B, C, and D) for load case WX-Y

The graphical representation of the two load cases, WY-X and WY+X, illustrates the displacement of the four corners (A, B, C, and D) in the Y-direction for RCC and composite shear wall systems. For the **WY-**

X load case, the RCC system exhibits the highest displacements, with 79.257 mm at corner A, 98.765 mm at B, 79.265 mm at C, and 97.765 mm at D. COMPOSITE-I reduces these values to 70.260 mm at A, 97.450 mm at B, 70.240 mm at C, and 97.452 mm at D, showing moderate improvement. COMPOSITE-II shows further reduction, with displacements of 62.077 mm at A, 86.647 mm at B, 62.087 mm at C, and 86.647 mm at D, while COMPOSITE-III exhibits similar performance, with 62.151 mm at A, 86.423 mm at B, 62.758 mm at C, and 86.422 mm at D.

For the WY+X load case, RCC displacements are slightly lower at 77.307 mm at A, 99.853 mm at B, 77.100 mm at C, and 99.872 mm at D. COMPOSITE-I reduces these to 69.251 mm at A, 96.751 mm at B, 69.251 mm at C, and 96.452 mm at D. COMPOSITE-II further lowers displacements to 61.242 mm at A, 85.243 mm at B, 61.322 mm at C, and 85.322 mm at D, while COMPOSITE-III shows almost identical values of 61.321 mm at A, 85.330 mm at B, 61.322 mm at C, and 85.324 mm at D.

In both graphs, corners B and D consistently show higher displacements than A and C, reflecting asymmetric lateral deformation likely due to load distribution or boundary effects. The graphs clearly demonstrate the trend observed in the graphs: RCC > COMPOSITE-I > COMPOSITE-II ≈ COMPOSITE-III, highlighting that composite shear wall systems, particularly COMPOSITE-II and COMPOSITE-III, are more effective in reducing lateral displacements and improving structural stiffness under both positive and negative X-direction lateral loads.

2. Story drift
To compare the story drifts, tabular data of story drifts are exported to Excel from ETABS and then based on that maximum story drift in model with RCC shear wall was observed to occur in Y directions load cases and maximum drift was found to be on 11th floor. This story drifts were then compared with the story drifts of models with Composite shear walls.
It can be seen that comp shear wall show lesser drifts as compared to RCC. Type I type of composite shear walls show around 6 percent decrease in story drift and Type II and III type of shear walls show 16 to 18 percent reduction on 11th floor.
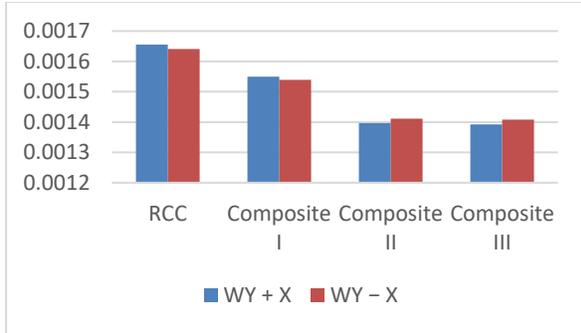
Fig. 5: Storey drift 11th floor

The graph presents the story drift values at the 11th floor for different structural systems, namely RCC, Composite I, Composite II, and Composite III, under two seismic load combinations: WY + X and WY − X. For the RCC structure, the story drift values are 0.001656 for WY + X and 0.001641 for WY − X. These are the highest drift values among all the systems considered, indicating comparatively lower lateral stiffness and greater lateral deformation under seismic loading.

In Composite I, the story drift reduces to 0.001550 (WY +X) and 0.001539 (WY−X). This reduction demonstrates an improvement in lateral stiffness over the RCC structure due to the contribution of composite action, which helps resist lateral forces more effectively.

A further reduction in story drift is observed in Composite II, with values of 0.001396 under WY + X and 0.001411 under WY − X. This indicates a significant enhancement in lateral load-resisting capacity compared to both RCC and Composite I systems.

The lowest story drift values are recorded for Composite III, with 0.001392 (WY + X) and 0.001408 (WY − X). This shows that Composite III provides the maximum stiffness and best seismic performance at the 11th floor among all the configurations analyzed.

Across all structural systems, the difference between the WY + X and WY − X load cases is minimal, suggesting that the structure exhibits nearly symmetrical behavior under positive and negative seismic loading directions.

Overall, the graph clearly indicates that composite structural systems are more effective than RCC structures in controlling story drift, with Composite III showing the most efficient performance, thereby enhancing structural stability and serviceability at higher floor levels.

Figure 5 illustrates the comparison of story drift at the 11th floor for RCC and different composite structural systems under WY+X and WY−X load combinations. The RCC structure shows the highest drift values, indicating greater lateral displacement under seismic loading.

All composite systems exhibit lower story drift compared to RCC, reflecting increased stiffness and improved lateral load resistance. Among them, Composite III shows the minimum story drift, followed by Composite II, while Composite I show a moderate reduction.

The drift values for WY+X and WY−X load cases are closely spaced for all systems, indicating nearly symmetrical structural behavior in both loading directions. Overall, the graph demonstrates that composite structures are more effective in controlling story drift at higher floors than conventional RCC structures.

VII. CONCLUSION

The present study investigates the wind-induced behavior of high-rise buildings incorporating composite shear walls in comparison with conventional reinforced concrete (RCC) shear walls using finite element based numerical analysis.

- The results clearly demonstrate that composite shear wall systems exhibit superior structural performance under wind loading conditions as prescribed by IS 875 (Part 3).
- Compared to RCC shear walls, composite configurations significantly reduce lateral displacements at critical corner locations, indicating enhanced global stiffness and improved serviceability performance.
- Among the composite systems studied, Composite-II and Composite-III consistently showed the lowest displacements under both WY+X and WY−X load cases, highlighting their effectiveness in controlling wind-induced responses.
- Story drift analysis further confirms the advantages of composite shear walls. The maximum story drift was observed at the 11th floor in RCC structures, whereas all composite systems showed notable reductions.
- Composite-I achieved a moderate reduction in drift, while Composite-II and Composite-III exhibited substantial reductions in the range of approximately

16–18%, demonstrating significantly improved lateral load-resisting capacity.

- The close agreement of results for positive and negative wind load directions indicates near-symmetric structural behavior, validating the robustness of the modeling approach.

Overall, the findings establish that composite shear walls provide enhanced stiffness, reduced lateral deformation, and improved serviceability compared to conventional RCC shear walls, while potentially allowing thinner wall sections and more efficient material utilization.

The study highlights the suitability of composite shear wall systems for wind-governed high-rise buildings in the Indian context and emphasizes their potential for safer, more economical, and performance-efficient structural design. The outcomes of this research contribute valuable insight toward advancing wind-resistant design strategies and support the wider adoption of composite shear wall systems in modern high-rise construction.

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