Numerical and experimental analysis on seismic behaviour of reinforced cement concrete shearwall

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***Abstract*—Evaluating the seismic performance of Reinforced Cement Concrete (RCC) shear walls is essential for developing earthquake-resistant structures. This study employs ETABS and Abaqus software to perform a detailed analysis of RCC shear walls, focusing on critical parameters such as material properties, wall thickness and aspect ratio. Time history analysis is used to investigate the dynamic response of these structural elements under seismic loading conditions.In ETABS, the analysis emphasizes the evaluation of structural displacements, natural frequencies, and mode shapes to identify key factors that influence seismic performance. Abaqus is utilized to simulate the response of RCC shear walls under dynamic earthquake loads, with particular attention to nonlinear material behaviors including strain rate sensitivity and fatigue damage. Parameters such as energy dissipation, joint acceleration, and compressive and tensile behavior are examined to gain a comprehensive understanding of structural response.The results of this study offer valuable insights into the seismic durability and overall resilience of RCC shear walls, contributing to improved design practices for earthquake-prone regions.**
shear walls

***IndexTerms*—RCC, ABAQUS, Shearwall, ETABS, Time History Analysis.**

I. INTRODUCTION

According to Fintel (1991), a renowned consulting engineer in the United States, "We cannot afford to design concrete buildings built to endure severe earthquakes without shear walls." Shear walls, also referred to as structural walls, play a crucial role in resisting lateral forces caused by seismic events, wind, or other horizontal loads acting within the plane of the wall. While the term "shear wall" may seem somewhat misleading, especially at high aspect ratios where these walls exhibit flexural behavior akin to beams or columns, their primary function remains to safeguard the overall stability of structures during lateral load excitation.

Shear walls are most commonly employed in tall structures, where their presence has been shown to greatly enhance resilience against earthquake-induced forces. By efficiently transferring lateral loads from columns to walls of greater stiffness, designers can significantly reduce bending stresses experienced by columns, thereby preventing catastrophic structural failure. The strategic integration of shear walls is thus essential for the safety and performance of multi-storey buildings in earthquake-prone regions.

Shear walls may be classified based on their shape and configuration. Common types include coupled shear walls, simple rectangular versions (which may or may not have additional boundary elements), nonrectangular shapes such as T- or C-type walls, and box-type walls. Rectangular shear walls provided with boundary features at the edges tend to offer higher strength and ductility. These walls are subjected to complex stress states comprising axial forces, flexural moments, and in-plane shear due to combined vertical and horizontal loading.

For the in-depth analysis and design of such structural elements, advanced software tools are widely adopted in research and industry. ETABS (Extended 3D Analysis of Building Systems) is a comprehensive tool for modeling, analysis, and design of structural systems such as buildings, bridges, dams, and towers. It allows engineers to simulate real-world load conditions and accurately predict structural behavior under various scenarios. Meanwhile, Abaqus, a powerful finite element analysis suite developed by Dassault Systems Simulia Corp., offers both explicit and implicit analysis solvers. The explicit solver is particularly well-suited to dynamic and transient simulations involving large deformations, whereas the implicit solver is ideal for static and quasi-static structural analysis.

The present study is focused on numerically investigating the seismic behaviour of reinforced cement concrete (RCC) shear walls using both ETABS and Abaqus software platforms. The primary objectives are to determine the dynamic characteristics of RCC shear walls, including their natural frequencies, displacements, and response to seismic loading. Key response parameters such as structural displacement, velocity, frequency, and joint acceleration are analyzed, thereby providing valuable insights into the performance and potential failure modes of shear walls subjected to earthquake loads. This dual-software approach aims to enhance both the accuracy and reliability of the numerical predictions, forming a strong foundation for further experimental validation and practical structural design improvements.

II. LITERATURE REVIEW

1) Edosa Megarsa (2022): This study focused on the shear performance of reinforced concrete (RC) beams enhanced with RCC composites. It revealed that increasing the diameter of wire mesh significantly improves the ultimate load failure, shear capacity, and stiffness of RC beams. However, increasing the spacing between wires results in a decline in performance. The optimal number of mesh layers was found to be three, beyond which no significant improvement in shear performance was observed. Hence, using three layers of mesh is considered the most efficient and cost-effective solution for improving RC beam shear behavior.

2) Yousry B.I. Shaheen (2021): An experimental investigation into RCC box shear walls with and without webs (ribs) under vertical loads demonstrated that ribs substantially improve the structural performance of these walls. The study compared walls reinforced with double layers of welded and expanded wire meshes, concluding that welded mesh offers superior results. The walls were analyzed using ANSYS simulation, which showed good agreement with experimental data, confirming that the presence of ribs and the type of reinforcement significantly influence strength, ductility, and crack behavior.

3) G.V. Rama Rao (2016): This research investigated the factors affecting the ductility of shear walls using nonlinear finite element modeling in ABAQUS with the Concrete Damaged Plasticity model. The study emphasized that ductility is influenced by aspect ratio, axial load level, and reinforcement percentages. To ensure a ductile seismic response, it was recommended that the axial load on a shear wall should not exceed 30% of its ultimate axial capacity. The findings led to valuable recommendations for modifying codal provisions to enhance ductile design practices in seismic zones.

4) N. Gopala Krishnan (2016): The nonlinear behavior of medium aspect ratio shear walls was analyzed under monotonic and cyclic loading conditions. Using both experimental testing and a layer-based analytical model, the study assessed plastic rotation, stiffness degradation, and ductility. Results showed distinct differences between monotonic and cyclic behavior, highlighting the importance of including cyclic load effects in design. The analytical pushover curves closely matched experimental ones, validating the modeling approach and reinforcing the significance of axial load influence on flexural response.

5) Rohit et al. (2013): This research derived expressions for the ultimate moment of resistance in RC walls based on equilibrium and strain compatibility without assuming secondary compression failure. The study challenged the overstrength moment capacity ratio of 1.4 provided by IS 13920, demonstrating that it was conservative across all axial load ratios. Furthermore, the research accounted for concrete confinement effects on the P-M interaction curve, indicating a need to revise IS 13920 to reflect more realistic moment capacities, ultimately aiming for safer and more economical wall design.

III. SHEAR WALL

The detailing of reinforcement in shear walls is a critical aspect of ensuring both structural integrity and ductility under seismic loading. For this study, the wall specimen was designed with specific dimensions comprising a height of 1000 mm, a width of 500 mm, and a thickness of 60 mm. These compact dimensions are suitable for laboratory-scale investigation while representing typical ratios seen in practice.

The reinforcement design strictly adheres to the guidelines stipulated in IS: 13920 – 2016. The design process began with gathering all relevant data, followed by classifying the section based on its height-to-width (h/w) ratio. According to the code, shear walls with $h/w \leq 1$ are categorized as squat walls, those with $1 < h/w \leq 2$ as intermediate walls, and $h/w > 2$ as slender walls.

For horizontal shear reinforcement, the code provides clear prescriptions if the shear stress (τv) exceeds 0.25 N/mm² or if the wall thickness (tw) is greater than 200 mm. The maximum permissible spacing for horizontal reinforcement should not exceed the least of: one-fifth of the horizontal length (Lw) of the wall, three times the wall thickness (tw), or 450 mm. In this study, the detailed reinforcement layout comprises vertical main bars of 6 mm diameter spaced at 100 mm intervals, providing a total of 10 bars over the wall width. Horizontal reinforcement consists of 4 mm diameter stirrups placed at 50 mm spacing along the height of the wall, amounting to a total of 21 stirrups per specimen. This configuration aims to ensure adequate confinement and crack control under seismic actions.

Appropriate cover is essential for both durability and protection of the reinforcement from environmental exposure. Accordingly, a concrete cover of 10 mm was provided for the wall and 20 mm for the slab portions, in accordance with code requirements.

IV. CASTING DIMENSIONS

The selection of material properties and casting methodology are pivotal in achieving both the strength and ductility required of shear wall systems. The concrete mix used was of grade M30, characterized by a density of 2500 kg/m³, and a modulus of elasticity of 25,000 MPa. With a Poisson's ratio of 0.2, the concrete achieved a compressive strength of 28.8 MPa and a tensile strength of 2.8 MPa after 28 days of curing. These properties are verified both numerically and through material tests on cylinders and cubes.

High-strength Fe550D steel was selected for the reinforcement owing to its favorable combination of yield strength and ductility. The steel bars, with a density of 7850 kg/m³, offer a modulus of elasticity of 200,000 MPa and a minimum yield strength of 550 MPa, thus ensuring that the reinforcement can sustain significant stresses that result from seismic loading.

The wall specimens were cast by first erecting formwork to the specified dimensions, securing the reinforcement cage in position, and then pouring the concrete in layers to prevent segregation. Each layer was mechanically vibrated to ensure full compaction and minimize voids. After casting, the specimens were cured for a minimum of 28 days under moist conditions to achieve the desired material properties. Stringent quality control measures were followed throughout the process to ensure conformity with the design and consistency across all specimens prepared for further testing and analysis.

V.FREQUENCIES

The dynamic characteristics of the RCC shear wall were investigated through modal analysis using both ETABS and ABAQUS software. In ETABS, the eigenvalue analysis of the modeled wall—factoring in its mass and stiffness distributions—revealed a fundamental, or first mode, natural frequency of 14.194 Hz. This fundamental frequency is particularly significant, as it predominantly governs the structure's response during seismic events. The identified frequency provides valuable insight into the likelihood of resonance effects when the wall is subjected to earthquake excitations, and underscores the importance of accurate modeling for earthquake-resistant structural design.

Complementing this, finite element modeling with ABAQUS was conducted to validate and compare dynamic properties through a different analytical approach. The modal assessment in ABAQUS found the primary natural frequency of the same shear wall specimen to be 19.766 Hz. This higher value, when compared to the ETABS result, may be attributed to variations in modeling techniques, such as distinct element formulations, the representation of boundary conditions, the manner in which material properties are specified, and the mathematical solvers used by the two software platforms. The observed difference, approximately 39%, highlights the sensitivity of modal parameters to these modeling choices and the need for careful calibration in numerical studies.

The frequency range established by both analyses, spanning from about 14 to 20 Hz, positions the shear wall well above the most common dominant frequencies associated with strong seismic ground motions, which typically fall within the 1-10 Hz range. As a result, the structure is less likely to experience resonance amplification, thus reducing the risk of excessive displacement or damage during real earthquake events. This frequency range also indicates the shear wall possesses adequate stiffness to effectively resist lateral loads, confirming that its design is suitable for structural applications in seismically active regions.

VI.CONCLUSION

The present study has provided a comprehensive assessment of the seismic behavior of reinforced cement concrete shear walls, employing both advanced numerical modeling and experimental methodologies. Through careful detailing and design of the shear wall specimen in accordance with IS: 13920 – 2016, and selection of appropriate material properties, the research has ensured that the specimen achieved the necessary strength.

The dynamic analyses conducted using ETABS and ABAQUS revealed fundamental frequencies of 14.194 Hz and 19.766 Hz, respectively, positioning the wall outside the critical resonance range of typical earthquake excitations and thereby reducing the risk of amplification of structural response. The observed variation in natural frequencies between the two software platforms highlighted the importance of considering differences in modeling techniques and boundary condition applications. Furthermore, the reinforcement layout and casting methodology ensured both structural adequacy and consistency for experimental verification. The study's findings confirm that with systematic reinforcement detailing and adherence to design codes, RCC shear walls can deliver robust performance under seismic loading—providing vital lateral stiffness, minimizing displacement, and mitigating potential structural damage. This dual approach not only enhances the reliability of the numerical predictions but also establishes a strong foundation for further experimental testing and practical implementation of earthquake-resistant design strategies.

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