

Seismic Evaluation of Masonry-Infilled Buildings with Open Ground Storey and Refuge Floor

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ABSTRACT

This study evaluates the seismic performance of reinforced concrete (RC) frame buildings with masonry infill walls, considering Open Ground Storey (OGS) and Refuge Storey irregularities. L-shaped and Box-shaped building models are analyzed using ETABS according to IS 1893:2016. Dynamic analysis is carried out using the Response Spectrum Method for different seismic zones of India. The results show that structures with OGS and refuge floors are more vulnerable to earthquake effects due to soft-storey behavior and stiffness irregularities. The study suggests the use of improved lateral load-resisting systems and ductile detailing to enhance seismic safety and structural resilience.

Keywords: Response Spectrum Analysis, Masonry Infills, Open Ground Storey, Refuge storey, E-TAB.

I. INTRODUCTION

Rapid urbanization and increasing population density in India have resulted in the widespread construction of multi-storey reinforced concrete (RC) buildings with masonry infill walls. Although masonry infill walls are generally treated as non-structural elements, they considerably affect the stiffness, strength, and overall seismic response of buildings. The provision of Open Ground Storeys (OGS) for parking and Refuge Storeys for safety purposes introduces vertical irregularities that may create soft-storey effects during earthquakes.

Major seismic events such as the 2001 Gujarat earthquake and the 2015 Nepal earthquake demonstrated the vulnerability of buildings with irregular storey configurations. Therefore, understanding the seismic behavior of masonry infilled RC structures with OGS and refuge floors has become essential, particularly in moderate and high seismic regions.

This study investigates the seismic performance of a G+10 RC building using ETABS in accordance with IS 1893:2016. Masonry infill walls are modeled using the Equivalent Diagonal Strut Method. Both bare frame and infilled frame structures are analyzed for seismic Zones II, III, IV, and V under medium soil conditions. Two plan configurations, namely L-shaped and box-shaped buildings, are considered to evaluate the influence of plan irregularity and infill walls on parameters such as base shear, storey drift, lateral displacement, and lateral loads. The study aims to propose suitable design recommendations for improving earthquake resistance and structural safety.

II. Literature Reviews

1. Parth Shah, Roshni John (Jan-2024) – “Study of Seismic Effect on Different Types of Infill Walls”

The paper discusses to evaluate the response of infill walls subjected to seismic loads for regular plans located in zone 3. The response includes Story displacement, Story drift, Base shear. They analyze to study the behavior and pattern of seismic waves of buildings with various types of infill walls in this case G+20 RCC framed building is used. The paper concludes that Base shear for x direction came the most for precast concrete infill walls and the least was of bare frame.

2. Shuenn-Yih Chang , Guo-Chen Hsu, and Chiu-Li Huang (Aug 2023) – “Experimental Study of RC Frame Infilled with Opening Brick Wall”

This study tested three reinforced concrete bare frames filled with brick walls in different shapes i.e full brick walls, opening brick walls, and top opening brick walls. The failure modes of each specimen were observed through cyclically loading tests. The study suggests that diagonal force transfer mechanisms can be simulated using compressive bracing.

3. Pranav Dhumal, Prof. R.M. Desai (Feb 2022) – “Nonlinear Performance of Reinforced Concrete Frame with Infill Wall”

Masonry infill walls significantly affect the overall seismic response of reinforced concrete (RC) structures and therefore cannot be ignored in structural analysis. This study investigates the nonlinear seismic behavior of fully infilled and open ground storey buildings by comparing them with bare frame structures. The infill panels are modeled using an equivalent single diagonal strut approach calibrated with experimental data to accurately represent their structural behavior during earthquakes.

4. Ahmet Gullua and Genco Karames (Aug 2021) – “Effect of building importance factor on seismic performance of rc frame type shopping malls subjected to pulse-like records ”

This study examines two malls with the lower factor using new seismic standards, finding that while there may be issues with story drifts, the average results meet the life safety level. It suggests keeping the importance factor at 1.0 for malls near faults to control costs.

5. Ali Jalaeefara, Azam Zargar (June 2021) – “Effect of infill walls on behavior of reinforced concrete special moment frames under seismic sequences ”

This study examined how infill walls affect reinforced-concrete frames during earthquakes. It used 4, 8, and 12-storey frames with different configurations analyzed using Open Sees software . Results show infill walls increase strength but reduce ductility.

6. Hendrik Wijaya, Pathmanathan Rajeev, Emad Gad and Anita Amirsardari (June 2020) – “Effect of Infill-Wall Material Types and Modeling Techniques on the Seismic Response of Reinforced Concrete Buildings”

This study explored how different infill materials and modeling methods affect the seismic performance of RC buildings. Three building heights with various masonry types were analyzed using nonlinear dynamic analysis and probabilistic seismic demand models.

7. Syed Humayun Basha, Sachin Surendran and Hemant B. Kaushik, M.ASCE (June 2020) – “Empirical Models for Lateral Stiffness and Strength of Masonry-Infilled RC Frames Considering the Influence of Openings”

The study explored how reinforced concrete frames filled with fly-ash brick masonry and different sizes of central openings respond to lateral loads. Results showed that frames with openings behaved differently than those without. The drift limits improved with openings when adhering to earthquake standards.

8. Manisha Nikoshey, Prof. RVRK Prasad (Dec 2019) – “Literature Review-Seismic Analysis of Infill Wall Frame Building with Openings”

Infill walls play an important role in increasing the stiffness of reinforced concrete framed structures during earthquakes. Although commonly treated as non-structural elements in design, they contribute significantly to resisting seismic forces at the initial stages of ground motion. This study evaluates the influence of masonry infill walls on structural stiffness and also examines how openings in infill walls affect the seismic performance of buildings.

9. Shuang Li, Aff.M.ASCE, Mehmet Metin Kose, Sidi Shan and Halil Sezen, F.ASCE (June 2019)- “*Modeling Methods for Collapse Analysis of Reinforced Concrete Frames with Infill Walls*”

The study examines the progressive collapse behavior of RC infilled frames through experiments and numerical simulations. A new three-strut model is developed to better simulate damage in infill walls.

10. Fabio Di Trapani, Luca Giordano, and Giuseppe Mancini (Feb 2019) – “*Progressive Collapse Response of Reinforced Concrete Frame Structures with Masonry Infills*”

The paper studies how masonry infills affect the collapse response of reinforced concrete frame structures. Results indicate that infilled frames are significantly stronger and stiffer than bare frames, also changing damage patterns and safety margins.

11. Peter B.K. Mbewea, Gideon P.A.G. van Zijl (Oct 2018) – “*A simplified non-linear structural analysis of reinforced concrete frames with masonry infill subjected to seismic loading*”

This study presents a simplified nonlinear method for evaluating the seismic behavior of reinforced concrete (RC) frames with masonry infill walls. Using truss analogy and pushover analysis, RC members are modeled as truss elements while infill walls are represented as equivalent struts. The method efficiently predicts structural performance and is validated using experimental results.

12. Koce TODOROV, Ljupco LAZAROV (June 2018) – “*Incremental Dynamic analysis of Infilled frames with open ground storey*”

A study analyzed reinforced concrete frames with masonry infill, revealing irregular distribution can lead to unfavorable seismic performance. The study found that low-rise buildings experience soft storey mechanisms, while mid-rise buildings reduce seismic demand. High-rise buildings' damage distribution depends on infill characteristics and ground motion frequency.

13. Charan chikka javaregowda k s, Mahadev prasad (Aug 2017) – “*Seismic Analysis on bare frame, infilled frame and soft story RC framed buildings*”

Strength and stiffness are essential requirements for any structural building. However, modern constructions often use bare frame systems where the effect of masonry infill walls is neglected. Since masonry infills significantly influence structural behavior, this study compares bare frame, infilled frame, and soft-storey structures. The comparison is based on seismic response parameters such as base shear, storey drift, natural time period, and natural frequency.

14. B Neha kumari, Tejas D Doshi (July 2017) – “*Linear Analysis on Infill Wall with Openings Including Shear Wall at Building Core*”

This study examines the seismic behavior of RC framed buildings with masonry infill walls, which are often neglected in structural design. The analysis focuses on the effect of different opening percentages in infill walls and the role of core shear walls under static and dynamic loading conditions.

15. Geethu Bhanu, Greeshma A K (Apr 2017) – “*SEISMIC BEHAVIOUR OF INFILLED FRAME STRUCTURES WITH AND WITHOUT SHEAR WALL*”

Shear walls improve the lateral strength and stiffness of RC bare frame buildings against wind and earthquake forces. Considering masonry infill walls in structural design can further enhance seismic performance, strength, and overall structural efficiency.

III. METHODOLOGY

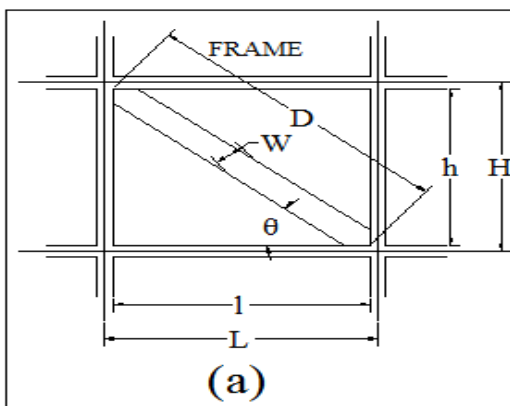
- The study considers a G+10 building subjected to seismic analysis across different seismic zones (II, III, IV, and V).
- The analysis is carried out using ETABS.
- The models are compared based on lateral displacement, lateral loads, storey drift, and base shear.
- Materials used include concrete with a characteristic compressive strength (f_{ck}) of 30 MPa and steel reinforcement with a yield stress (f_y) of 500 MPa.

➤ Loads Calculation approach

The analysis is performed using ETABS considering dead load (DL), live load (LL), and earthquake loads in both directions (−EL and +EL), with load combinations defined as per Clause 6.3 of IS 1893:2016.

$$\begin{array}{lll}
 1.5 (DL+LL) & 1.2 (DL+LL+EL) & 1.2(DL+LL-EL) \\
 1.5 (DL+EL) & 1.5 (DL-EL), & 0.9DL+1.5EL \\
 0.9DL-1.5EL & &
 \end{array}$$

➤ Equivalent Diagonal Strut Methods



➤ Design Seismic Base Shear

The total design lateral force (seismic base shear) along any principal direction is determined using the following expression:

$$V_b = A_h W$$

Where

W –Seismic weight of the building

A_h = Design horizontal acceleration spectrum value

$$A_h = \frac{Z}{2} \times \frac{I}{R} \times \frac{S_a}{g}$$

Where,

Z= Zone factor

Seismic Zone	II	III	IV	V
Seismic Intensity	Low	Moderate	Severe	Very Severe
Z	0.10	0.16	0.24	0.36

Sl No.	Structure	Importance Factor
(1)	(2)	(3)
i)	Important service and community buildings, such as hospitals, schools, monumental structures; emergency buildings like telephone exchange, television stations, radio stations, railway stations, fire station buildings; large community halls like cinemas, assembly halls and subway stations, power stations	1.5
ii)	All other buildings	1.0

Importance Factor I

NO.	TYPE OF RESISTIG FRAME	R-Factor
1	Ordinary RC moment resisting frame (OMRF)	3
2	Special RC moment resisting frame (SMRF)	5

Response Reduction Factor R

IV. CONCLUSION

Masonry infill walls increase the stiffness and strength of RC frames, leading to lower natural periods and better seismic performance.

Structures with open ground storeys are vulnerable to soft-storey effects, resulting in higher inter-storey drifts and increased risk of collapse during earthquakes.

L-shaped buildings show torsional irregularities, causing uneven seismic force distribution and higher structural vulnerability.

Box-shaped (regular plan) buildings exhibit a more uniform seismic response with minimal torsional effects, resulting in improved overall performance under earthquake loading.

Structures in higher seismic zones, such as Zone V, are subjected to higher seismic forces and require stronger design measures, including proper use of masonry infill and suitable structural configurations, to ensure safety and performance.

V. REFERENCES

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