

A Comprehensive Review of Interface Systems in Masonry Reinforced Concrete Frames Under Lateral Loading

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Abstract:

Considering their affordability, ease of construction, and architectural advantages, masonry infill walls are frequently utilised in reinforced concrete (RC) frame buildings. Masonry infills have been shown in numerous studies to have a substantial impact on the stiffness, strength, ductility, energy dissipation, and overall seismic performance of RC frames, despite being traditionally regarded as non-structural elements. However, stress concentration, early cracking, and brittle failure mechanisms are frequently caused by the infill's rigid interaction with the surrounding frame. Researchers have suggested a variety of interface systems and novel materials to alter the frame–infill interaction in order to address these problems. An extensive review of experimental, analytical, and numerical studies on interface systems utilised in masonry-filled reinforced concrete frames under lateral loading is presented in this paper. Rubber joints, lead-based interfaces, pneumatic interfaces, adaptive interface systems, and numerical modelling techniques are the main topics of the review. Additionally covered is research on the impact of openings in infilled frames on structural performance. The study highlights significant advancements, present constraints, and upcoming research requirements for enhancing the seismic behaviour of masonry infilled frames via interface engineering.

Keywords — Masonry infill, RC frame, interface material, seismic behaviour, lateral loading, numerical modelling.

I. INTRODUCTION

Due to the rapid urbanization and population growth modern construction practices primarily involve high-rise buildings, and these structures are more vulnerable to seismic activity [1],[6]. So, high-rise buildings are engineered to ensure seismic activity.

Masonry infill walls are commonly used as partition elements in RC buildings and tend to be considered as a non-structural element during the design process. However, masonry infill walls create an impact on increasing stiffness, strength, and energy dissipation under seismic events; therefore, they should not be ignored in seismic analysis [8],[15],[24]. Experimental and analytical studies shown that the interaction between the infill panel and the RC frame

changes the response of the structure and modifies its failure mechanism [16],[17],[20],[21]. It influences the lateral load transfer mechanism, diagonal strut action, and affects the ductility and seismic performance of the frame.

Under lateral loading caused by seismic activity and wind forces, the infills increase the initial stiffness and reduce the inter-storey drift. Stress concentrations are created at the contact areas as the result of the infill's strong interaction with the external frame, which triggers diagonal cracking, corner crushing, shear failures, and brittle collapse mechanisms [26],[28],[34]. Many researchers have suggested interface systems and decoupling strategies to mitigate the negative consequences of rigid infill-frame interaction. These approaches

enhance the seismic performance, ductility, and damage resistance of RC infilled frames [50].

To address these limitations, researchers investigated various interface systems that alter the contact conditions between the infill and the surrounding frame. Controlling load transfer, lowering stress concentration, increasing energy dissipation, and improving ductility are the goals of these interface systems [37],[49]. Rubber layers, lead interfaces, adaptive interfaces, and pneumatic interface systems that can change their behaviour based on loading conditions are examples of recent advancements. The impact of interface systems in masonry infilled frames on stiffness, strength, ductility, crack propagation, and seismic performance is examined critically in this review.

II. BEHAVIOUR OF CONVENTIONAL MASONRY INFILLED FRAMES

Conventional infilled frames typically fail due to diagonal cracking, corner crushing, sliding shear, and separation between the surrounding frame and the masonry panel. These restrictions encouraged researchers to look into different interface systems that can enhance structural behaviour.

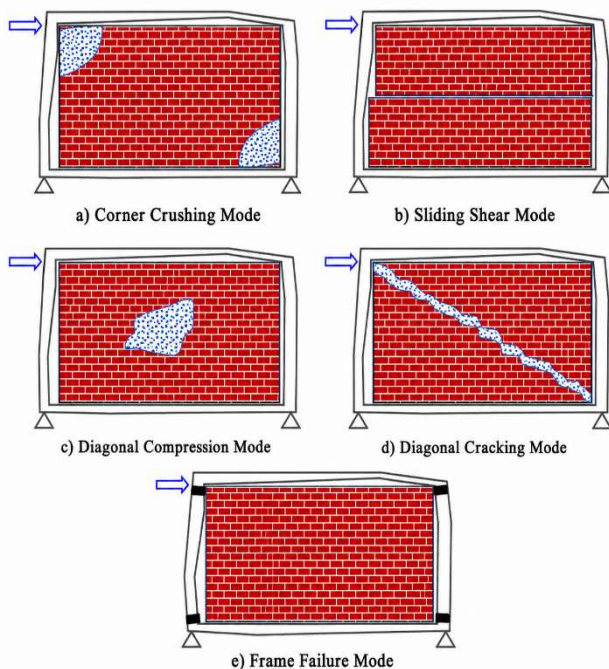


Fig.1 Possible failure modes in infilled frame [11]

The structural response of RC frames is considerably changed by masonry infills. An equivalent diagonal strut mechanism forms as a result of compressive stresses developing along the masonry panel's diagonal direction under lateral loading. The structure's lateral stiffness and load-bearing capacity are increased by this mechanism.

In addition, high stress concentrations are frequently produced at beam-column joints and panel corners due to the rigid contact between masonry and frame. Cracks start close to these areas and gradually spread throughout the masonry panel as lateral loading increases. As the infill gradually deteriorates, the structural system's stiffness deteriorates, its load-carrying capacity decreases, and it eventually fails.

III. INTERFACE SYSTEMS IN MASONRY INFILLED FRAMES

A. Pneumatic interface system

Research focuses on understanding how varying pneumatic pressures at the interface between the infill and the surrounding reinforced concrete frame affect the structural behaviour. Through experimental analyses, the authors likely explore parameters such as compressive strength, deformation characteristics, and the overall response of the infilled frames under different pneumatic pressures. The research contributes to the knowledge of innovative techniques to influence the behaviour of reinforced concrete infilled frames, potentially offering insights into improving their seismic performance or other structural aspects. This study is relevant for structural engineers and researchers seeking to optimize the design and construction practices of reinforced concrete structures with infills, particularly those incorporating pneumatic elements [46].

B. Lead Interface Systems

The effectiveness of lead as a material to minimize the transmission of vertical loads within these structures. Through experimental analyses, the authors likely examine factors such as lead's compressive behaviour, its impact on load distribution within the frames, and overall structural

response. The research aims to provide practical insights into the viability of lead for altering load transfer mechanisms in infilled frames, potentially offering innovative solutions for seismic retrofitting or structural optimization. The studies reported improved deformation capacity and reduced crack propagation due to the ability of lead materials to undergo significant plastic deformation. The findings are relevant for structural engineers seeking novel materials or techniques to enhance the performance and seismic resilience of infilled frame structures, particularly in scenarios where managing vertical load transmission is a critical consideration [44], [42]. Re- distribution of stresses and reduced interface damage are also observed [40]. Enhanced ductility and energy absorption characteristics were also observed [41].

C. Rubber Joint Interfaces

The application of rubber joints as a novel approach to improve the seismic performance of masonry infill walls. The finite element modelling provides a computational framework to analyze the behaviour of the proposed system, while in-plane tests validate the model against practical scenarios. The study contributes to the advancement of seismic retrofitting strategies by introducing and evaluating the effectiveness of rubber joints in enhancing the performance and resilience of masonry infill walls [38].

D. Influence of Openings in Infilled Frames

Openings significantly affect structural behaviour by reducing stiffness, strength and load carrying capacity with increasing opening size. Failure mechanism and crack development also influenced by the size of the opening [50]. Understanding the behaviour of infilled frames under cyclic loading is crucial for optimizing design practices and retrofitting strategies, especially in seismic-prone areas, where structures experience repeated loading cycles during an earthquake [50].

E. Partial and Adaptive Interfaces

Partial interface coverage under monotonic loading it improves deformation characteristics, Reduces

localized stresses, Enhances crack distribution [45]. Adaptive interfaces capable of responding to changing loading conditions. Self-adjustment under dynamic loads, reduced structural damages were observed [39].

F. Variable Interface Thickness

Interface thickness influences the stiffness, reduces stress concentration and increases the energy dissipation [48]. Appropriate interface thickness can therefore contribute to improved seismic performance by controlling load transfer mechanisms and reducing the likelihood of brittle failure [37].

G. Cement mortar interface

The findings contribute valuable insights into the influence of interface conditions on the overall performance of infilled frames, aiding in the refinement of design practices and enhancing the understanding of how different materials at the interface affect the behaviour of such structures [37],[47].

TABLE I
 COMPARATIVE ASSESSMENT OF INTERFACE SYSTEMS

Interface Type	Stiffness	Ductility	Energy Dissipation	Crack Control
Conventional Mortar	High	Low	Low	Poor
Pneumatic Interface	Moderate	High	High	Excellent
Lead Interface	Moderate	Very High	Very High	Good
Rubber Joint	Low-Moderate	High	High	Excellent
Adaptive Interface	Variable	High	High	Excellent
Partial Interface	Moderate	Moderate	Moderate	Good

IV. RESEARCH GAP

There are a number of significant research gaps in the field of masonry infilled frame systems with interface materials, according to the review of the literature. Despite their promising seismic performance, there are few studies examining how pneumatic interfaces behave under cyclic loading conditions. Finding the best solution for structural applications is challenging due to the lack of comparative evaluations of various interface systems.

Additionally, there hasn't been enough research done on these interface materials' long-term durability and service-life performance. The majority of research that is currently available is limited to single-story or small-scale specimens, and studies on multi-story structures are still scarce. Additionally, sophisticated numerical studies that simulate interface behaviour using FEM-DEM techniques are inadequate.

In order to address these gaps and enhance the seismic performance and design of masonry infilled frame structures, more experimental and numerical research is needed.

V.CONCLUSION

By modifying load transfer mechanisms, lowering stress concentrations, and regulating crack propagation within the infill panel, interface systems are essential for improving the seismic performance of masonry infilled frames. Compared to traditional mortar interfaces, advanced interface materials like pneumatic interfaces, lead layers, rubber joints, and adaptive interfaces have been demonstrated to increase ductility and energy dissipation capacity while offering superior crack control. By lowering stiffness and strength and altering crack development patterns, openings in infill walls have a substantial impact on structural behaviour, making the choice of suitable interface systems even more crucial.

The Finite Element Method (FEM), Discrete Element Method (DEM), and coupled FEM-DEM approaches are examples of numerical modelling techniques that have shown promise in simulating frame-infill interaction, forecasting failure mechanisms, and assessing the impact of various interface configurations. To support the creation of trustworthy design guidelines for masonry infilled frame structures, more research is needed to examine how advanced interface systems behave under cyclic loading, evaluate their long-term durability, and conduct thorough comparative studies.

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