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Investigation into Earthquake of Buildings with Mass Imbalance

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Abstract:

This research focuses on examining how different forms of vertical irregularities influence the seismic performance of reinforced concrete (RC) structures. The main objective is to conduct both Response Spectrum Analysis (RSA) and Pushover Analysis on RC building frames exhibiting vertical irregularities, and to compare their seismic behavior with that of regular configurations. The study specifically considers mass irregularities and other forms of vertical discontinuities. It was observed that the storey shear force reaches its peak at the lower storeys, particularly at the base, and progressively reduces in the upper levels. Notably, structures with mass irregularities exhibited higher base shear values compared to their regular counterparts, indicating a greater demand on lateral load resistance.

1. Introduction

Understanding how vertical irregularities affect the seismic performance of reinforced concrete (RC) buildings has become an essential aspect of modern structural engineering. With the growing demand for architecturally complex buildings and increasing land-use constraints in urban areas, vertical irregularities—such as mass discontinuities, stiffness variations, and setbacks—have become increasingly common. These irregularities significantly influence how structures respond to seismic forces, often leading to complex dynamic behaviors not present in regular configurations [1]. A structure is considered vertically irregular when there are abrupt changes in stiffness, strength, or mass along its height. These irregularities disrupt the uniform distribution of lateral forces, often resulting in stress concentrations and displacement amplifications in certain regions of the structure. Among the various types, mass irregularities, such as a sudden increase in floor mass due to changes in occupancy or architectural design, can severely affect the dynamic characteristics of buildings [2].

To evaluate the impact of such irregularities, both Response Spectrum Analysis (RSA) and Pushover Analysis are widely used. RSA offers a linear-elastic approximation of seismic demands based on the building's natural frequencies and modal responses, while pushover analysis provides a more nuanced, nonlinear understanding of a structure's capacity by progressively applying lateral forces until failure mechanisms emerge [3].

Past studies have demonstrated that vertically irregular buildings tend to exhibit larger inter-storey drifts and base shear demands compared to regular counterparts. For instance, it has been found that in mass irregular buildings, the storey shear force is often maximum at the lower levels**, especially near the base, and tends to reduce progressively towards the top [4]. This behavior is attributed to the dynamic interaction between mass and stiffness irregularities, which

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modifies the energy absorption and distribution pathways within the structure during an earthquake.

Furthermore, research highlights that RC buildings with mass irregularity consistently develop higher base shear forces under lateral loading scenarios compared to similarly sized regular structures. This increased shear demand indicates the need for enhanced detailing and stronger lateral force-resisting systems in such configurations [5][6].

Given the criticality of the subject, the present work focuses on analyzing RC frame structures with vertical irregularities using both RSA and pushover methods. The aim is to quantify the differences in seismic performance between irregular and regular configurations, particularly in terms of displacement patterns, base shear, and overall lateral capacity.

This study serves not only to deepen the understanding of how vertical irregularities influence seismic behavior but also to provide actionable insight for structural designers aiming to ensure seismic resilience in buildings that deviate from traditional, regular forms.

2. **Modelling**

The building presented in fig 1 is analyses as per different time period vs spectral acceleration graph presented in fig.2. The result are presented after analysis the model in prescribed software which is commercially used by various agency to analysis such type of building.

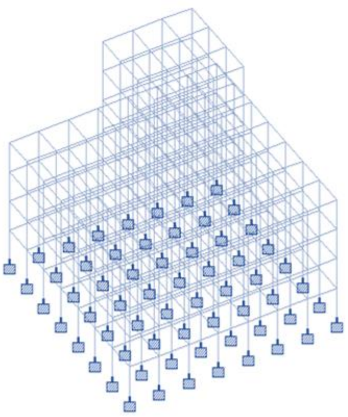

Fig.1 Regular Building Plan

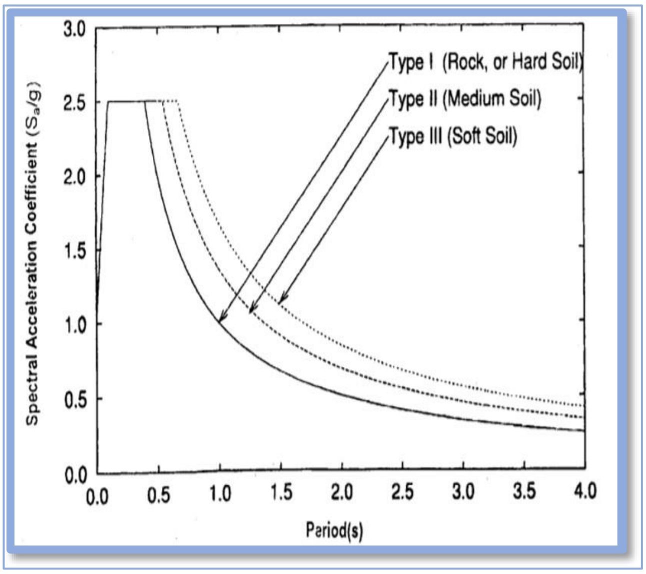

Fig. 2 Graph of Spectral Acceleration and Time period

The deformation pattern a structure exhibits when it vibrates at one of its natural periods is referred to as its mode shape. Each of these mode shapes corresponds to a specific natural frequency of the structure. In theory, a building can have an infinite number of natural periods and, consequently, an equal number of mode shapes. However, in practical engineering applications, only the most significant lower modes are typically considered, as they contribute the most to dynamic response.

For a multi-storey building undergoing vibration in the X-direction, the first mode shape typically involves a smooth sway motion with a single reversal in direction (zero crossing). The second mode introduces a more complex shape with two such reversals, while the third mode shows three zero crossings, indicating progressively higher vibration complexity as the mode number increases.

3. Result and Conclusion:

This study has focused on evaluating the seismic performance of reinforced concrete (RC) building frames exhibiting vertical irregularities, specifically in terms of mass distribution and geometrical discontinuities. Both regular and irregular structures analyzed in this research shared plan symmetry, ensuring that the observed differences in seismic response were purely due to vertical irregularities.

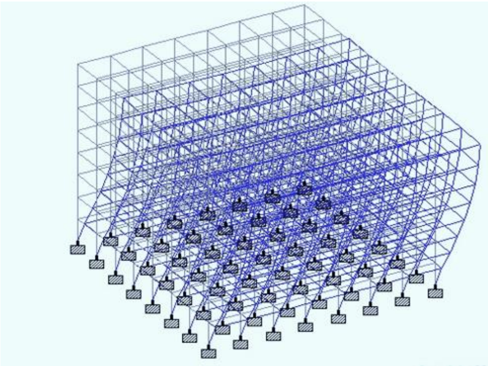

Fig 3 Mode Shape 1

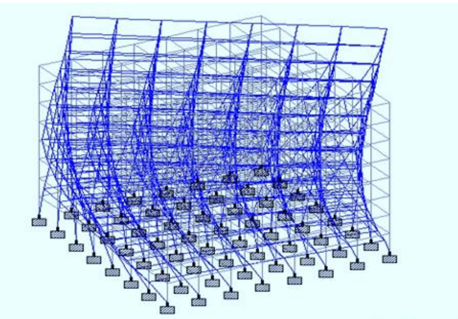

Fig. 4 Mode Shape-2

The mode shape under various loading in the commerical softawre is dicited in fig.3 and fig 4. Through Response Spectrum Analysis, the structural behavior of a G+7 storey RC frame was assessed, and the influence of irregularities was quantified by comparing critical parameters such as base shear, lateral storey forces, and seismic weight distribution.

The findings indicate that mass irregular buildings tend to develop higher base shear compared to regular ones of similar scale and geometry. This is primarily due to abrupt changes in vertical mass distribution, which significantly alter the dynamic response characteristics of the structure. For example, while the total seismic weight of the regular structure was calculated less as the irregular counterpart had a lower overall weight of strucutre However, the irregular mass distribution led to concentrated demands at specific levels.

When comparing lateral load distribution, the regular building showed a gradual increase in forces from middle part of the strucutre in contrast, the irregular structure experienced this illustrte the abrupt mass changes lead to non-uniform force distributions, which can create weak storey effects and raise structural vulnerability during seismic events.

Overall, the results underscore the importance of maintaining consistent mass and stiffness profiles in the vertical direction of buildings to ensure better seismic performance. Vertical irregularities, especially in mass distribution, introduce complex dynamic behaviors that may not be adequately captured without thorough analysis. This reinforces the need for detailed seismic evaluation during the design phase, particularly for structures with architectural or functional constraints that demand irregular forms.

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