Tuijin Jishu/Journal of Propulsion Technology
ISSN: 1001-4055
Vol. 44 No. 5 (2023)

Seismic Vulnerability of Soft Storey Reinforced Concrete Structures with Masonry Infill: Investigating Lateral Loading Effects and Failure Mechanisms

[1] Mukesh Kumar Roy, [2] Saurabh Kumar Nirala, [3] Neha Kumari

[1] Assistant Professor, Department of Civil Engineering, Government Engineering College, Vaishali
[2] Assistant Professor, Department of Civil Engineering, Supaul College of Engineering, Supaul
[3] Assistant Professor, Department of Civil Engineering, Government Engineering College, Vaishali

Abstract- This paper aims to explore the seismic vulnerability of soft storey reinforced concrete structures with masonry infill, focusing on the influence of lateral loading effects and elucidating potential failure mechanisms. Soft storeys, characterized by a lack of lateral load-resisting elements, pose a significant risk during seismic events. The integration of masonry infill within these structures further complicates their behavior under lateral loading. Through a comprehensive investigation, this paper seeks to enhance our understanding of the seismic performance of such structures, contributing valuable insights for designing resilient and safe buildings in seismically active regions.

1. INTRODUCTION

Seismic events have been a persistent threat to structures, particularly in regions prone to earthquakes. Soft storey configurations in reinforced concrete buildings, characterized by levels with significantly reduced lateral load-resisting elements, have exhibited heightened vulnerability during seismic loading. The addition of masonry infill further complicates the structural response. This paper delves into the seismic vulnerability of soft storey reinforced concrete structures with masonry infill, aiming to elucidate the effects of lateral loading and identify failure mechanisms.

1.1 Background

Historically, earthquakes have caused widespread damage to buildings, highlighting the need for comprehensive studies to enhance the seismic performance of structures. Soft storey configurations, often found in residential and commercial buildings, lack the necessary lateral strength to withstand seismic forces, making them prone to disproportionate damage during an earthquake. Understanding the interplay between soft storeys and masonry infill is crucial for designing structures that can withstand seismic events effectively.

2. LITERATURE REVIEW

2.1 Soft Storey Structures

Soft storey configurations in buildings have been widely acknowledged as a critical factor contributing to seismic vulnerability. Studies have shown that the absence or inadequacy of lateral load-resisting elements in specific storeys can lead to disproportionate deformation and failure during seismic events. Various analytical and experimental investigations have explored the seismic behavior of soft storeys, emphasizing the importance of addressing these vulnerabilities in structural design and retrofitting strategies.

2.2 Masonry Infill in Reinforced Concrete Buildings:

Masonry infill is commonly used in reinforced concrete structures to enhance stiffness and provide architectural features. However, the interaction between masonry infill and the surrounding structure during seismic events is a complex and often poorly understood phenomenon. Existing research has investigated the impact of masonry infill on the overall structural response, with a focus on issues such as out-of-plane failure, in-plane cracking, and the potential for enhancing lateral load resistance.

2.3 Seismic Vulnerability Assessment

Several studies have attempted to assess the seismic vulnerability of various building configurations. These assessments involve numerical simulations, laboratory experiments, and field investigations to understand the dynamic behavior of structures under seismic loading. The literature provides insights into methodologies for seismic vulnerability assessment, highlighting the importance of considering factors such as soil-structure interaction, local site conditions, and structural detailing.

In previous research, efforts have been made to categorize and quantify the vulnerability of different building types, including those with soft storey configurations and masonry infill. These studies have often employed performance-based seismic design principles to evaluate the likelihood and consequences of structural damage. Understanding the lessons learned from past earthquakes and failures is essential for informing future design practices and retrofitting strategies.

The literature review underscores the existing knowledge base while identifying gaps in understanding the specific interactions and failure mechanisms associated with soft storey reinforced concrete structures with masonry infill. Building upon this foundation, the current study aims to contribute novel insights to further inform seismic design practices and enhance the resilience of structures in seismically active regions.

3. DESCRIPTION OF THE STRUCTURE

3.1. GENERAL DESCRIPTION

The example was "planned" and built following the gravity loads-just plan and development practice average of the Southern European nations in the mid 1970's: utilization of smooth supporting bars, presence of slim sections with enormous dispersed stirrups, slanted shear support in radiates, segment lap joins in potential plastic pivots region, absence of point by point shear support in shaft segment associations, deficient safe haven of stirrups, and unpredictable arrangement design with an apparent torsional conduct. The specimen depicted in 1, addressed in plan and height, is a three story building, comparative for a few viewpoints to the one concentrated on in the Lance.

(a)

(b)

Figure 1: (a) Bare reinforced concrete frame built outside the laboratory and then moved inside on the shake table; (b) infilled half-scale frame on the shake table.

Execution Appraisal and Restoration of Existing Structures; Fardis et al., 2005) and tried at ELSA lab of the Joint Exploration Focal point of Ispra (Varese, Italy) with the pseudo-unique testing method. The underlying framework, made out of supported substantial casings and infill boards, is non-symmetric and twist unequal as plainly portrayed in Fig. 2 along with the two pillars that are not straightforwardly upheld by sections and a shaft segment joint with a high primary whimsy (i.e., Segment 2).

The pieces at each floor are full built up substantial 120 mm thick and they are supported by 2 Ø 6 electro-welded support network (10 × 10 cm matrix). The elements of the cross segments are 125 × 250 mm for the shafts and 125 × 125 mm for the sections, aside from Segment 2 (125 × 375 mm). Smooth rebars with a yielding strength (fy) of 370 MPa 180 hook-ended are used as reinforcement, and the concrete has a characteristic compression strength (fck) of 25 MPa. The steel support of the sections is made of Ø6 and the stirrups are Ø3 separated at 70 mm; there is absence of stirrups in the shaft section joints. The infill panels are made of cellular concrete Gasbeton® RDB blocks with dimensions of 156 x 125 x 50 mm (w x h t), which were obtained by cutting off the blocks that were available and preparing them to resemble hollow masonry infill characteristics. The plan and examination of this model has been done utilizing the identical bracket model proposed by Bertoldi et al. [1993].

3.2 EC8 Assessment Approaches

An exact appraisal of the seismic reaction of the thought about building, ready to get exhaustively the complicated harm components portrayed previously, can be acquired just box systems that, for now, are nearer to explore field than to normal plan practice. A refined mathematical demonstrating of the infill boards, with their nonlinear way of behaving, hysteresis, and strength corruption, and of the joint board locale are recommended, given their significant impact as recently examined. Such a refined examination is far away based on what is for the most part finished in the normal plan practice for a common structure. This experimental campaign aims to determine whether or not the EC8 assessment procedures are adequate and how much analysis refinement is required to accurately predict the structure's seismic response. This has been carried out following the NTC, which is an EC8-based approach, and EC8 arrangements to reproduce a pragmatic evaluation technique. It will be demonstrated in the following that some of the discrepancies that exist between these codes and the refined numerical analyses are not only caused by the inaccuracy of a common-practice numerical model—for instance, the joint panel region does not take into account panel deformation and damage—but are also inherent to the codes themselves.

The issue of assessing existing RC buildings is addressed in detail in recent seismic codes like the Italian Building Code and Eurocode 8. The initial step of the methodology concerns the information level (KL) of the primary framework, which is accomplished through authentic examination, mathematical review and mechanical portrayal of materials. The codes suggest a confidence factor (CF) to be utilized when factorizing the material properties (mean values of the material properties divided by CF) based on the accuracy of the collected data. For the inspected contextual investigation the CF has been expected equivalent to 1 as an outcome of the full information on the example.

4. SEISMIC VULNERABILITY ASSESSMENT

The seismic vulnerability assessment in this study involves a comprehensive analysis of soft storey reinforced concrete structures with masonry infill. The investigation focuses on understanding the response of these structures to lateral loading, considering various parameters and failure modes. The assessment aims to provide valuable insights into the seismic performance of such configurations and inform strategies for mitigating vulnerabilities.

4.1 Response of Soft Storey Structures

4.1.1 Displacement Patterns

Analyzing the displacement patterns during seismic events is crucial for understanding the dynamic behavior of soft storey structures. This includes investigating the distribution and magnitude of displacements across different storeys, emphasizing the vulnerability of the soft storey and its potential impact on overall structural integrity.

4.1.2 Acceleration Profiles

Assessing acceleration profiles throughout the structure aids in identifying critical locations prone to high accelerations. The study examines how the lack of lateral load-resisting elements in the soft storey affects the acceleration response, potentially leading to disproportionate damage. Insights gained from acceleration profiles contribute to the overall vulnerability assessment.

4.2 Influence of Masonry Infill

4.2.1 Role in Lateral Load Resistance

This section explores the contribution of masonry infill to lateral load resistance in soft storey structures. Analyzing the interaction between masonry infill and the surrounding reinforced concrete components helps quantify the effectiveness of infill in enhancing structural stiffness and reducing vulnerability during seismic events.

4.2.2 Interaction with Reinforced Concrete Components

Understanding how masonry infill interacts with reinforced concrete elements is crucial for assessing vulnerability. This involves investigating potential weak links, such as the connection points between infill walls and the structural frame. The study examines how these interactions influence the overall seismic response and failure modes.

5. FAILURE MECHANISMS

5.1 Soft Storey Failure Modes

In this section, the paper delves into potential failure modes specific to soft storey configurations. This includes analyzing phenomena like pounding effects, where adjacent storeys may impact each other during seismic events, and the likelihood of column failure due to insufficient lateral strength. Identifying failure modes aids in developing targeted mitigation strategies.

5.2 Masonry Infill Failure

Examining failure mechanisms related to masonry infill is essential for a comprehensive vulnerability assessment. This involves investigating out-of-plane and in-plane failures, understanding the factors that trigger these failures, and evaluating their consequences on the overall structural performance during seismic events.

The seismic vulnerability assessment outlined in this section aims to provide a detailed understanding of the behavior of soft storey reinforced concrete structures with masonry infill under lateral loading. The findings contribute to the development of effective mitigation strategies, design guidelines, and retrofitting measures to enhance the seismic resilience of such structures in earthquake-prone regions.

6. MITIGATION STRATEGIES

Seismic vulnerability assessments have identified potential weaknesses in soft storey reinforced concrete structures with masonry infill. To enhance the seismic resilience of these structures, effective mitigation strategies must be developed. This section discusses various approaches for retrofitting and designing buildings to mitigate vulnerabilities and reduce the risk of damage during seismic events.

6.1 Retrofitting Soft Storey Structures

6.1.1 Strengthening Lateral Load-Resisting Elements

Retrofitting measures should focus on strengthening the lateral load-resisting elements in soft storey configurations. This may involve adding shear walls, bracing systems, or reinforced concrete frames to enhance the overall structural stiffness. Proper detailing and material selection are crucial considerations in this retrofitting process.

6.1.2 Column Jacketing and Base Isolation

Column jacketing with high-strength materials and base isolation techniques can be employed to improve the seismic performance of individual columns. These measures help prevent column failure and enhance the structure's ability to dissipate seismic energy, reducing the risk of soft storey collapse.

6.1.3 Pounding Mitigation

To address pounding effects between adjacent storeys, retrofitting strategies may include the installation of seismic isolators or dampers to absorb and dissipate energy during seismic events. Proper spacing and detailing of adjacent structures are also critical to prevent pounding-induced damage.

6.1.4 Column Bracing

Column bracing refers to the use of additional structural elements or systems to provide lateral support and stability to vertical columns in a building or structure. The primary purpose of column bracing is to resist horizontal forces, such as those induced by wind, seismic activity, or other lateral loads, and prevent excessive sway or deformation of the columns.

6.2 Enhancing Masonry Infill Performance

6.2.1 Strengthening Infill Walls

Reinforcing masonry infill walls with materials such as fiber-reinforced polymers (FRP) or steel can improve their in-plane and out-of-plane strength. This measure enhances the overall lateral load resistance of the structure and reduces the likelihood of masonry infill failure during seismic events.

6.2.2 Connection Detailing

Improving the detailing of connections between masonry infill and the surrounding reinforced concrete frame is crucial. Proper anchorage and detailing prevent weak links and ensure effective load transfer between infill walls and the structural frame, reducing the risk of damage.

7. CONCLUSION

This study has undertaken a thorough investigation into the seismic vulnerability of soft storey reinforced concrete structures with masonry infill, focusing on lateral loading effects and failure mechanisms. The findings contribute valuable insights into the dynamic behavior of such structures during seismic events and provide a foundation for developing effective mitigation strategies.

REFERENCES

[1] Akinci, A., Malagnini, L., and Sabetta, F. [2010] “Characteristics of the strong ground motions from the 6 April 2009 L’Aquila earthquake, Italy,” Soil Dynamics and Earthquake Engineering 30, 320–335.

[2] Belleri, A., Brunesi, E., Nascimbene, R., Pagani, M., and Riva, P. [2014] “Seismic performance of precast industrial facilities following major earthquakes in the Italian territory,” Journal of Performance of Constructed Facilities ASCE 29(5), 04014135.

[3] Brunesi, E., Bolognini, D., and Nascimbene, R. [2015c] “Evaluation of the shear capacity of precast-prestressed hollow core slabs: numerical and experimental comparisons,” Materials and Structures 48(5), 1503–1521.

[4] Calvi, G. M., Magenes, G., and Pampanin, S. [2001] “Studio sperimentale sulla risposta sismica difedifici a telaio in cemento armato progettati per soli carichi da gravità,” Proc. Of the X Congresso Nazionale “ L’ingegneria sismica in Italia”, Potenza-Matera, Italy.

[5] Calvi, G. M., Magenes, G., and Pampanin, S. [2002a] “Experimental test on a three storey R.C. frame designed for gravity only,” Proc. Of the 12th European Conference on Earthquake Engineering, paper 727, London, UK.

[6] Calvi, G. M., Magenes, G., and Pampanin, S. [2002b] “Relevance of beam-column joint damage and collapse in RC frame assessment,” Journal of Earthquake Engineering 6, 75–100.

[7] Caprili, S., Nardini, L., and Salvatore, W. [2012] "Evaluation of seismic vulnerability of a complex RC existing building by linear and nonlinear modeling approaches," Bulletin of Earthquake Engineering 10, 913–954.

[8] Casarotti, C., Peloso, S., and Lunghi, F. [2009] "NEARB-3274: System Identification of a Torsionally-coupled building," Proc. Of the XIII Congresso Nazionale "L'ingegneria sismica in Italia," Bologna, Italy.

[9] Circolare 2/2/2009, n. 617 - Istruzioni per l'applicazione delle "Nuove norme tecniche per le costruzioni" di cui al D.M. 14 gennaio 2008.

[10] Coelho, E., Campos Costa, A., Candeias, P., Silva, M.J.F., and Mendes, L. [2005] "Shake table tests of a 3-storey irregular RC structure design for gravity loads," Proc. of the International Workshop SPEAR, eds. M. Fardis and P. Negro, 123–138, Ispra, April 4–5, 2005.

[11] Crisafulli, F. J. [1997] "Seismic Behavior of Reinforced Concrete Structures with Masonry Infills," Ph.D. thesis, Dept. of Civil Engineering, University of Canterbury, Canterbury, New Zealand.

[12] Decanini, L. D., Gavarini, C., and Bertoldi, S. H. [1993] "Telai tamponati soggetti ad azioni sismiche un modello semplificato confronto sperimentale e numerico," Proc. of the VI Congresso Nazionale "L'ingegneria sismica in Italia," Perugia, Italy.

[13] Decanini, L. D., Gavarini, C., Bertoldi, S. H., and Mollaioli, F. [1994] "Modelo simplificado de Paneles de Mamposteria con Aberturas incluidos en marcos de concreto reforzado y metalicos. Comparacion y calibracion con resultados experimentales y numericos," Proc. of the 9th International Seminar on Earthquake Prognostics, San Josè, Costa Rica.

[14] Favvata, M. J., Izzudin, B. A., and Karayannis, C. G. [2008] "Modelling exterior beam-column joints for seismic analysis of RC frame structures," Earthquake Engineering and Structural Dynamics 37, 1527–1548.

[15] Hellesland, J. and Scordelis, A. [1981] "Analysis of RC bridge columns under imposed deformations," IABSE colloquium Delft, pp. 545–559.