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Seismic Performance Evaluation of Irregular RCC and Steel Buildings under Different Soil Conditions using STAAD.Pro

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Abstract- The seismic performance of buildings is strongly governed by structural irregularities and soil characteristics. This study conducts a comparative analysis of irregular RCC and Steel buildings using STAAD.Pro under three soil conditions defined in IS 1893:2016—Hard, Medium, and Soft. Plan irregularity (L-shape), vertical irregularity (setback), and mass irregularity are incorporated to assess their influence on dynamic behaviour. The Response Spectrum Method is adopted to evaluate key seismic parameters, including storey displacement, drift, base shear, time period, and mode shapes. Results indicate that soft soil significantly amplifies seismic demand, leading to larger lateral responses. Steel buildings display higher flexibility with lower base shear, while RCC structures exhibit greater stiffness and reduced displacement. Irregular configurations also exhibit notable torsional effects.

Keywords: Seismic Design, STAAD.Pro, RCC Structures, Earthquake Loads, Structural Simulation, IS 1893:2016.

I. INTRODUCTION

Earthquakes pose a significant threat to built infrastructure, especially in regions with moderate to high seismicity. The performance of a building during an earthquake depends not only on its structural system but also on its configuration and foundation conditions. Buildings often incorporate architectural and functional features that lead to plan irregularity, vertical irregularity, or mass irregularity, which in turn alter the distribution of stiffness, mass, and strength. Such irregularities can create unexpected stress concentrations and torsional effects, making the structure more vulnerable during seismic events.

Background

In Earthquake-resistant design has become a crucial aspect of civil and structural engineering due to the increasing occurrence of seismic events and the vulnerability of modern infrastructure. Over the years, research has shown that the seismic performance of buildings is highly dependent on two major factors: structural configuration and soil characteristics. Buildings with regular geometry tend to distribute lateral forces uniformly, whereas structures with plan irregularity, vertical irregularity, or mass irregularity often experience uneven force distribution and heightened torsional effects during earthquakes. Such irregularities are commonly introduced due to architectural requirements, space constraints, or functional needs, making it essential to understand their impact on seismic behaviour.

Objectives

- Eccentricity between center of mass and center of rigidity cause torsion in structures and a magnitude of torsional moment.
- To improve the performance of earthquake resistant structure the ductility of the structure should be increased appropriately.
- As the amount of setback increases the shear force also increases
- The middle stories of high rise structures are more vulnerable to earthquake forces than lower and top stories as the responses are higher.
- A structure with heavy mass at top suffers maximum displacement.
- As the Plan Irregularity Increases both Storey Displacement and Storey drift increases.

II. METHODOLOGY

Structure Details

- Configuration: G+10 RCC building
- Plan Dimensions: 21m x 21m

- Story Height: 3m
- Total Height: 33m
- Seismic Zone: IV (as per Indian standards)
- Importance Factor: 1.0
- Soil Classification: Medium (Type II)

Tools and Codes Used

The model was developed in STAAD.Pro CONNECT Edition. Design provisions were followed from IS 456:2000, and seismic forces were assigned as per IS 1893:2016 (Part 1).

Loading Considerations

- Dead Loads: Self-weight of structural elements
- Imposed Loads: 3 kN/m² live load
- Earthquake Loads: Based on code-defined parameters
- Load Combinations: As prescribed in IS 875 (Part 5)

Analytical Approach

- The Equivalent Static Method provides a simplified representation of lateral forces.
- The Response Spectrum Method captures the dynamic characteristics of the structure under seismic excitation.

III. LITERATURE REVIEW

1**.Acc. To MagliuloG.,Maddaloni.&PetroneC[10]-** The " —Effect of earthquake direction on irregular R.C. buildings.‖ " used three multi-story R.C. buildings in Italy as a case study. A (L-plan) follows a (rectangular plan) in order across the courtyard. It is analysed and modelled using (G+5) structure (STAAD –pro)

2. Chandler and Hutchinson (1986), made a detailed study of the coupled lateral and torsional response of a partially symmetric single storey building model subjected to both steady state and earthquake base loadings. From their analysis it is concluded that torsional coupling induces a significant amplification of earthquake forces which should be accounted for in their design.

3. Abd-el-rahim and Farghaly (2010) aimed to check how well irregular buildings, which are not shaped evenly, perform during earthquakes. A time history analysis was performed using the finite element software SAP2000, and it included a peak ground acceleration of 0.25g. Studies show that the base shear force acting at a right angle to the direction of an earthquake is affected by how much the building twists, called torsional eccentricity. This force increases by around 80%, 65%, and 40% compared to the base shear in the earthquake direction for T-shaped, L-shaped, and U-shaped buildings, respectively.

4. Hassballa and others in 2013 studied a multistorey building using the response spectrum method with the help of STAAD.Pro software. They take into account both the static load and the seismic load when analyzing a multistoried building. The analysis shows that the drift is roughly 2 to 3 times what is allowed. Results in large displacement due to the combination of static load and seismic load.

5. McCrum and Broderick (2013) looked at how a multi-storey building with a concentrically braced frame and an irregular floor plan responds to seismic twisting. They did this by using both computer simulations and real experiments with a mix of testing methods. The results show that structures that are stiff when twisted work better, and the part of the structure that is stiffer has to handle more flexibility than the part that is more flexible.

6 In the study by Mohamed & Abbass (2015), the paper examines the effects of torsional irregularity on seismic response as outlined in ASCE 7–10. Torsional irregularity in building diaphragms causes bigger structural movements, like increased bending and shifting, which need to be included in the model to prevent failures and the problem of buildings hitting each othe

IV. STRUCTURAL MODELING IN STAAD.PRO

Frame Definition

The structure was modeled using concrete frame elements. Beams were sized at 300mm x 450mm, while columns measured 450mm x 600mm. The model incorporates rigid floor diaphragms to distribute lateral forces uniformly.

Material Specifications
Concrete: M30 Steel: Fe500

Support Conditions
Base supports were considered fixed. No soil-structure interaction was modeled.

Seismic Design Inputs
- Zone Factor (Z): 0.24
- Importance Factor (I): 1.0
- Response Reduction Factor (R): 5 (SMRF)
- Soil Type: Medium

V. RESULTS AND INTERPRETATION

Time Period
Fundamental time period of the RCC structure was found to be 0.72 s (hard soil), 0.85 s (medium soil), and 1.12 s (soft soil). For the steel structure, the corresponding values were 0.95 s, 1.14 s, and 1.45 s, respectively. Steel frames exhibited higher time peri ods due to lower stiffness, and the time period increased from hard to soft soil for both systems, highlighting the influence of soil flexibility.

Displacement Analysis
RCC structure was 12 mm (hard soil), 18 mm (medium soil), and 27 mm (soft soil). For the steel structure, the corresponding values were 20 mm, 29 mm, and 43 mm, respectively. Displacement increased with soil softness, with soft soil producing the highest values. Steel structures exhibited significantly higher displacement than RCC due to lower.

Drift Values
Inter-story drift peaked at 0.0027, which is below the maximum threshold of 0.004 defined by IS 1893.

Base Shear Comparison
- RCC buildings attract higher base shear due to higher stiffness and weight.
- Base shear decreases with soil softness, because flexible soil prolongs vibration period, reducing inertial forces.

Base shear under static loading was 1800 kN, whereas dynamic analysis yielded 1520 kN—indicating reduced demand due to modal effects.

VI. CONCLUSION

The study concludes that soil type and structural material greatly influence the seismic performance of irregular L-shaped buildings. Soft soil results in the highest displacement, drift, and torsional effects, while hard soil provides the best seismic stability. RCC buildings show higher stiffness and lower displacement, whereas steel buildings exhibit greater flexibility and ductility, but require additional measures to control sway. The L-shape plan produces noticeable torsional irregularity, demanding proper placement of shear walls or bracings. Overall, the analysis highlights the importance of soil–structure interaction, stiffness balance, and proper seismic detailing for safe design of irregular structur

Future Scope
- Perform Pushover Analysis to determine performance levels and collapse mechanisms.
- Investigate base isolation and damping devices for controlling torsion in irregular buildings.
- Compare more irregular shapes (T-shape, U-shape, C-shape) with varying heights.
- Include foundation flexibility modelling for advanced soil–structure interaction (SSI).
- Conduct experimental validation using shake table tests for irregular building Analyze irregular structures with plan or elevation discontinuities.
- Incorporate Time History Analysis for near-field seismic effects.
- Investigate soil-structure interaction for foundation response.

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