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Assessment of Seismic Performance in Buildings with Plan Irregularities

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Abstract:

This study investigates the seismic behavior of reinforced concrete buildings with different types of vertical irregularities using Response Spectrum Analysis (RSA). Both regular and H-shaped plan irregular buildings were modeled, each with a footprint of 20x15 meters and a typical floor height of 3.2 meters, excluding the ground floor, for an 8-storey (G+7) structure. The seismic performance under a earthquake conditions was evaluated based on how stiffness, mass, and strength are distributed throughout the structure. The analysis compares plan-irregular building models featuring varying vertical irregularities. All models were analysed using STAAD.Pro V8i software.

Key words: Base shear; frequency; displacement; Vertical irregularities; Staad Pro.

1. Introduction

Structures with geometric or structural discontinuities are prone to localized concentrations of stress and deformation during seismic events. These discontinuities often occur at junctions or offsets in geometry, leading to an increased likelihood of member failure and potential structural collapse at these weak points [1]. The response of a building to seismic activity is influenced by the chosen method of structural analysis, which varies depending on factors such as the building's importance, function, and associated construction costs. Analytical techniques range from linear static analysis to more advanced nonlinear dynamic methods, each offering different levels of accuracy and computational demand [2].

The seismic performance of a building is largely governed by several key parameters, including lateral stiffness, strength, ductility, and the simplicity of the structural layout. Buildings with a regular and symmetric geometry—characterized by a uniform distribution of mass and stiffness across both the plan and elevation—tend to exhibit better seismic behavior and suffer less damage during earthquakes [3]. In contrast, irregular structures often display uneven load paths and unpredictable dynamic responses, making them more vulnerable under seismic loads.

Despite the known advantages of regular configurations, contemporary architectural and urban demands—driven by increasing population densities, space constraints, and aesthetic considerations—have led to a rise in the design and construction of vertically and horizontally irregular buildings. Consequently, understanding and addressing the seismic vulnerabilities associated with such irregularities has become a critical area of research and practice in earthquake engineering [4].

In seismic design, the structural configuration of a building significantly influences its ability to withstand lateral loads. Among various irregularities, torsional irregularities are

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particularly critical due to their tendency to cause rotational motion of the structure's floor diaphragm, which can lead to uneven force distribution and localized failures. Torsion in buildings generally arises when the center of mass and the center of stiffness do not align, resulting in eccentric lateral displacement during seismic activity [5].

Buildings with asymmetric layouts or non-uniform stiffness in plan tend to exhibit excessive torsional responses. These irregularities are often unavoidable in modern architecture due to spatial constraints or aesthetic preferences. As a result, torsional effects have garnered significant attention in seismic design codes and structural research [1].

It has been observed that the presence of torsional irregularity can amplify the seismic demand on edge columns and walls, especially in buildings with rigid diaphragms, where the floor acts as a single unit transferring rotational effects to vertical load-resisting members [3].

The role of the diaphragm usually the floor or roof slab—in distributing seismic forces across a structure is equally crucial. Diaphragms are classified as rigid, semi-rigid, or flexible, based on their relative in-plane stiffness compared to vertical members. In structures with rigid diaphragms, such as those with concrete slabs, seismic forces are effectively transferred to shear walls or moment-resisting frames. However, if the diaphragm is flexible, as seen in some wood or steel structures, the lateral load transfer becomes less predictable and more susceptible to localized failures [6].

The interaction between diaphragm flexibility and torsional response adds another layer of complexity. Research indicates that in flexible diaphragms, torsional effects are less pronounced due to partial decoupling between lateral and rotational displacements. However, this often leads to increased displacement demands on individual frames, compromising structural integrity [7]. Conversely, in rigid diaphragms, while torsional rotation is more uniform, the resulting stress concentrations can become problematic without adequate detailing and reinforcement.

To address these challenges, modern design guidelines—such as those provided by the IS 1893 (Part 1): 2016 and ASCE 7-16—recommend limiting torsional irregularities through configuration control and provide amplification factors for design forces in edge members. Moreover, the use of dual systems or supplemental damping has been proposed as a means to counteract torsional effects in both flexible and rigid diaphragm systems [**8**]. The analysis compares plan-irregular building models featuring varying vertical irregularities. All models were analysed using STAAD.Pro V8i software.

2. **Modelling**

In the limit state design of reinforced concrete structures, the following load combinations shall be accounted for building presented in fig.1 and fig.2.

- 1.5(Dead load + Impose load)
- 1.2(Dead load + Imposed load ± Earthquake load)
- 1.5(Dead load ± Earthquake load)
- 0.9Dead load ± 1.5 Earthquake load

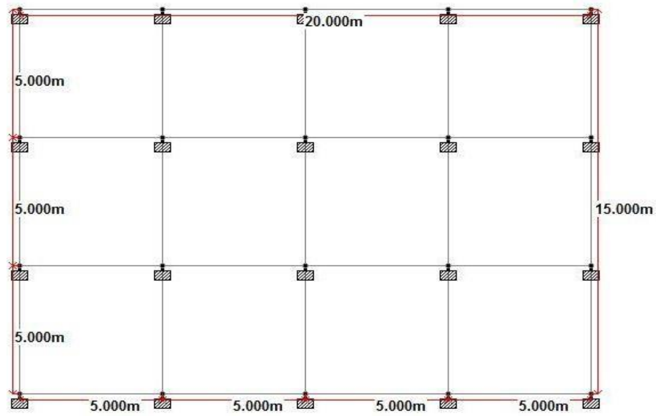

Fig.1 Regular Building Plan

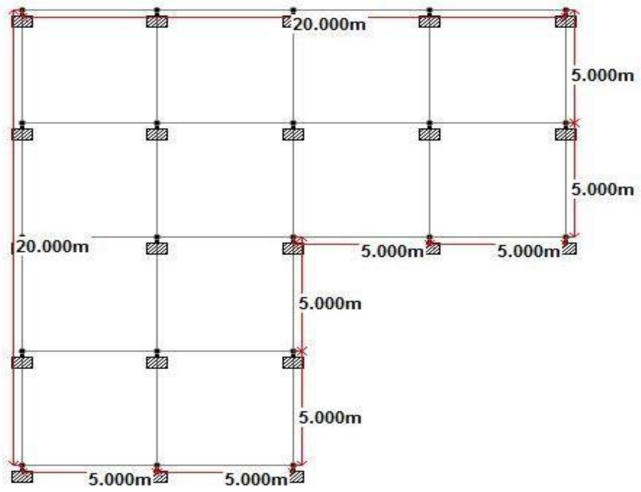

Fig.2 Irregular Building Plan

3. Result and Conclusion:

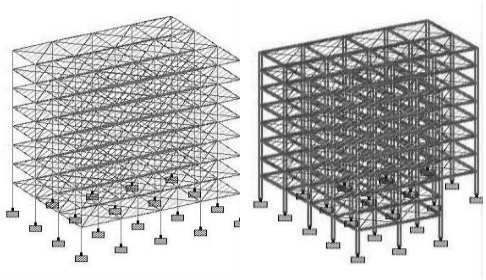

Fig 3: Loading Applied on building in Isometric View

The loading applied for the various load case is presented in figure 3.

An in-depth analytical evaluation was conducted on multi-storey (G+7) reinforced concrete buildings with both regular and irregular geometries using the Response Spectrum Method, focusing on their behavior under seismic loads.The structural models shared identical overall height and plan area, ensuring that the primary variable influencing seismic performance was the plan shape and degree of irregularity. It was consistently observed that as the geometric irregularity increases, the base shear capacity of the building tends to reduce indicating a diminished ability to resist lateral forces effectively. At the same time, lateral displacement was found to increase with greater irregularities, which may lead to serviceability concerns and potential instability if not properly addressed through design.

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