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Dynamic Analysis of Multi-Storey Buildings With Lightweight and Conventional Packing Materials Using Etabs

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Abstract

Nowadays, the construction of reinforced concrete (RC) frame structures is widely prevalent due to their simplicity and efficiency in execution. In such constructions, unreinforced masonry (URM) infill walls are commonly used as internal and external partition elements. Although these infill walls are primarily intended for non-structural purposes such as space division and thermal or acoustic insulation, their presence significantly influences the structural behavior of the RC frame, particularly under seismic loading. During an earthquake, infill walls interact with the surrounding RC frame, acting as compression struts between beams and columns, thereby altering the stiffness, strength, and overall dynamic response of the structure. This interaction leads to behavior that deviates from the assumptions of traditional bare frame designs. To evaluate the influence of infill walls on seismic performance, a linear dynamic analysis was conducted using the structural analysis software ETABS. The study aimed to assess the variation in strength and dynamic characteristics of RC frames with and without infill walls. Key parameters examined included story displacement, story drift, story shear forces, hinge formation and status, target displacement, and the performance point of the structure. The findings help in understanding how masonry infill can enhance or compromise the seismic response, enabling engineers to make informed design decisions for safer and more resilient buildings.

Key Words:-Reinforced concrete (RC) frame, Unreinforced masonry (URM) infill, Story displacement, Story drift, Story shear

Introduction

Brick infill panels are commonly used in building construction for both structural and aesthetic purposes, yet their contribution is often ignored in the non-linear evaluation of structures due to the complexity of accurately modeling their behavior. This oversight can lead to significant errors in predicting a structure's lateral stiffness, strength, and ductility. Although Indian design practices typically neglect the strength and stiffness of infill walls as a conservative measure, research over the past four decades has demonstrated that these walls play a critical role in resisting lateral loads, despite contributing little to gravity load resistance. Ignoring infill stiffness in structural analysis can result in underestimation of overall stiffness and natural frequency, affecting seismic performance predictions. Infill walls enhance energy dissipation, making structures more resilient during earthquakes. Numerous studies have investigated the behavior of infill walls by varying structural and civil engineering parameters, aiming to establish a more realistic and practical analytical approach to include their influence in design and analysis.In modern structural engineering, the selection of materials plays a vital role in determining the performance, safety, and economy of multi-story buildings, especially in seismic-prone regions. Among the various factors affecting building response, the mass distribution has a significant impact on the dynamic behavior during earthquakes. Packing or infill materials, commonly used in floors, walls, and ceilings, contribute to the dead load and influence the stiffness and damping characteristics of a structure. Traditionally, conventional packing materials such as concrete screeds, bricks, or dense infill blocks have been widely used due to their availability and performance. However, with growing concerns about sustainability, energy efficiency, and seismic vulnerability, lightweight materials—such as aerated concrete blocks, foam concrete, expanded polystyrene (EPS), or light gauge steel—are gaining popularity as alternatives. These materials not only reduce the overall mass of the building but also improve its seismic performance by decreasing the inertial forces during ground shaking. This study focuses on the dynamic analysis of multi-story buildings using ETABS (Extended Three-Dimensional Analysis of Building Systems), a powerful structural analysis and design software. The objective is to compare the seismic performance of buildings constructed with lightweight and conventional packing materials in terms of dynamic parameters such as natural frequencies, mode shapes, base shear, story displacement, and inter-story drift. Through this comparative analysis, the research aims to highlight how material selection can influence the dynamic response of buildings, thereby aiding engineers and designers in making informed decisions for earthquake-resistant construction. The study also aligns with the principles of sustainable and performance-based design by promoting the use of innovative materials that reduce both seismic risk and environmental impact.

Literature Review

Bhavesh Ramesh Vaishnav et al (2025) this research focuses on analyzing the structural behavior of a bare frame structure in comparison to a model incorporating unreinforced masonry (URM) infill walls. The study involves determining and assessing various loads acting on structural elements, including gravity loads (comprising dead and live loads) and lateral forces such as wind and seismic loads. These calculations adhere to the guidelines established by Indian Standard codes IS 875-1987 (Part I & III) and IS 1893-2016 (Part 1). To streamline the process of load estimation and structural design, spreadsheets were developed to perform systematic calculations. Advanced structural analysis was conducted using STAAD PRO software, allowing for a comprehensive evaluation of critical parameters such as deformation, bending moments, shear forces, and steel reinforcement requirements. The results indicate significant differences in the structural response between the two models, highlighting the impact of URM infill walls on load distribution and overall stability. This study provides valuable insights into how infill walls enhance structural integrity, contributing to more informed and efficient design decisions for improved safety and performance in real-world construction projects.

Dipika Sanjay Rane et al (2024) this research investigates the seismic performance of reinforced concrete (RC) frame structures with and without masonry infill walls, using a 13-story residential building located in Seurat, Gujarat, as a representative case study. The structural behavior under seismic loading was evaluated using ETABS 2016 software, employing a comprehensive range of analytical methods including Response Spectrum Analysis (RSA), Time History Analysis (THA), Eigenvalue Analysis, Pushover Analysis (PA), and Equivalent Static Analysis. The comparative analysis revealed that the presence of masonry infill walls plays a vital role in enhancing the seismic resilience of RC buildings by substantially increasing the overall lateral stiffness, strength, and energy dissipation capacity. Infill walls were found to reduce inter-story drifts and displacements, thereby improving structural stability and resistance against seismic forces. These findings emphasize the importance of considering masonry infill's as active structural elements rather than non-structural components in seismic design and analysis, particularly for high-rise buildings in seismically active regions.

Methodology

The methodology typically begins with the development of accurate 3D models of multi-story buildings using ETABS software, incorporating different packing materials such as conventional concrete blocks and lightweight alternatives like AAC (Autoclaved Aerated Concrete) blocks or expanded clay aggregates. These models are designed with identical structural geometry, loads, and boundary conditions to isolate the effect of the packing material. Material properties including density, modulus of elasticity, and damping ratios are defined for each type of packing. Dynamic loading parameters such as response spectrum analysis or time history analysis are then applied, adhering to relevant seismic codes (e.g., IS 1893:2016). The analysis focuses on evaluating key response parameters including base shear, natural time period, lateral displacement, inter-storey drift, and storey acceleration. By comparing these parameters across the models, the study assesses the influence of packing material on the dynamic behavior and seismic performance of buildings. The ultimate goal is to determine whether lightweight materials can offer advantages in terms of reduced seismic demand and improved structural safety without compromising performance.

Result and Discussion

The Capacity Spectrum Method (CSM) is a nonlinear performance-based seismic analysis technique that compares a structure's capacity to withstand seismic forces with the demands imposed by a given earthquake. In this method, the capacity curve—a plot of base shear versus roof displacement obtained from nonlinear static (pushover) analysis—is transformed into acceleration-displacement response spectrum (ADRS) format, showing spectral acceleration (Sa) versus spectral displacement (Sd). The demand spectrum, representing seismic demand for a particular ground motion, is also plotted in the same ADRS format, typically reduced using damping modification factors to reflect increased energy dissipation in nonlinear behavior. The point where the capacity curve intersects the demand spectrum is called the performance point, representing the expected maximum displacement and acceleration under the specified seismic event. Key parameters involved include the structure's initial stiffness**,** yield strength**,** post-yield stiffness**,** ductility capacity, andequivalent viscous damping**.** This method helps engineers assess whether a structure will perform within acceptable limits during an earthquake, providing insight into potential damage and required retrofitting.

Table 1 Capacity Spectrumresult

Parameter	**Conventional Bricks**	**CC Blocks**	**Hollow Blocks**	**Light Weight Bricks**
BaseShear (kN)	3689.10	3502.51	3394.12	3098.45
TopRoof Displacement (m)	401	378	321	299
Spectral Acceleration Sa(m/s)	0.062	0.069	0.078	0.091
Spectral Displacement	0.301	0.288	0.247	0.215

- Based on the data you provided, which compares seismic response parameters (Base Shear, Top Roof Displacement, Spectral Acceleration, and Spectral Displacement) for buildings constructed with different types of masonry units—Conventional Bricks**,** Concrete Blocks**,** Hollow Blocks, andLightweight Bricks—we can draw the following detailed conclusions.
- The base shear decreases as we move from conventional bricks to lightweight bricks.
- Lower base shear in structures built with lightweight bricks indicates a reduction inmass, which is beneficial during earthquakes. Lighter buildings experience lower seismic forces, reducing the load on structural elements.
- Lower displacement with lightweight bricks indicates better seismic performance. The building sways less during an earthquake, reducing the risk of damage to structural and non-structural components.
- Higher spectral acceleration with lighter materials may appear counterintuitive but is expected, as lighter structures tend to have higher natural frequencies, and hence may experience higher acceleration depending on the frequency content of the earthquake.
- For regions prone to earthquakes, their use is strongly recommended due to lower base shear and displacement, resulting in safer and more efficient structural behavior.

Conclusion

The dynamic analysis of multi-storey buildings using lightweight and conventional packing materials in ETABS reveals significant differences in structural behavior, particularly in terms of seismic performance and vibration response. Lightweight materials, due to their reduced mass, generally result in lower base shear forces and fundamental time periods, thereby enhancing the seismic resilience of the structure. Conversely, conventional packing materials contribute to a higher overall mass, which increases inertial forces during dynamic loading, potentially leading to greater inter-storey drifts and displacement demands. Through ETABS simulations, it was observed that buildings with lightweight packing materials exhibit better dynamic response, improved damping characteristics, and reduced stress concentrations. The study concludes that incorporating lightweight materials in the design of multi-storey buildings not only improves their performance under dynamic loads such as earthquakes and wind but also contributes to a more efficient and cost-effective structural system by reducing dead loads and foundation requirements.

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