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Dynamic analysis of G+20 multi storied building by using shear walls in various locations for different seismic zones

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Abstract

In contemporary urban landscapes, the escalating demand for space has propelled the construction of tall buildings as a pragmatic solution. The scarcity of available land has necessitated the vertical expansion of structures, leading to the development of low-rise, medium-rise, and tall buildings. While reinforced concrete (RCC) framed structures are commonly employed to withstand both vertical and horizontal loads, their efficacy diminishes for buildings exceeding 15 to 20 stories due to inadequate lateral stiffness. This paper aims to investigate the seismic performance of a 50-storey RCC building equipped with shear walls. Shear walls, strategically placed vertical elements, are introduced to enhance the building's lateral stiffness, particularly crucial in regions prone to seismic activity. The study focuses on understanding the impact of seismic forces on the structural integrity and stability of the building.

The seismic forces acting on tall structures can induce complex responses, necessitating a thorough analysis of the structural system. By incorporating shear walls at suitable locations, the lateral load resistance capacity of the building can be significantly improved. The paper delves into the analytical aspects of the seismic design, considering factors such as building height, material properties, and the dynamic nature of seismic forces. The methodology involves a comprehensive structural analysis using advanced computational tools to simulate seismic events. The study evaluates the building's response to lateral forces, emphasizing the role of shear walls in mitigating deformations and enhancing overall structural performance. Additionally, considerations for the economic feasibility and practical implementation of shear walls in tall structures are discussed.

The findings of this study contribute valuable insights into the seismic resilience of tall buildings with shear walls, offering guidance for future construction practices in seismically active regions. The research aims to bridge the gap in understanding the dynamic behavior of tall structures during seismic events and highlights the significance of incorporating shear walls as an effective strategy to ensure structural stability and occupant safety.

Keywords: Tall Buildings, RCC Construction, Shear Wall, Seismic Performance, Structural Resilience

1. Introduction

The unpredictable and forceful nature of earthquakes presents a significant challenge to the stability and integrity of structures. Any abrupt shaking of the ground, resulting from the passage of seismic waves through the Earth's rocks, can lead to destructive seismic events. The Indian subcontinent, in particular, has a historical backdrop marked by devastating earthquakes, emphasizing the critical importance of seismic-resistant construction practices.

When seismic waves induce ground shaking, buildings respond by vibrating, mirroring the motion of the surrounding ground. This phenomenon poses a threat to the structural integrity of buildings, potentially causing damage and compromising the safety of occupants. In regions prone to seismic activity, understanding and implementing effective seismic design strategies are imperative.

Shear walls emerge as a fundamental solution in seismic design, providing buildings with substantial strength and stiffness. These vertical structural elements resist lateral forces within the plane of the wall through a combination of shear and bending. The behavior of shear walls is intricately linked to various factors, including the material used, wall thickness, and the wall's length and position within the building frame. In tall structures, where conventional systems may fall short, shear walls play a pivotal role. Their thickness, ranging from above 150 mm to below 400 mm, transforms them into vertical-oriented wide beams that efficiently carry earthquake loads towards the foundation. These walls serve as a robust defense against lateral loads induced by wind, seismic events, or even hydrostatic and lateral earth pressure.

Shear wall buildings have become a preferred choice in earthquake-prone regions worldwide due to their efficiency in reducing construction costs and minimizing earthquake damage. Their impact extends beyond structural elements, encompassing non-structural components such as glass windows and construction materials. Empirical evidence has demonstrated the commendable performance of buildings with shear walls during earthquakes in high seismic areas. The primary aim of the present study is to conduct a comparative analysis of the behavior of multi-storey buildings with shear walls. Specifically, the focus is on analyzing the influence of building height on the performance of these structures under earthquake forces. By delving into this investigation, we aim to contribute insights that enhance our understanding of how shear walls can be optimized for different building heights, thereby advancing seismic design practices for resilient and secure structures.

2. Research Objectives

This research has three primary objectives. Firstly, it aims to scrutinize the efficacy of shear walls in resisting seismic forces. This involves a comprehensive exploration of the role shear walls play in enhancing the structural stability of buildings subjected to seismic events. Understanding the capacity of shear walls to mitigate seismic forces is pivotal for informing seismic design practices.

The second objective involves the utilization of STAAD Pro software for an in-depth seismic analysis of the target building. Known for its prowess in structural analysis and design, STAAD Pro will simulate seismic events to assess the building's structural response thoroughly. This objective seeks to unravel how the building behaves under diverse seismic conditions, providing critical insights into its seismic performance.

The third objective is the examination and analysis of various parameters, including displacement, torsion, and deflection. These parameters serve as vital indicators of the structural response to seismic forces. Displacement reveals how much the structure shifts during seismic events, torsion assesses the twisting effect, and deflection gauges the bending or flexural response. Analyzing these parameters aims to draw meaningful conclusions about the building's behavior under seismic loading.

3. Methodology

The research methodology adheres to relevant Indian Standard Codes, specifically IS 1893:2016 (Part 1) and IS 456:2000, ensuring that the design conforms to established industry standards. Essential data for analysis and design, sourced from a construction site of a multi-storey building, includes architectural plans and dimensions of beams and columns, providing practical relevance to the study. The data used for modeling the reinforced concrete (RC) framed building incorporates crucial details, such as structure type (residential and commercial), number of stories (50), seismic zone (4), and various dimensions of structural elements. Employing STAAD Pro as the analysis tool ensures a sophisticated and accurate assessment of the building's response to seismic forces.

Modeling steps in STAAD Pro encompass the preparation of grid lines, definition of materials (concrete and steel), and detailed specifications of frame sections for beams, columns, shear walls, and slabs. Load cases are assigned, encompassing dead load, live load, wind loads, and seismic loads. The model is then analyzed with the assumed support conditions, providing a comprehensive understanding of the structural response under varying loads and conditions. This meticulous methodology is designed to yield valuable insights into the seismic performance of multi-storey buildings with shear walls, contributing to advancements in seismic design practices and enhancing the resilience of structures under seismic conditions.

4. Data Used for Modeling of RC Framed Building

In the meticulous modeling of the reinforced concrete (RC) framed building, a plethora of key parameters have been considered to ensure a comprehensive and accurate representation. The structure, amalgamating both residential and commercial functionalities, spans an impressive 50 stories, emphasizing its vertical scale and versatility. Situated in Seismic Zone 4, the building is designed to withstand moderate to high seismic activity, prompting meticulous considerations in its structural design. Each floor maintains a consistent height of 3 meters, contributing to the overall architectural cohesion and verticality of the building.

The structural components are characterized by robust dimensions, with columns featuring dimensions of 700 mm x 500 mm and beams measuring 500 mm x 500 mm. These elements play pivotal roles in providing vertical support and ensuring structural integrity. Slabs, with a thickness of 150 mm, separate each floor, influencing both structural stability and aesthetic considerations. Exterior and interior masonry walls, each with a thickness of 150 mm, contribute significantly to the overall stability and partitioning of spaces within the building. The consideration of dynamic loads is crucial in structural analysis. The live load, representing dynamic and variable loads imposed on the structure, is measured at 4.5 KN/m^2, accounting for potential occupant movements and furnishings. An additional load of 1.5 KN/m^2 is allocated for floor finishes, ensuring a holistic analysis that encompasses the impact of all relevant loads. The building stands on Type II – Medium Soil, influencing foundation design and seismic response. All columns are assumed to be fixed at the base for modeling simplicity and initial assumptions, influencing their behavior under various loads.

Concrete parameters include a characteristic compressive strength (fck) of 50 N/mm2, a modulus of elasticity of 2000 N/mm2, and a density of 26 N/mm2. Steel elements boast a grade of 500 N/mm2, ensuring adequate tensile strength. Masonry walls, with a density of 19.4 KN/m3, contribute to overall mass considerations in the structural model. Poisson's ratios for concrete and brick masonry are defined as 0.3 and 0.2, respectively. A damping ratio of 5% is considered, reflecting the structure's ability to dissipate energy during oscillation. This exhaustive set of data forms the bedrock for the intricate modeling and subsequent analysis of the RC framed building, providing a nuanced understanding of its structural behavior under diverse conditions.

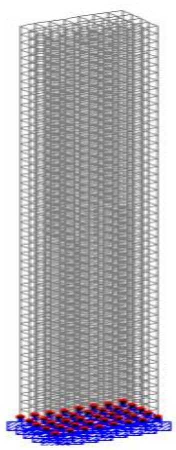

Fig. STAAD Model

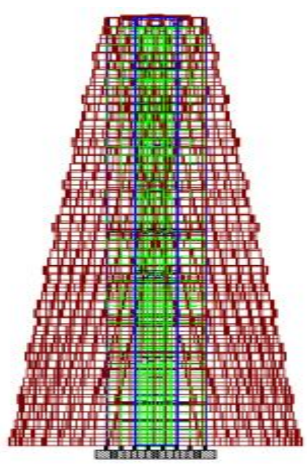

Fig. Axial Force

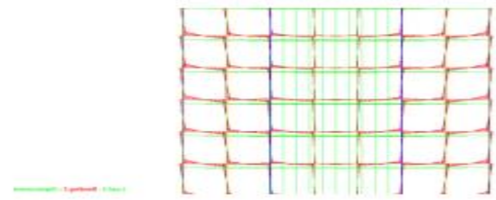

Fig. Bending

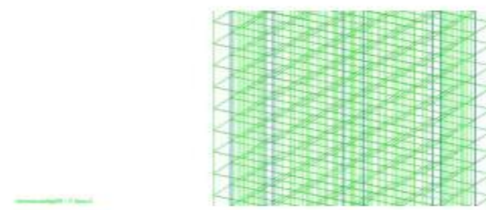

Fig. Displacement

The Load Bearing Shear Wall (LBSW) system in Reinforced Concrete Construction (RCC) stands out from traditional framed systems due to its distinctive inclusion of additional load-bearing walls. Unlike conventional systems, the RCC LBSW system integrates longer walls with higher stiffness in response to lateral loads, resulting in exceptionally rigid buildings with satisfactory ductility. This design detail has proven effective globally, particularly during natural calamities, where RCC LBSW structures have consistently demonstrated the expected levels of structural integrity and life safety.

In the step-by-step modeling process, the initial stage involves utilizing the Geometry and Structural Wizard tool to model the structure, considering the specific type of structure under analysis. Nodal points are then generated based on the positioning of columns within the building, serving as critical markers in the structural model. Shear walls are meticulously designed using the Add Surface tool at specified locations, ensuring an optimal distribution of load-bearing elements. The subsequent step involves defining the properties of beams and columns using the General-Property command in STAAD Pro, where sizes and dimensions are specified based on structural requirements.

The modeling process continues with the creation and assignment of support conditions and member properties in Step-5. Columns are assumed to be fixed at the base, and properties are defined based on load calculations. Moving into load assignment and structural analysis, various loads, including dead load, live load, and seismic load, are assigned based on standard codes such as IS:1893 and IS:875. Load combinations are established in line with seismic analysis requirements. Structural analysis is then conducted using STAAD-Pro, studying forces, bending moments, shear forces, and moment diagrams in detail

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during the post-processing mode to ensure structural safety.

The subsequent step involves the design of the structure according to IS 456:2000 for RCC, utilizing M50 concrete and Fe500 steel. Design parameters, including percentage steel, are specified as per IS Code standards for each beam and column. Finally, the output generation phase produces a comprehensive file containing detailed structural designs for each individual beam and column member of the structure. This output provides crucial insights into the structural integrity and performance of the RCC LBSW system, demonstrating a meticulous approach to modeling, analyzing, and designing structures with Load Bearing Shear Walls to ensure robustness and safety under various loading conditions.

The information provided highlights crucial parameters for seismic analysis using STAAD-Pro, a structural analysis and design software. First and foremost, the fundamental period of vibration (Ta) for the building is specified as 3.02 seconds. This fundamental period represents the time taken for one complete cycle of vibration within the structure, a fundamental aspect in understanding its dynamic response to seismic forces.

Additionally, the seismic coefficient (Sa/g) is detailed with a value of 4.5. This ratio, expressing the spectral acceleration to the acceleration due to gravity (g), plays a pivotal role in determining the intensity of seismic forces acting on the structure. A higher seismic coefficient indicates a greater potential for seismic impact, influencing the structural design considerations.

The load factor is another essential parameter mentioned, assigned a value of 1. The load factor, a dimensionless factor applied to loads, accounts for uncertainties and variations in real-world conditions, ensuring a safety margin in structural design. This factor is integral in making structural designs robust and resilient under varying load scenarios.

Moreover, the seismic zone factor (Ah) is introduced with a specific value of 0.0308. This factor is closely tied to the seismic zone in which the building is situated. In this case, the building is located in Seismic Zone IV, denoting a high seismic risk region. The seismic zone factor influences the calculations of seismic forces and assists in tailoring the structural design to the specific seismic characteristics of the region.

In practical terms, the objective is to equip the structure to withstand seismic forces. To achieve this, the fundamental period of the building is calculated and then input into STAAD-Pro, which utilizes this information along with the seismic coefficient, load factor, and seismic zone factor to conduct a comprehensive seismic analysis. STAAD-Pro employs these inputs to calculate seismic forces acting on the structure, ensuring that the design is resilient and can withstand the potential seismic impact anticipated in Seismic Zone IV.

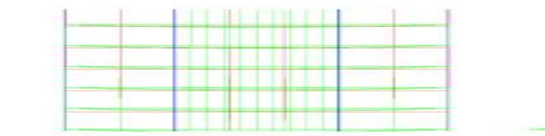

Fig. Shear in Z direction

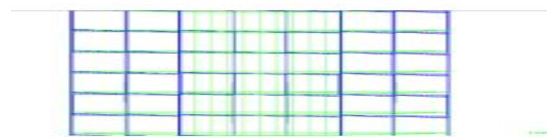

Fig. Shear in Y direction

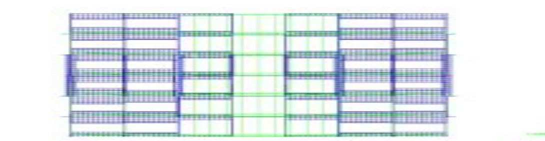

Fig. Torsion

5. Conclusion

The seismic analysis conducted on a multi-storey RC framed building incorporating shear walls reveals compelling insights. The results affirm that the building, fortified with shear walls, exhibits remarkable resistance to earthquakes, showcasing reduced maximum displacement compared to structures without shear walls. The effectiveness of shear walls in mitigating structural responses to seismic forces underscores their crucial role in enhancing earthquake resilience.

Furthermore, the study highlights the versatility of STAAD.Pro software, showcasing its capability to determine the required reinforcement for concrete sections based on loading conditions. This software's proficiency in calculating nodal deflections induced by lateral forces contributes to a comprehensive understanding of structural behavior under various conditions. The accurate and comprehensive results obtained through static and dynamic analyses further emphasize the significance of employing advanced software tools in engineering applications, particularly in earthquake-prone regions. In conclusion, the incorporation of shear walls in RC framed buildings emerges as a potent strategy for fortifying structures against seismic events, and advanced tools like STAAD.Pro play a pivotal role in ensuring accurate assessments and robust design considerations for such structures.

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