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Seismic Behavior Study of RCC Structures with Different Shapes in Zone III Using ETABS

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Abstract

Earthquakes impose lateral forces on structures that often lead to severe damage and collapse, especially in seismically active regions. The geometry of a building significantly influences its seismic response due to the variation in mass distribution and stiffness. This study investigates the seismic performance of three Reinforced Cement Concrete (RCC) buildings with different shapes Square (Commercial), Rectangular (Residential), and Hollow-Rectangular (Educational) located in Seismic Zone III. All buildings were modelled and analyzed in ETABS using identical loading conditions, storey heights, and material properties to assure uniform comparison. The seismic responses including storey displacement, storey drift, and shear deformation were evaluated as per IS 1893:2016. Results indicate that shape configuration plays a crucial role in structural behaviour. The square-shaped building showed the least displacement due to uniform stiffness, whereas the hollow-rectangular structure exhibited the highest deformation because of stiffness discontinuity and torsional effects. The findings emphasize the importance of geometric planning in enhancing seismic resistance and minimizing structural damage.

Keywords: RCC Structures, Seismic Zone III, ETABS, Storey Displacement, Shear Deformation, Shape Effect

1. Introduction

Earthquakes are unpredictable natural forces that subject structures to dynamic loading, producing lateral forces and ground accelerations that can lead to collapse if not properly considered during design. India is divided into four major seismic zones, and Zone III covers several rapidly developing regions with increasing urbanization and mid-rise infrastructure demands. Structural failures during past earthquakes have highlighted that not only material quality, but building shape configuration plays a major role in determining structural performance.

Modern structural engineering integrates high-precision software tools such as ETABS to analyze seismic response parameters and enable performance-based design. Understanding the behaviour of buildings with varied plan geometries helps engineers determine safe and economic forms during early planning. This research evaluates three RCC building configurations (square, rectangular, and hollow-rectangular) to quantify how shape influences seismic performance in Zone III conditions.

2. Methodology

The methodology is based on comparative seismic analysis of three buildings using ETABS Version 22.

Model	Building Type	Shape	Floors	Storey Height	Seismic Zone
Model 1	Commercial	Square	G+3	3.35 m	III
Model 2	Residential	Rectangular	G+3	4.0 m	III
Model 3	Educational	Hollow-Rectangular	G+3	5.0 m	III

Loading Considerations

- **Dead Load and Self-weight:** Automated
- **Live Load:** As per IS 875 Part-2
- **Seismic Loading:** As per IS 1893:2016
  - Zone factor *(Z)* = 0.16
  - Response reduction factor *(R)* = 5
  - Importance factor *(I)* = 1.0 (Residential & Commercial), 1.5 (Educational)
  - Soil type = Medium

Analysis Parameters

- Equivalent Static Method
- Modal Response Spectrum
- Storey Displacement
- Shear Deformation and Drift

3. Results and Discussion

3.1 Storey Displacement

Maximum lateral displacement was recorded at the top storey for all three models.
Ranking (Highest to Lowest Displacement):

Building	Displacement Behaviour
Hollow-Rectangular (Educational)	Highest displacement due to stiffness irregularity and internal void
Rectangular (Residential)	Moderate displacement due to aspect ratio
Square (Commercial)	Lowest displacement due to symmetric geometry

3.2 Shear Deformation

Shear deformation varied among buildings based on geometry and lateral stiffness:

- **Square building:** Lowest deformation and stable deformation curve
- **Rectangular building:** Slightly greater deformation along the longer side
- **Hollow-rectangular building:** Sharp deformation increase around internal opening leading to torsional effects

3.3 Structural Stability Interpretation

The deformation trends reveal:

- Symmetry enhances seismic safety
- Irregularity and internal voids increase stress concentration
- Higher storey height increases lateral acceleration effects

4. Conclusion

This study clearly demonstrates that the shape of a building considerably influences its seismic performance. Based on the ETABS analysis:

- Square-shaped structures exhibit superior seismic behaviour due to uniform stiffness and mass distribution.
- Rectangular structures perform satisfactorily but are susceptible to increased drifts in the longer direction.
- Hollow-rectangular structures experience large displacement and shear deformation due to stiffness discontinuity and torsional irregularity.

Recommendations

- Avoid irregular plan configurations in high seismic zones.
- Provide shear walls and bracings at critical torsional regions if hollow configurations are unavoidable.
- Adopt performance-based seismic design during conceptual planning.

5. Future Scope

Future studies can focus on:

- Time-history analysis with real earthquake records
- Influence of shear wall placement in hollow/irregular buildings
- Cost and material optimization for seismic enhancement

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