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Seismic Analysis of Structures with Soft Storey and Irregularities: A Comprehensive Review

Mr. Pawan N. Wahane[(1)], Mr. Nitin B. Kothari[(2)]
[(1)(2)]*Assistant Professor, Department of Civil Engineering, JDIET, Yavatmal.*

Abstract: *Seismic vulnerability of soft storey and vertical irregular structures is a significant issue in structural engineering. Structures with open ground storeys, mass irregularity, and discontinuity have greater risks during earthquakes, mainly because of the concentration of forces and large displacement at certain storey levels. This review consolidates evidence from a series of investigations, with prominent features of seismic analysis of soft storey and irregular structures including modeling approaches, performance parameters, and code standards. The observations suggest the implementation of design solutions like shear walls, bracing, and strengthening of stiffness distribution to enhance seismic resilience. Suggestions are also given for future study directions with special emphasis on superior analytical approaches and hybrid structural measures.*

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I. Introduction

The devastating effect of earthquakes on buildings, especially multi-storeyed ones with irregularities, has been much evidenced by different seismic activities around the globe.One such structural irregularity is the soft storey mechanism, which is found commonly in buildings having open ground floors utilized for parking or commercial purposes. Mass irregularities due to sudden changes in mass between successive floors, which add to the seismic susceptibility, further augment the seismic risk. The Indian Standards IS 1893:2002 and IS 456:2000 present vital guidelines to counter such design problems. The present paper offers a thorough review of research studies that focus on the seismic behavior of buildings with soft storey and mass irregularities.

II. Seismic Behavior Of Open Ground Storey Buildings

2.1 General Overview

Open ground storey (OGS) buildings have a discontinuity of stiffness and strength at ground level, causing considerable storey drift during earthquake action.

- Gairola and Dhyani (2019) compared various soft storey models and found that open storey structures undergo greater lateral displacement and inter-storey drift, leading to increased collapse risks.
- AkshayPaidalwar and Awchat (2017) determined that providing strengthening at the ground level is vital to reduce seismic damages.

2.2 Earthquake-Resistant Design Recommendations

Tiwari et al. (2015) emphasized that, without structural interventions like RC shear walls and bracings, the open storey remains a weak point. Retrofitting and design modifications such as providing additional columns or increasing column sizes at ground floor levels were suggested to mitigate seismic effects.

III. Comparative Studies Of Ground And Parking Storey Structures

- Ghalimath et al. (2016) compared the conventional ground storey buildings with buildings that have open parking levels. They found that parking buildings, because of their absence of infill walls at the ground floor, showed much higher lateral drifts.
- AkhileshYadav and Dr. Mishra (2017) pointed out that although architectural requirements encourage open parking systems, seismic requirements necessitate high consideration for stiffness continuity throughout the building.

IV. Effect Of Infill Walls On Structural Seismic Performance

4.1 Contribution of Infill Walls

The role of infill walls, while normally overlooked in design, is key to the development of the lateral strength and stiffness of buildings.

- Tidke and Jangave (2016) illustrated that structures with no infill walls exhibited higher deformation and less base shear capacity.

- Rajurkar and Meshram (2016) illustrated that structures with infill walls performed better in dynamic seismic simulation.

4.2 Design Considerations

The researchs call upon designers to take infill walls into account either as part of the lateral force-resisting system or to model their absence explicitly so that seismic forces are not underestimated.

V. Effect Of Mass Irregularities On Seismic Response

5.1 Analytical Findings

Mass irregularity gives rise to non-uniform dynamic responses and force concentration:

- Shah and Vyas (2017) indicated that vertical mass irregularities result in torsional effects and significant stress concentrations at the location of discontinuity.
- Anvesh et al. (2015) using ETABS modeling, found that structures with mass irregularities exhibit higher base shear demands and overturning moment.

5.2 Time History Analysis

- MyaMya Aye and Narasimharao (2017) employed time history analysis to show that mass irregularities can substantially change the natural time period of the building, thus subjecting them to resonance effects during earthquakes.

VI. Seismic Analysis Of Soft Storey At Different Levels

6.1 Effect of Storey Positioning

- Mohamed Riyas et al. (2016) noticed that placing soft storeys in mid-height or higher levels heightened the total displacement and made the higher modes of vibration dominate the response.
- Pavithra and Prakash (2018) analyzed that the concentration of damage is greatest when the soft storey is near the base because of the inertia forces.

6.2 Comparative Studies

Sanjay G.K. and ShivakumaraSwamy (2018) emphasized that shear walls at key positions greatly minimize the soft storey effect, particularly when supplemented with appropriate stiffness distribution.

VII. Seismic Performance Of Structures With Vertical And Mass Irregularities

- Vishal et al. (2020) and Sharma and Nasier (2019) investigated the dynamic behavior of irregular structures and highlighted the application of bracing systems to regulate lateral deformations and enhance overall seismic performance.
- Dubule and Ainchwar (2018) recommended cautious modeling and analysis of vertical and mass irregularities together to provide overall safety.

VIII. Pushover Analysis And Nonlinear Static Analysis

Pushover analysis has emerged as a crucial tool for the assessment of post-elastic behavior of buildings:

Naphade and Patil (2016) and Basavaraju and JayashankarBabu (2016) employed pushover analysis to investigate failure mechanisms in soft storey buildings. According to their findings, plastic hinges tend to form prematurely at soft storey levels unless strengthened adequately.

IX. Discussion

The literature clearly shows a trend: seismic susceptibility is greater where there are soft storeys and mass irregularities.Yet, proper design interventions such as shear walls, added stiffness at key positions, and optimal mass distribution make these weaknesses considerable to be decreased. Indian earthquake codes offer robust guidelines, whose execution needs strict adherence and combining with sophisticated methods of analysis such as time history and pushover analysis. Research in the near future should explore hybrid solutions featuring dampers, base isolation, and smart material to further resist seismic forces.

X. Conclusion

Soft storey buildings and mass irregularities are extremely prone to seismic damage unless properly designed.

The research studies considered reaffirm the need for proper stiffness and mass distribution, infill wall incorporation, and utilization of advanced modeling.

Proper seismic design requires meticulous attention to structural irregularities backed by dynamic analysis and adherence to appropriate IS codes. The experience and lessons from previous research and earthquake incidents should be incorporated into design procedures to provide safety and sustainability of buildings in seismic areas.

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