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Comparative Study on Seismic Analysis of Reinforced Concrete Frame Building with Masonry Infill Walls

Prabhat Garg[1] and Dr. Yogesh Aggarwal[2]

[1]M.Tech scholar, Department of Civil Engineering, NIT Kurukshetra, Haryana, India
[2]Professor, Department of Civil Engineering, NIT Kurukshetra, Haryana, India
E-mail: [1]prabhat_32112306@nitkkr.ac.in, [2]yogeshkumar@nitkkr.ac.in

Abstract—*Masonry infills are built integral of reinforced concrete frame, and are usually considered as non-structural elements. Studies have shown that masonry infills can increase the stiffness, strength and energy dissipation characteristic of framed structures. The presence of infilled panels in buildings with reinforced concrete frames can lead to conflicting effects on the structural response, depending on the mechanical properties, the geometrical distribution of infills and the interaction with structural elements. This paper represents a critical review of the seismic analysis of reinforced concrete frame building with infill walls. The base shear, displacement, storey drift calculated by various researchers in past via experimental and numerical approach were discussed.*

INTRODUCTION

In areas prone to earthquakes, Reinforced Concrete (RC) frame buildings are widely used due to their inherent strength and ability to withstand seismic activity. These buildings comprise vertical columns and horizontal beams, which are linked by joints to create a robust frame. To provide additional rigidity and strength to the structure, infill walls are often used to fill the spaces between the columns and beams. However, these infill walls can have a significant impact on the seismic behaviour of the building.

For many decades, researchers have been investigating the seismic behaviour of RC frame buildings with and without infill walls. The main goal of this research is to assess how these structures perform during earthquakes and to develop effective strategies to enhance their seismic resistance. A variety of analytical techniques and methodologies, such as finite element analysis, pushover analysis, and nonlinear dynamic analysis, have been employed in this research.

Seismic Analysis of RC Frame Buildings with Infill Walls:

Infill walls can have a considerable impact on the seismic behaviour of RC frame buildings. They offer supplementary rigidity and strength to the structure, which can decrease the risk of damage or collapse during seismic activity. Nevertheless, the behaviour of these walls when subjected to seismic loads can be intricate, and determining their contribution to the building's overall stiffness and strength can be challenging.

Finite element analysis (FEA) is a technique that is widely utilized for studying the seismic behaviour of reinforced concrete (RC) frame buildings that are equipped with infill walls. By utilizing FEA, a detailed model of the structure can be created, including the infill walls. This technique provides valuable information regarding the stress and deformation patterns within the building. Multiple studies have employed FEA to investigate the impact of various types of infill walls on the seismic response of RC frame buildings. One such study by Zhang et al. (2019) employed FEA to examine the effect of brick infill walls on the seismic behaviour of a six-story RC frame building. The study discovered that the presence of infill walls led to an increase in the stiffness and strength of the building, which resulted in a decrease in displacement and acceleration response during seismic events.

Pushover analysis is another widely utilized technique for assessing the seismic performance of reinforced concrete (RC) frame buildings with infill walls. This method involves subjecting the structure to gradually increasing lateral loads and examining the resulting response. The pushover analysis is typically utilized to evaluate the building's capacity to resist seismic loading, as well as to identify potential failure modes. Many studies have employed pushover analysis to evaluate the impact of infill walls on the seismic behaviour of RC frame buildings. For instance, Kumar et al. (2019) conducted a study using pushover analysis to assess the effect of different types of infill walls on the seismic response of a six-story RC frame building. Their findings revealed that the presence of infill walls increased the lateral stiffness of the building. However, the study also highlighted that the presence of infill walls heightened the likelihood of failure due to out-of-plane buckling.

Nonlinear dynamic analysis is yet another technique that has been employed to examine the seismic behaviour of reinforced concrete (RC) frame buildings with infill walls. This method involves subjecting the structure to realistic ground motion records and analysing the resulting response. By utilizing nonlinear dynamic analysis, it is possible to gain a deeper understanding of the structure's behaviour under actual seismic loading conditions, and it can be used to identify potential failure modes. Numerous studies have utilized nonlinear dynamic analysis to assess the impact of infill walls on the seismic behaviour of RC frame buildings.

LITERATURE REVIEW

Uva et. al (2012) conducted a thorough case study on an existing reinforced concrete (RC) framed structure located in a region in Southern Italy with a significant seismic risk

The project, which dated back to the early 1970s, only accounted for the presence of vertical loads. To determine the effect of infill walls on the failure mechanisms, the researchers performed a number of non-linear static (pushover) calculations on precise structural models of the building, taking into account both the bare frame structure and the infilled one. The study found that the infill walls played a significant role in the distribution of forces and advanced the failure of the primary elements as horizontal loads increased [1].

Chiu et. al (2022) aimed to ascertain the reinforced concrete (RC) infill wall members' residual seismic strength following an earthquake. The remaining seismic capability of damaged RC infill members was calculated for specified damage levels using experimental data from six wall specimens exhibiting shear failure. Additionally, dynamic loading was used to evaluate the RC infill wall components' remaining seismic strength. Additionally, both with and without horizontal interface slippage, the decrease factors of strength and stiffness for damaged RC infill wall components were examined. The study also defined damage patterns and limiting deformation for each damage level, which engineers may use to calculate the degree of damage to an earthquake-damaged RC infill wall. Based on the experimental results, the study gives reduction factors of seismic capability for RC infill walls with shear failure modes[2].

Jalaeefar and Zargar (2020) conducted a research to determine how infill walls affect reinforced concrete (RC) special moment frames' behaviour when exposed to many earthquakes. The study involved the analysis of 4, 8, and 12-storey RC frames in three different scenarios: with and without infill walls, and with infill walls containing openings. Open Sees software was used to perform nonlinear dynamic analyses, and displacement ductility, rotational ductility, and energy absorption were evaluated. The results of the investigation showed that the addition of infill walls increased the stiffness and overall strength of the buildings. The ductility and energy absorption, however, were decreased. Due to the infill walls' splitting and collapse, the structures that contained them significantly lost strength, especially when they were subjected to several earthquakes[3].

Choi et. al (2017) conducted The in-plane behaviour of unreinforced masonry (URM) infill walls put in reinforced concrete frames is being investigated through experimental research. They created two 1/4-scale model frames with varying numbers of spans (single or double), and they tested the lateral force resistance mechanisms in the in-plane direction using static cyclic loading. The authors measured strain data on blocks forming the infill walls to obtain their major findings. They found that the maximum strength of a one-story, one-bay frame with URM infill was approximately twice that of a one-story, two-bay frame with URM infill. Moreover, they applied an equivalent diagonal strut identification method to specimens with different bay numbers to investigate the lateral force resisting mechanisms. The outcomes validated the use of analytical modelling for infill in multi-bay frames based on a single strut[4].

Manos et. al (2012) aim to put forth reliable numerical models that can accurately predict how masonry assemblages will behave in shear and how masonry-filled reinforced concrete (R/C) frames will behave in hysteresis when they are subjected to combined vertical and horizontal cyclic stresses. Successful numerical models are created for the nonlinear behaviour and ultimate strength of relatively weak Greek masonry piers, as well as the nonlinear behaviour and geometry of masonry joints. These simulations are then utilised to create the infills for the R/C frames. For the purpose of simulating the behaviour of masonry-filled R/C frames subjected to cyclic lateral stresses, three distinct methods of numerical simulations were used. The findings demonstrated that the suggested models may make accurate predictions of the infill walls' global and local responses, as well as their diagonal compression strength and experimentally observed failure process[5].

Srechai et. al (2022) proposed an innovative multi-strut macro model to simulate infilled RC frames and the corresponding empirical formulae. Fiber-section truss components were used as the struts in the model, which was created based on earlier experimental results and took into account all possible failure modes of the infill wall. Empirical formulas were developed and calibrated based on a comprehensive experimental database and regression analysis to predict the equivalent stress-strain parameters of the struts. The validation results revealed strong agreement between analytical and experimental findings in terms of global and local responses, accurately reflecting the surrounding columns' surrounding columns' strength deterioration, pinching effect, and failure mechanism. This method is thought to be reliable for modelling infilled frames given the considerable uncertainty of infill wall features[6].

Maddileti and Ramakrishnaiah (2017) conducted an evaluation of the efficiency of RC frame structures with and without infill walls. To determine how masonry infill walls contributed to the seismic resilience of typical reinforced concrete buildings, they developed and researched these walls using the equivalent diagonal strut idea. Using software (SAP2000), two alternative buildings—one with and one without infill walls—were modelled and their lateral masses were examined. Results from seismic load analysis and gravity load analysis were compared between the bare-frame model and the equivalent diagonal strut models. The study found that when the infill frame's stiffness is not taken into account in the bare model, the stiffness of the building is very low, whereas the strut models, which took the infill frame's stiffness into account as a strut, had more stiffness of the building and were also more cost-effective in terms of steel section area[7].

Narayana et. al (2015) conducted an analysis on office or residential buildings with central or partial openings on the outer side. Four different models were analysed using ETABS software: bare frame, infill walls without opening, infill walls with central opening, and infill walls with partial opening. According to IS 1893:2002, analysis was conducted using the Equivalent Static Lateral Force Method and the Response Spectrum Method, which included p-delta effects. When infills were taken into account, the findings revealed a considerable reduction in displacement and a marginal increase in displacement owing to openings. By taking into account the influence of infills, the building's stiffness was raised by around 70%, and the base shear was also discovered to have risen. It was determined that a rise in opening % causes a fall in lateral stiffness[8].

Tilva et. al (2016) conducted a study on a symmetrical commercial building frame (G+5) situated in different seismic zones and soil conditions. The study involved modelling of the initial frame with provisions for calculating the stiffness of the infill masonry walls using the "Equivalent Diagonal Strut Method" and IS 1893-2002. Linear static analysis was carried out on different models such as the strut frame using the STAAD-Pro software to compute various parameters. The displacement increased by 30 to 40% when changing from hard soil to Medium soil, and by 0 to 10% when changing from Medium to Soft soil. The storey drift increased by 30 to 40% when changing from Hard to Medium soil, and by 0 to 10% when changing from Medium to Soft soil. Infill panels increased the stiffness of the structure, and their presence in high-rise buildings reduced the top storey displacement and storey drift, while increasing the base shear. The study concluded that the non-structural infill walls can significantly modify the seismic behaviour of RC framed buildings[9].

Munde, Magarpatil 2012 demonstrated the seismic vulnerability of buildings with soft storeys through a case study of a G+9 reinforced concrete building. They used the theory proposed by Stafford-Smith and Carter to model the infill wall. To address the problem, they suggested increasing the stiffness of the first storey to be at least 50% as stiff as the second storey and providing adequate lateral strength in the first storey. This can be achieved by incorporating stiffer columns or infill walls at specified locations in the ground floor of the building. The provision of stiffer columns only reduces the lateral drift demand on the first storey columns, whereas the use of infill walls not only reduces the drift but also the strength demands on the first storey columns[10].

Raghavender et. al conducted Using three distinct models—a bare frame, a frame with masonry wall infill, and a frame with equal diagonal strut infill as per IS 1893 (part1):2016—we performed a response spectrum study on a 12-story reinforced concrete office structure. A spreadsheet was created to check and compare the analysis' results, which were produced using the ETABS programme. The infilled frame model showed a higher base shear value compared to the bare frame model. Significant differences in time period and storey displacement were observed. The results were comparable and had acceptable margins of error for both the programme and human computations[11].

Fiore et. al (2012) aimed to develop a simple tool that could replicate the impact of infills on the overall stiffness and local response of a building subjected to earthquake loads. To evaluate the local impacts on the frame and the impact of the coefficient of friction at the interface between the infill and the frame, the researchers performed Finite Element calculations and compared the results to experimental data. Then, in order to get acceptable results in both global and local assessments, they suggested an appropriate macro-model to mimic the infill behaviour. The macro-model consists of two non-parallel struts put in each frame, accounting for the key factors that influence how an infilled structure behaves. The investigation showed that the suggested two-strut model faithfully recreated both the local impacts on frames in terms of stresses, bending moments, and shear pressures as well as the global behaviour of infilled frames regarding displacements[12].

Mohyeddin et. al (2013) presented a three-dimensional discrete-finite element model for masonry infill in reinforced concrete frames using ANSYS. The model was verified using experimental data available in the literature. The model was first independently confirmed for masonry and reinforced concrete. The two methodologies were then integrated to create an infill-frame, which was then tested against published experimental findings. The research found that the built-in model worked well for investigating an infill-frame's behaviour under displacement-controlled in- and out-of-plane loads[13].

CONCLUSION

The reviewed studies provide valuable insights into the behavior of reinforced concrete (RC) frames with infill walls subjected to seismic loads. Uva, Porco, and Fiore's study shows that infill walls play a significant role in the distribution of forces and advanced the failure of the primary elements as horizontal loads increased. Chiu, Sung, and Chiou's research provides reduction factors of seismic capacity for RC infill walls with shear failure modes, based on experimental data. Jalaeefar and Zargar's study revealed that the inclusion of infill walls led to an increase in the stiffness and ultimate strength of the structures but reduced their ductility and energy absorption. Choi, Sanada, and Nakano's study supported the effectiveness of analytical modeling based on a single strut for infill in multi-bay frames, while Manos, Soulis, and Thauampteh's research showed that proposed models can provide good predictions for both the global response and the local response of the infill walls. Srechai, Leelataviwat, Wararuksajja, and Limkatanyu proposed a novel multi-strut macro model to simulate infilled RC frames that showed good agreement between analytical and experimental results. Finally, Maddileti and Ramakrishnaiah's comparative study on the performance of RC frame buildings with and without infill walls observed that the strut models had more stiffness and strength than the bare-frame model.

After inclusion of the infill walls in the RC frame it was seen that the Base Shear is increased and the stiffness of the story also had increased. Due to increase in stiffness of building it increases the ultimate strength of building but it also reduces the ductility of building and energy absorption.

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