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A Review of Analysis Methods for High-Rise Structures Considering Hybrid Shear Walls

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Abstract- Shear walls are vital structural components safeguarding buildings against lateral forces like wind and earthquakes. When external walls lack adequate strength and stiffness, shear walls are incorporated within the interior to bolster overall structural integrity. They become imperative when the allowable span width ratio for the floor or roof diaphragm is surpassed. Commonly employed as flexural members, shear walls play a crucial role in high- and low-rise constructions, mitigating the risk of complete collapse under seismic pressures. This paper comprehensively reviews various articles about shear walls in high-rise structures.

Keywords: Hybrid Shear Wall, Response Spectrum Analysis, Shear Wall, Seismic Forces.

I. INTRODUCTION

The design of tall buildings involves a series of stages, including conceptual design, approximate analysis, preliminary design, and optimisation to withstand gravity and lateral loads effectively. Structural systems in building construction aim to efficiently transfer gravitational loads, including dead, live, and snow loads. Additionally, buildings are subjected to lateral forces induced by wind and seismic activities, leading to high stresses, sway movement, and vibrations. Hence, structures must possess sufficient strength to resist vertical loads and stiffness to withstand lateral stresses. High-rise buildings are prevalent worldwide, and their structural design incorporates dynamic calculations for wind and earthquake forces. With significant advancements in computer technology, structural designers now heavily rely on computer software to design high-rise buildings. Shear walls are critical in high-rise buildings, especially in mitigating lateral wind and seismic forces. Combined with the weight of the structure and its occupants, these forces can result in substantial torsional forces, potentially causing structural failure. Shear walls are strategically placed within the building to maintain the frame's shape and prevent joint rotation.

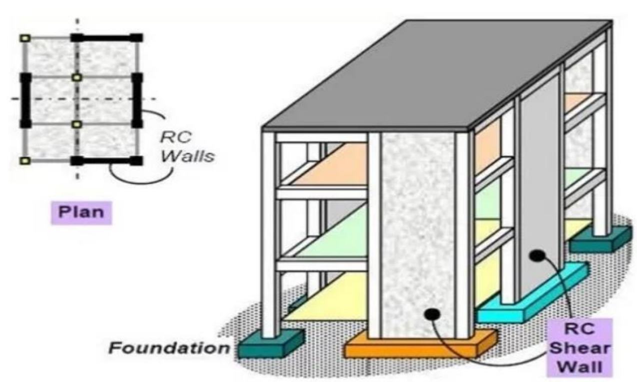

Figure 1. Shear Wall

They are particularly essential when the centre of gravity of the building area and the applied loads differ significantly, typically exceeding 30%. By incorporating concrete walls, lateral forces can be effectively managed without significant increases. The optimal placement of shear walls is crucial for their effectiveness in stabilising tall structures against heavy horizontal wind and seismic loads. Thus, this paper explores various strategies for utilising shear walls to enhance the stability of tall structures under such loads.

II. SHEAR WALLS

A shear wall is a crucial structural component designed to withstand lateral forces, such as wind and seismic loads, in reinforced concrete framed constructions. Particularly prevalent in high-rise buildings, shear walls play a pivotal role in mitigating the impact of these lateral forces. As the height of a structure increases in reinforced concrete framed constructions, wind forces become increasingly substantial. Therefore, shear walls are strategically placed to limit horizontal movement or sway, adhering to industry codes and standards.

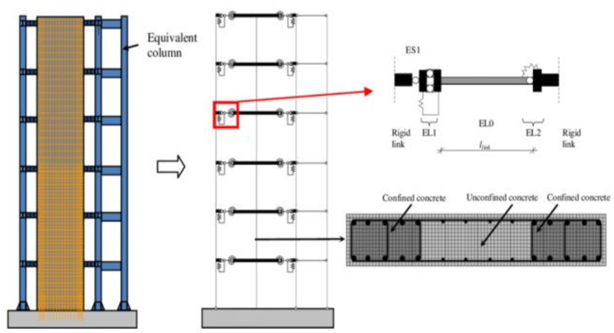

Figure 2. Hybrid Shear Wall

III. HYBRID SHEAR WALLS

Hybrid systems are widely adopted globally and are incorporated into various constructions using diverse materials. Any system integrating two or more structural materials is termed a hybrid system. Among these, the combination of steel and concrete is particularly prevalent, with examples including concrete on metal decks supported by steel beams as a floor system. Additionally, for several decades, fibre-reinforced polymers (FRP) have been utilised in structural engineering to reinforce or retrofit concrete structures, enhancing the capacity of bridges, dams, and columns. Commonly used fibres for strengthening include Glass Fiber Reinforced Polymers (GFRP) and Carbon Fiber Reinforced Polymers (CFRP), owing to their advantages, high strength, maximum tensile ratio, ease of application, and corrosion resistance.

II. LITERATURE REVIEW

Satya Narayan Reddy et al. (2019) conducted a study evaluating the dynamic performance of a residential building modelled as the conventional frame, shear wall, and hybrid structure under different seismic zones using ETABS (2016). The analysis, complying with IS 1893: 2016 PART I, compared storey stiffness, storey shear, maximum storey drift, and maximum story displacement of the three models across various seismic zones. Results indicated that shear wall structures perform effectively in severe seismic zones, whereas conventional RC frames exhibit higher storey drifts and displacements. The study found that storey drift and displacements in shear wall structures were within the limits prescribed by IS codes, with significantly lower values compared to conventional RC frames. However, stiffness variation in shear wall structures slightly fluctuated due to a high percentage of openings in stilt and parking floors. Shear wall structures also exhibited lower-storey shear compared to conventional and hybrid structures. Xu L. et al. (2014) presented an experimental and numerical study on a hybrid shear wall system for taller buildings. The hybrid shear wall, comprising two outer precast wall layers and one internal cast-in-place concrete layer, was investigated using experimental observation and finite element method (FEM) simulation validation. Full-scale shear walls were tested under vertical pressure and cyclic horizontal load, with ABAQUS utilised to generate 3D nonlinear finite element models for analysis. The study revealed that the hybrid shear wall exhibited less effective energy dissipation than conventional shear walls.

Moreover, the larger longitudinal rebar ratio in hybrid shear wall panel connections benefited cyclic behaviour. Under monotonic load, the strength levels between cast-in-place and hybrid walls showed minimal difference, although fracture patterns differed. Shuzhen Chen and M. Poongodi (2020) designed a bolted connection method to study the seismic performance of composite concrete shear wall specimens with horizontal split joints. The specimens, connected with full-scale bolts, were evaluated for bearing capacity, ductility, energy dissipation, deformation capacity, and failure mode. Results indicated that the connectors effectively joined precast shear walls, enhancing lateral rigidity similar to prior precast concrete shear wall systems. The specimens demonstrated good deformation capacity under significant earthquakes, with energy dissipation capabilities equivalent to previous systems. Nursiah Chairunnisa et al. (2017) proposed a shear wall coupling beam using a hybrid steel truss encased with reinforced mortar as an alternative to conventional reinforced concrete coupling beams. Analytical modelling using SAP2000 showed that the proposed model provided a reliable design for substituting diagonal reinforced concrete coupling beams in coupled shear walls. The study suggested that applying encased mortar could reduce profile steel dimensions in hybrid steel trusses. Chong-fang Sun et al. (2020) conducted experimental and numerical simulations on the seismic performance of a precast shear wall with rabbet-unbonded horizontal connections. Three specimens with different characteristics were tested under cyclic quasi-static loads. FE analysis revealed that the horizontal bearing capacity of specimens decreased with a lower axial compression ratio and higher unbonded level. Additionally, specimens with smaller axial compression ratios exhibited higher displacements and ductility factors. The study concluded that ductility and energy dissipation of the shear wall increased with unbonded length and level, while bearing capacity increased with axial compression ratio, suggesting that excessive unbonded length and level should be avoided under high-pressure conditions.

IV. CONCLUSION

Reviewing over twenty research papers has provided valuable insights into hybrid shear walls' components, capabilities, and analysis. Various authors have employed diverse structural data, investigating shear walls of different sizes and placements to assess their behaviour under different lateral loads. Researchers have comprehensively analysed shear wall systems in high-rise structures using software tools such as ETABS, STAAD.pro, and SAP 2000. From comparative studies to experimental investigations, the research findings underscore the significance of shear walls in enhancing structural stability against lateral forces like wind and earthquakes. Hybrid shear wall systems have emerged as effective solutions through advancements in materials and construction techniques, offering improved performance and resilience. These findings contribute to the ongoing efforts in designing robust structural systems for tall buildings, ensuring their safety and durability in dynamic environmental conditions.

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