SEISMIC EFFECT OF OPENING IN MASONRY WALL IN THE RCC STRUCTURE AT DIFFERENT POSITIONS: A REVIEW

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Abstract - *The exploration of the seismic behavior exhibited by masonry walls integrated within reinforced concrete (RCC) structures, particularly when incorporating apertures, has garnered substantial attention within the field of earthquake engineering. Within this review paper, a comprehensive synthesis of existing research endeavors is undertaken to shed light on the seismic repercussions stemming from the inclusion of openings in masonry walls positioned at various locations within RCC structures. By meticulously scrutinizing a breadth of literature encompassing experimental, analytical, and numerical investigations, the overarching goal of this review is to unravel the intricacies and obstacles inherent in the seismic performance of such structural configurations. Essential factors that exert influence on seismic response, such as wall geometry, the dimensions and placement of openings, reinforcement specifications, and dynamic loading attributes, are subjected to detailed analysis. Through the amalgamation of insights gleaned from a myriad of studies, this paper endeavors to furnish valuable perspectives pertinent to researchers, engineers, and practitioners engaged in the seismic evaluation of masonry-infilled RCC structures. The amalgamated knowledge delineated herein not only accentuates gaps in current comprehension but also serves as a cornerstone for future research pursuits aimed at enhancing the seismic resilience and safeguarding of constructed infrastructure.*

***Key Words*:** Seismic effects, Masonry walls, Reinforced concrete structures, Openings, Structural positioning, Seismic behavior, Structural dynamics.

1.HISTORY

During the latter half of the 20th century, a period characterized by the widespread adoption of reinforced concrete construction owing to its commendable strength and adaptability, a cohort of dedicated researchers and engineers embarked on an extensive journey to explore the intricate behavior of masonry walls integrated within RCC structures. This era marked a profound shift towards unraveling the complex interplay between masonry infills and the encompassing concrete framework, with a particular emphasis on seismic loading dynamics [1]. Motivated by the realization that the presence of openings, ranging from windows to doors, introduces notable alterations in the stiffness and distribution of strength within walls, researchers embarked on focused inquiries into the seismic repercussions induced by these apertures. Experimental testing emerged as a pivotal methodology, with researchers meticulously orchestrating laboratory experiments to faithfully simulate seismic loading conditions and meticulously observe the response of walls exhibiting a myriad of configurations of openings. Simultaneously, the development of analytical models gained prominence, enabling the accurate prediction of the dynamic behavior of such structures and the meticulous assessment of their susceptibility to seismic forces, thereby establishing a robust foundation for the continual advancement of numerical simulation techniques [1].

2.INTRODUCTION

In regions susceptible to earthquakes, where the safety and preservation of both human life and property are paramount concerns, the seismic performance of structures assumes utmost significance. The robustness and adaptability of reinforced concrete (RCC) structures make them a preferred choice in such areas, offering resilience against seismic forces while accommodating diverse architectural designs. Embedded within these RCC structures, masonry walls play multifaceted roles, serving as partitions, load-bearing elements, and aesthetic features [2]. However, the inclusion of openings such as windows and doors within these masonry walls substantially modifies their structural response, particularly when subjected to seismic loading conditions.

Understanding the seismic implications of openings in masonry walls within RCC structures is imperative for safeguarding buildings in earthquake-prone regions. The dynamic behavior of these structures under seismic forces is intricate, influenced by a multitude of factors including wall geometry, the dimensions and positioning of openings, reinforcement specifics, and the characteristics of dynamic loading. Moreover, the placement of openings within the structure can yield diverse effects on its overall seismic performance [2]. Hence, conducting a comprehensive exploration into the seismic behavior of masonry walls with openings at various positions within RCC structures is indispensable for informing effective design strategies and retrofitting interventions.

By amalgamating insights from experimental investigations, analytical studies, and numerical simulations, this review endeavors to shed light on the intricacies and hurdles associated with the seismic performance of such structural configurations. Additionally, the paper seeks to pinpoint existing knowledge gaps and chart pathways for future research endeavors aimed at bolstering the seismic resilience of masonry-infilled RCC structures. Through this concerted effort, invaluable perspectives can be gleaned to enhance the safety and sustainability of built environments in earthquake-prone regions [9].

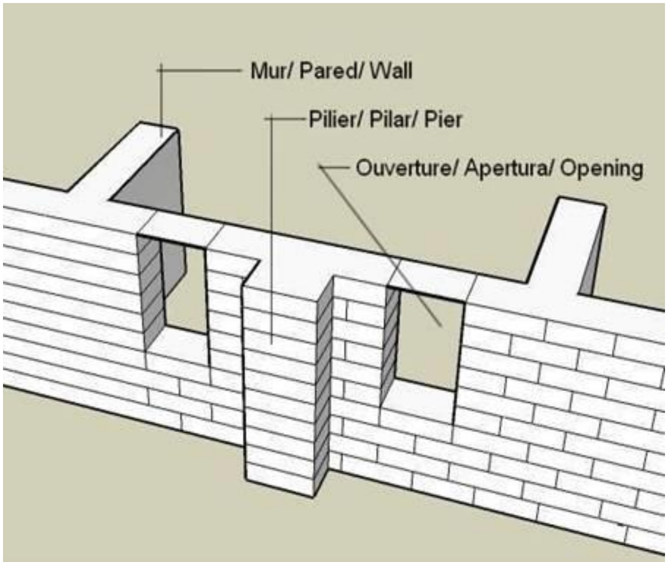

Figure-1: Opening in the Building [1].

3.OPENING IN THE MASONARY WALL

To create an opening in a masonry wall, meticulous planning and execution are essential to uphold structural integrity, beginning with a thorough assessment of the opening's purpose and its potential impact on the wall's stability, especially for complex projects, seeking guidance from a structural engineer if necessary [8]. Once the parameters are established, accurately mark the outline of the opening using chalk or pencil, and for load-bearing walls, provide temporary support to redistribute the load during the cutting process. Utilize appropriate tools such as masonry saws or diamond-tipped blades to cut through the marked area with precision, taking care to avoid damage to adjacent surfaces. Reinforce the opening with lintels or other supports as required to maintain structural stability. Following the cutting phase, meticulously finish the edges with mortar or trim pieces to ensure a refined appearance and prevent water infiltration. Thoroughly clean the area and proceed to integrate frames for windows or doors, adhering closely to manufacturer instructions [10]. Conclude the process by conducting a comprehensive inspection to ensure compliance with building codes and add final touches such as painting to seamlessly blend the opening with the surrounding wall. Throughout the entire procedure, prioritize safety considerations and enlist professional assistance when deemed necessary.

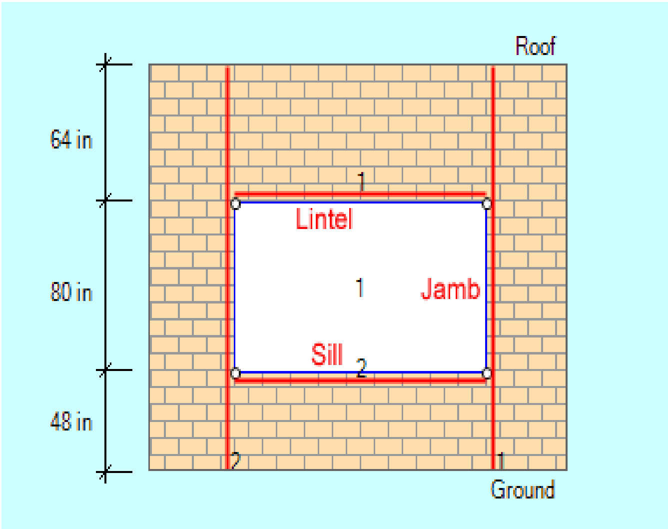

Figure-2: Opening in the Masonary Wall [1].

2.1.Purpose of Opening in the Structure

Openings within structures fulfill a myriad of indispensable functions, serving as conduits for various essential activities. Firstly, they act as portals for ingress and egress, facilitating the smooth flow of individuals, vehicles, and materials in and out of a building. Additionally, apertures such as windows, vents, and louvers assume a pivotal role in ventilation, ensuring optimal airflow to uphold indoor air quality and regulate humidity levels effectively [11]. Moreover, these openings permit natural light to permeate indoor spaces, diminishing reliance on artificial lighting and augmenting the occupants' overall well-being. Furthermore, these apertures frame scenic vistas, fostering a harmonious connection with the surrounding environment and enriching the overall sensory experience within the structure. In emergency situations, designated openings function as critical escape routes, adhering to safety regulations to facilitate swift egress and ensure occupants' safety [3].

Beyond their functional aspects, openings also contribute significantly to the aesthetic appeal of a structure, adding architectural intricacy and imbuing it with character.

Thoughtfully positioned openings may alleviate structural stresses, distribute loads more effectively, or accommodate structural movement, thereby bolstering the building's overall stability and safety. Hence, openings emerge as integral components of structural design, catering to a spectrum of needs ranging from practical functionality to aesthetic enhancement and paramount safety considerations [4-5].

2.2.Type of Opening in the Structure

Structures are characterized by a multitude of openings, each serving distinct functions and adapting to a wide array of architectural and practical needs. Doors, acting as primary access points, facilitate entry and exit throughout buildings and individual rooms. Windows, with their dual functionality, not only allow natural light to flood indoor spaces but also aid in ventilation and provide captivating views of the surrounding environment. Vents, strategically positioned within structures, regulate airflow, particularly in enclosed areas such as attics and mechanical rooms, ensuring proper ventilation. Skylights, ingeniously integrated into roofs or ceilings, infuse interiors with daylight, especially in spaces where traditional windows are not feasible. Louvers, distinguished by their slatted design, strike a balance between airflow and privacy, serving essential roles in HVAC systems and enhancing the visual appeal of building facades. Transoms, positioned above doors or windows, augment both illumination and airflow, often contributing to the refinement of traditional architectural aesthetics. Garage doors, tailored for vehicular access, come in diverse configurations to accommodate various spatial constraints and functional necessities [6]. Emergency exits, indispensable for safety, provide swift egress during crises, featuring specialized hardware and adherence to stringent building codes. Collectively, these diverse openings play a pivotal role in enhancing the functionality, aesthetics, and safety of structures, meticulously tailored to meet the unique demands of each architectural endeavor [7].

3.LITERATURE SURVEY

In the section of the literature survey, we have studied the previous research papers which is related to the opening in the structure due to various loading conditions. The summary of the previous research is given below:

Shariq et.al (2007): The critical direction of seismic force responsible for inducing maximum stresses within the walls of a room containing openings predominantly aligns along the shorter wall of the room. When the aspect ratio of such a room with openings is augmented, while maintaining one side fixed, there is a corresponding escalation in both the maximum principal tensile stress and maximum shear stress experienced within the structure. Specifically, the principal tensile stress and shear stress attain their peak magnitudes when the direction of seismic force coincides with the wall housing the highest concentration of openings. Furthermore, an increase in the number of openings within a wall invariably leads to a corresponding elevation in the stresses encircling these apertures.

Vedang, Abhishek (2014): Various earthquake reactions are encompassed within the modeling process, including storytelling, storytelling moment, storytelling ability, and storytelling strength, as these parameters serve as prominent features in any comprehensive analysis. Consequently, it becomes imperative to conduct a thorough structural analysis of the asymmetrical cantilever with a shear wall positioned in different areas under varying loads to ascertain the optimal location for the shear wall.

Ashok et.al (2016): The presence of both external and internal shear walls results in a reduction of column moment and axial force when compared to configurations employing only a core or a core with internal shear walls. Among the various models considered, shear wall model IV demonstrates superior effectiveness due to its higher building stiffness. Additionally, the Response Spectrum Method yields predictions of lesser forces in contrast to the Seismic Coefficient Method. The inclusion of openings within shear walls diminishes both their strength and rigidity, with the extent of this reduction contingent upon the sizes and shapes of the openings. As the sizes of the openings increase, there is a corresponding increase in column moment and axial force due to the decrease in shear wall stiffness. However, the detrimental effects of openings on shear wall performance are mitigated with an increase in the length of the shear wall in plan, while the shape of the opening has minimal impact on structural responses, although the height and width of the openings do exert significant influence.

Gaikwad (2017): Observations reveal that twisting within a building exhibits an increasing trend as the eccentricity between the geometrical centroid of the structure and its center of mass is heightened. Notably, the torsional values of structures with shear walls positioned at elevator lifts are significantly lower—approximately 24% for a 400mm eccentricity and 34% for a 150mm eccentricity in both EQX and EQY directions—compared to structures devoid of shear walls. Furthermore, the base shear for structures with concentric shear walls is notably reduced in comparison to those without shear walls, exhibiting decreases of 31% for a 450mm eccentricity and 25% for a 150mm eccentricity in both EQX and EQY directions. Conversely, there is minimal alteration in base shear and torsion when shear walls are oriented parallel to the Y direction due to EQX and EQY seismic forces, with torsion being particularly unaffected at top floors. However, on the ground floor, torsion is diminished by 16% to 24% when shear walls are present. Interestingly, the inclusion of shear walls at exterior corners leads to a substantial reduction in both base shear (ranging from 28% to 35% for EQX and EQY) and torsion (decreased by 29% to 35%). Despite this, augmenting the thickness of shear walls does not notably enhance structural strength, resulting in uneconomical designs across all scenarios. Furthermore, the displacement of the top floor is significantly diminished in all cases involving shear walls; however, the reduction is more pronounced when shear walls are situated at corners as opposed to other locations within the structure.

Nila et.al (2018): In order to enhance the earthquake resistance of masonry walls, it is imperative to establish proper attachments between the masonry panels at their junctions. However, the seismic capacity of unreinforced masonry (URM) walls experiences a significant reduction with an increase in geometric irregularity. Notably, symmetrical buildings demonstrate superior performance during earthquakes compared to asymmetrical or biaxially asymmetrical structures. Among these, biaxially asymmetric buildings exhibit better performance in their long wall direction. Moreover, as the percentage of openings in walls increases from 3 to 7, there is a notable 40% reduction in shear carrying capacity. Interestingly, buildings with openings positioned at the center of walls showcase a 30-40% higher performance than those with openings located at other positions.

Amit et.al (2019): The investigation entails the utilization of Staad Pro software to determine the most effective, economical, and optimal positions for shear walls in a high-rise building situated in diverse locations. Specifically, a G+7 high-rise structure located in zone IV of Delhi serves as the focal point of the study. Preliminary investigations are conducted, and the building is analyzed through five distinct models: a structure without shear walls, shear walls positioned along the periphery, at corners, in the middle, and at corner locations in various positions. Subsequently, the maximum shear wall moments and deflections are calculated and scrutinized across all considered scenarios. For the analysis, M30 grade concrete and Fe415 steel are employed, with the design and analysis processes being executed using the STAAD Pro software package.

Hamid, Saraswati (2019): The construction of multi-storey buildings often employs a reinforced concrete frame with masonry infill walls, incorporating door and window openings for functional purposes. Although masonry infill walls are not typically considered structural elements that contribute to the overall mass of the structure, their strength and stiffness are commonly disregarded in general design practices outlined in IS:1893-2002, potentially resulting in unsafe designs. To address this oversight, IS:1893-2016 recommends modeling the in-plane stiffness of unreinforced masonry (URM) infill walls or panels using equivalent diagonal struts, with no reduction in strut width required for URM infill walls with openings. However, in this paper, the effect of openings in URM infill walls is taken into account by applying a width reduction factor for diagonal struts. The seismic response of a G+5 L-shaped reinforced concrete frame building with various openings in URM infill walls, situated in seismic zone IV, is analyzed using linear dynamic Response Spectra Method with ETABS software. The parameters under investigation include lateral stiffness, displacement, story drift, base shear, and overturning moment.

Abin et.al (2020): Based on past global earthquake occurrences, it is evident that unreinforced masonry structures are significantly more vulnerable to seismic events compared to reinforced structures, often leading to sudden and catastrophic collapses. The focus of this review paper primarily revolves around the seismic analysis and design methodologies pertaining to masonry structures. Initially, architectural drawings are meticulously prepared, taking into account various functional, geometrical, and engineering considerations. The building under scrutiny is situated in the Himalayan region of Nepal, designated as a high seismic zone, namely zone V. The structure subjected to analysis and design is a single-story dressed stone masonry building featuring a metal roof structure with CGI roof sheets. Subsequently, the building is meticulously modeled using FEM-based software (SAP2000, version 18.1.1) to conduct a detailed structural analysis encompassing all pertinent material properties, loads, and load combinations. The resulting analysis entails the determination and scrutiny of parameters such as direct stresses, bending stresses, shear stresses, tension, among others, against the prescribed material limits as per relevant code provisions. Adjustments to the architectural drawings are made as necessary to ensure compliance with the safety standards mandated by applicable codes.

Boria, Tamal (2021): It has been observed that positioning shear walls in the core as well as at the corners results in minimal storey drift compared to other types of shear wall placements, albeit with an increased amount of base shear observed in both the x and y directions. Conversely, for bare frames, a typical displacement trend is observed. According to IS code 1893:2002, storey drift should not exceed 0.004 times the storey height, and the studies indicate that storey drift remains within this limit. As a prospect for future research, further pushover analysis and time history analysis could be proposed to yield more conclusive results.

Udit et.al (2022): Shear wall structures with no opening, vertical opening, and staggered opening have time periods of 0.531, 0.585, and 0.591 seconds, respectively. In comparison to vertical opening and no opening in shear wall, staggered opening in shear wall takes more time. By using the Equivalent Static Method, the storey displacement for a shear wall structure without opening, with vertical opening, and with staggered opening is 21.443 mm, 23.171 mm, and 23.169 mm, respectively. According to the Response Spectrum Method, the storey displacement for a shear wall structure without opening, with vertical opening, and with staggered opening is 18.196 mm, 20.161 mm, and 20.123 mm, respectively. The presence of an opening increases storey displacement in both methods, but storey displacement in a staggered opening in a shear wall is slightly less than in a vertical opening in a shear wall. By using the Equivalent Static Method, the Storey drift for a shear wall structure without opening, with vertical opening, and with staggered opening is 0.000755, 0.000798 and 0.000806, respectively.

Desale et.al (2022): The presence of shear walls substantially enhances the structure's ability to resist lateral forces, while also significantly augmenting storey stiffness across all levels. Particularly noteworthy are the notably elevated storey shear values observed in CASE 3 relative to all other models. Additionally, the inclusion of shear walls effectively mitigates storey drift within the building, with CASE 3 exhibiting the lowest storey drift compared to all other models.

Vedang et.al (2023): In the current scenario, many buildings exhibit irregularities in both their floor plans and elevations, necessitating measures to safeguard them from potentially devastating earthquakes. Understanding the structural performance under seismic loading is imperative for both existing and newly constructed buildings. Lateral deflections experienced under earthquake loading systems are of significant concern, influenced by various factors such as structural configuration, mass distribution, and material properties. Analyzing reinforced concrete multistoried buildings poses considerable complexity due to their intricate structural systems. Current standards, like IS:1893-2002 (Part 1), mandate the analysis of multi-storey buildings as three-dimensional systems. In this study, we aim to investigate the introduction of shear walls into a multi-storey building to evaluate their impact on seismic performance. The study focuses on a G+9 multi-storey building subjected to seismic loading, where structural irregularities play a crucial role in diminishing seismic resilience. The investigation aims to assess the effect of shear walls on dynamic characteristics and various influencing parameters such as story displacement, drifts between adjacent stories, excessive torsion, and base shear. It is observed that altering the position and shape of shear walls, while maintaining constant area, mitigates irregularity effects against lateral loading in G+9 RC buildings, leading to reductions in story displacement, story drift, and overturning moment. Additionally, changes in shear wall location affect the stiffness distribution among building stories, while significant shear forces are noted within the structure.

4.CONCLUSION

In conclusion, the seismic effects of openings in masonry walls within RCC structures at various positions present a complex interplay of factors that significantly influence structural performance during seismic events. Through a comprehensive review of existing literature, it is evident that while openings introduce vulnerabilities, strategic design considerations and reinforcement techniques can effectively mitigate adverse impacts. By incorporating appropriate measures such as strengthening elements, redistribution of loads, and enhancing ductility, the structural integrity of RCC buildings with masonry wall openings can be substantially improved. Furthermore, advancements in analytical tools and experimental methodologies continue to refine our understanding and ability to predict the behavior of such structures under seismic loading. Ultimately, the findings underscore the importance of informed design practices and ongoing research efforts aimed at enhancing the resilience of buildings against seismic hazards, thus contributing to safer and more resilient built environments.

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