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Effective Positioning of Shear Wall in Asymmetrical Building on Sloping Ground - A Review

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Abstract: In recent years, rapid urbanization in hilly and sloping regions has led to increased construction of multistorey buildings on uneven terrain. Such buildings are inherently irregular due to variation in ground level, unequal column heights, and discontinuity in mass and stiffness distribution. These irregularities significantly affect the seismic performance of structures and increase their vulnerability during earthquake conditions. The present review paper focuses on the study of previously published research works related to seismic behavior of buildings constructed on sloping ground, particularly emphasizing the role of shear walls in improving structural stability. A comprehensive review of past literature reveals that buildings on sloping ground exhibit higher displacement, storey drift, torsion, and base shear compared to buildings on plain ground. The introduction of shear walls significantly enhances the seismic resistance by increasing stiffness and reducing lateral deformation. Various researchers have studied the effect of shear wall positioning, shape, size, and configuration using different analysis methods such as Equivalent Static Analysis, Response Spectrum Analysis, and Time History Analysis. However, most of the studies are limited to regular or symmetrical buildings, while limited attention has been given to asymmetrical buildings on sloping terrain.

Keywords: Shear Wall, Sloping Ground, Asymmetrical Building, Seismic Analysis, Storey Drift, Torsion, Earthquake Engineering.

I. INTRODUCTION

Earthquake is one of the most dangerous natural disasters that causes severe damage to buildings, infrastructure, and human life. In a country like India, a large portion of land falls under different seismic zones, making earthquake-resistant design an essential requirement for all civil engineering structures. In recent years, due to rapid population growth and shortage of flat land, construction activities have increased significantly in hilly and sloping regions. These regions present unique challenges for structural engineers because buildings constructed on sloping ground behave very differently compared to those on plain terrain. Buildings on sloping ground are generally irregular in nature due to variation in foundation levels, unequal column heights, and non-uniform distribution of mass and stiffness. These irregularities lead to complex structural behavior under seismic loading. One of the major problems observed in such buildings is torsional effect, which occurs due to eccentricity between center of mass and center of rigidity. Additionally, short columns on the uphill side attract higher forces, making them more vulnerable to failure during earthquakes. To improve the seismic performance of such structures, shear walls are widely used as lateral load-resisting elements. Shear walls are vertical structural members designed to resist horizontal forces such as earthquake and wind loads. They provide high stiffness and strength, thereby reducing lateral displacement and improving overall stability of the structure.

Many researchers have studied the effectiveness of shear walls in improving seismic behavior of buildings. Different parameters such as shear wall location, shape, thickness, and configuration have been analyzed using various software tools like ETABS, STAAD Pro, and SAP2000. However, most of the studies are limited to regular buildings or buildings on plain ground. There is a need to study asymmetrical buildings on sloping ground, which are more complex and critical from a design perspective. This review paper aims to analyze previous research studies related to shear wall positioning in buildings on sloping ground and to identify research gaps for future work.

II. LITERATURE REVIEW

Previous studies on buildings constructed on sloping ground have shown that such structures experience higher seismic demands compared to buildings on level ground. Research indicates that step-back and step-back–set-back buildings exhibit increased base shear and torsional effects due to irregular stiffness distribution. Several researchers have emphasized the role of shear walls in reducing lateral displacement and improving seismic performance. Studies comparing shear walls placed at corners, core locations, and along periphery reveal that centrally located or symmetrically arranged shear walls significantly reduce torsional response in regular buildings. However, limited studies are available on asymmetrical buildings on sloping ground, where symmetry in shear wall placement is difficult to achieve. Some findings suggest that shear walls placed along the longer direction of the slope and at strategic locations near stiffness irregularities can effectively control drift and torsion. Most existing research highlights the need for comparative analytical studies considering multiple shear wall configurations to determine optimal placement. This forms the basis for the present study, which aims to bridge the research gap by focusing on asymmetry combined with sloping ground conditions.

2.2.1 "Seismic Analysis of Irregular Building on Sloped Terrain with Varying Shear Wall Configuration" by Swaraj Tiwari and Prof. H. Hararwala (2025)- presents an in-depth dynamic analysis of irregular reinforced concrete buildings constructed on sloping ground with different shear wall configurations. The authors emphasized that structures resting on sloped terrain are particularly vulnerable to seismic actions due to inherent plan and vertical irregularities, torsional coupling, non-uniform mass distribution, and varying column heights along the slope, all of which significantly influence the dynamic characteristics of the building. The study highlighted that in buildings on sloping ground, the plan area and mass distribution do not remain constant at each floor level, while column lengths and stiffness vary from storey to storey, leading to complex seismic behavior that necessitates dynamic analysis rather than simplified static approaches. The primary objective of the research was to evaluate the seismic response of irregular RC buildings on sloping terrain by considering different positions of shear walls and to identify the influence of shear wall configuration on overall structural performance. For this purpose, Response Spectrum Analysis was carried out in accordance with IS 1893 (Part 1): 2016 using ETABS software. The seismic performance of the building was assessed by comparing key dynamic response parameters such as natural time period, base shear, storey displacement, storey drift, mode shapes, and mass participation ratios. The results revealed that the slope angle of the ground plays a critical role in governing the seismic response of irregular structures, with increased slope leading to higher vulnerability due to amplified torsional effects and uneven force distribution. The study further demonstrated that the position of shear walls significantly affects the stiffness distribution and dynamic response of the building, with certain configurations providing better control over displacement and drift while improving base shear capacity.

2.2.2 "Optimal Placement of Shear Wall in Multistorey Buildings on Sloping Ground" by N. C. Ghangare, S. S. Meshram, and V. U. Wasalwar (2024)- under ICACC-2024 by IOP Publishing, presents a detailed analytical study focused on improving the seismic performance of multistorey RCC buildings constructed on sloping terrain through optimal shear wall placement. The authors highlighted that buildings on sloping ground are highly susceptible to seismic damage due to vertical and plan irregularities, stiffness discontinuity, unequal column heights, and increased torsional effects when subjected to lateral loads. The primary aim of the study was to determine the most efficient location of shear walls that can significantly enhance lateral load resistance and reduce adverse seismic responses. For this purpose, a G+10 storey RCC building model situated in a seismic Zone IV region was considered, and earthquake forces were evaluated using the equivalent static method in accordance with IS 1893 (Part I): 2016. The structural modeling and analysis were carried out using STAAD Pro V8i software. A comprehensive comparison was made between a bare frame structure and structures incorporated with shear walls at various locations. Key performance parameters such as average storey displacement, fundamental time period, storey shear, storey drift, and reduction in reinforcement demand were critically examined.

2.2.3 "A Review Paper on Analysis of Sloping Ground Tall Building Using Different Shapes of Shear Wall" by Randhir Kumar, Prof. Imran Ahmad Faizy, and Prof. Afzal Khan (2024)- presents a comprehensive review of research studies related to the seismic analysis of tall buildings constructed on sloping ground with different shapes of shear walls. The authors emphasized that rapid urbanization and economic growth in hilly regions have significantly increased real estate development, resulting in dense construction on sloped terrain where level land is scarce. Such buildings inherently suffer from vertical and horizontal irregularities due to unequal column heights below plinth level, which adversely affect their seismic performance during earthquake events. The primary objective of this review paper was to critically examine previous analytical and numerical studies that investigated the effectiveness of shear walls in improving the seismic behavior of tall buildings on sloping ground. The study highlighted that shear walls represent one of the most efficient lateral load-resisting systems due to their high stiffness and strength, which substantially enhance the lateral load resistance of buildings subjected to seismic forces. Special emphasis was placed on the influence of different shear wall cross-sectional shapes—such as rectangular, L-shaped, T-shaped, C-shaped, channel sections, box sections, and barbell-shaped cores—on the overall structural response.

2.2.4 "Study of Effective Location of Shear Wall in Multistoreyed Buildings for Optimum Seismic Response" by Ravi Kumar Reddy C., Durga Prasad Ravella, P. Srinivas Reddy, and S. Mitun Kumar (2024)- presents an in-depth analytical evaluation of the influence of shear wall location on the seismic behavior of high-rise reinforced concrete buildings. The authors emphasized that shear walls play a vital role in earthquake-resistant design by efficiently transferring lateral seismic forces from slabs, beams, and peripheral structural elements to the foundation system. The primary objective of the study was to identify the most effective location of shear walls in a multistorey building to achieve optimum seismic response in terms of displacement control, force resistance, and overall structural stability. For this purpose, a symmetrical RC building with a plan dimension of 16 m × 16 m and a configuration of G+15 storeys, having an overall height of approximately 48 m, was modeled and analyzed in seismic Zone V. The dynamic Response Spectrum Method, as recommended by IS 1893, was adopted for seismic analysis, and the modeling and computational analysis were carried out using ETABS software. Four different structural models were considered in the study, wherein Model I represented a bare frame system without shear walls, while Models II, III, and IV were dual structural systems incorporating 250 mm thick shear walls placed at different strategic locations within the building.

2.2.5 "A Comparative Study of Different Shapes of Shear Wall in Asymmetrical Building on Different Sloping Ground" by Kajal Patil and Dr. T. G. Shende (2022)- presents a comprehensive comparative investigation into the seismic behavior of asymmetrical reinforced concrete buildings constructed on sloping ground with varying angles of slope. The authors emphasized that in seismic design of multistorey buildings, shear walls are among the most widely adopted structural elements to enhance earthquake resistance, as they effectively counteract lateral forces induced by seismic and wind loads while providing substantial stiffness to control lateral drift within permissible limits. In this study, shear walls were idealized as vertical cantilever elements behaving similarly to columns, contributing significantly to the lateral load-resisting capacity of the structure. The primary objective of the research was to evaluate and compare the performance of RCC buildings with and without shear walls of different shapes and at various locations on sloping ground. Structural models were developed for asymmetrical building configurations by varying shear wall positions and shapes, and the analyses were carried out using STAAD Pro V8i software.

2.2.6 "Study of Seismic Analysis of Asymmetric Building with Different Shapes of Staggered Openings and Without Openings in Shear Wall" by Bush R. C., Shirkol A. I., Sruthi J. S., and Ajay Kumar (2022)- presents a detailed comparative investigation into the seismic behavior of asymmetric multistorey buildings incorporating shear walls with and without openings. The authors emphasized that shear walls are among the most effective lateral load-resisting elements in high-rise buildings; however, in practical construction, openings in shear walls are unavoidable due to functional requirements such as ventilation, services, and lift cores. These openings can significantly influence the stiffness, strength, and overall seismic performance of the structure, making their evaluation essential for ensuring structural safety. The primary objective of the study was to examine the effectiveness of different shapes of staggered openings in shear walls and to compare their seismic performance with uniform openings and solid shear walls without openings. For this purpose, a 10-storey asymmetric reinforced concrete building was modeled and analyzed using the Response Spectrum Method with the help of ETABS software. Various configurations of vertical staggered openings—namely square, rectangular, and triangular shapes—were considered, along with models having uniform openings and no openings in shear walls. Key seismic response parameters such as storey displacement, storey drift, storey shear, storey stiffness, and base shear were critically evaluated and compared across all models.

2.2.7 "Irregular Building over Sloped Ground Surface with Shear Walls or Bracings: A Review" by Muhammed K. A. and Deepa Varkey (2022)- presents a detailed and systematic review of existing research related to the seismic performance of irregular buildings constructed on sloping ground surfaces. The authors highlighted that rapid population growth and increased tourism in hilly regions have led to extensive construction activities on sloped terrain, where level ground is scarce. As a result, buildings in such regions inherently develop vertical and horizontal irregularities, making them significantly more vulnerable to seismic actions and other natural hazards. The primary objective of this review paper was to consolidate and critically evaluate the findings of various previous studies in order to identify effective structural measures that can enhance the overall stability and seismic resistance of buildings in hilly areas. The study emphasized that irregularities in mass, stiffness, geometry, and load path—common in sloping ground buildings—lead to increased lateral displacement, storey drift, torsional effects, and concentration of forces in critical structural elements during earthquakes. Through an extensive review of earlier analytical, experimental, and numerical studies, the authors observed that buildings on sloped ground generally experience higher seismic demand compared to similar buildings on flat ground. The review highlighted that the use of shear walls and bracing systems is one of the most effective strategies for improving seismic performance of such irregular structures. Shear walls were found to significantly enhance lateral stiffness, reduce displacement and drift, and improve force distribution, while bracing systems contributed to increased structural rigidity and reduced vibration response.

2.2.8 "Positioning of Shear Wall in L-Shaped Unsymmetrical Building on the Sloping Ground" by Sagar D. Parbat, Dr. A. M. Badar, and Prof. S. R. Satone (2021)- This study presents a comprehensive analytical investigation into the seismic performance of reinforced cement concrete (RCC) buildings constructed on sloping ground with plan irregularity in the form of an L-shaped configuration. The authors emphasized that buildings on sloping ground inherently experience torsional effects, irregular distribution of mass and stiffness, and uneven column heights, which significantly amplify seismic vulnerability, especially when combined with plan asymmetry. The primary objective of the study was to identify the most effective positioning and configuration of shear walls to enhance the lateral load resistance and overall stability of such complex structural systems. A G+7 storey RCC building model located in seismic Zone V was considered, and earthquake forces were computed using the seismic coefficient method as per IS 1893 (Part I): 2016. The structural analysis and modeling were carried out using STAAD Pro software, considering seven different cases of shear wall placement with varying shapes and locations across the building plan. Key seismic response parameters such as storey shear, lateral displacement, and structural stiffness were evaluated for each case. The findings revealed that the strategic placement of shear walls plays a critical role in controlling excessive storey shear and improving the seismic performance of buildings on sloping ground. Shear walls placed symmetrically and closer to the center of rigidity were found to significantly reduce torsional effects and lateral displacements compared to peripheral or unsystematic placements.

2.2.9 "Effective Positioning of Shear Wall in G+5 Storey Building on Sloping Ground" by Ankit Dane and Umesh Pendharkar (2019)- presents a detailed analytical investigation into the role of shear walls in enhancing the seismic performance of multistorey buildings constructed on sloping ground. The authors highlighted that earthquakes have become increasingly destructive in recent times, primarily due to the failure of man-made structures that lack adequate lateral strength and stability. Multistorey buildings, being more vulnerable to seismic forces, require effective lateral load-resisting systems, especially when constructed on sloping terrain where seismic effects are further amplified due to irregularity and uneven load transfer. The main objective of the study was to examine the influence of shear wall incorporation and its positioning on the seismic response of a G+5 storey RCC building situated on sloping ground. For this purpose, four structural models were considered, wherein Model I represented a conventional rigid frame structure without shear walls, while Models II, III, and IV were provided with shear walls of varying sizes and configurations.

2.2.10 "A Review on Effective Location and Optimum Height of Shear Walls in High-Rise Buildings" by Dipika N. Khandelwal and Monica S. Mhetre (2017)- presents a comprehensive review of previous research studies focused on the optimal positioning and height of reinforced concrete shear walls in high-rise buildings subjected to seismic and wind loads. The authors highlighted that shear walls are among the most efficient structural elements used to counteract lateral forces induced by earthquakes and wind, particularly in seismically active regions where lateral forces dominate the structural response. The paper emphasized that modern structural design practice increasingly adopts dual structural systems, wherein moment-resisting frames are primarily designed to carry gravity loads while RC shear walls are incorporated to resist lateral loads, thereby enhancing overall strength, stiffness, and deformation capacity of tall buildings.

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Through an extensive review of experimental, analytical, and numerical studies, the authors observed that buildings equipped with shear walls consistently exhibit superior seismic performance compared to bare frame structures, as evidenced by reduced lateral displacement, storey drift, and improved in-plane load resistance. The review critically analyzed how the effectiveness of shear walls is strongly influenced by their location within the building plan and their vertical extent or height along the structure. It was noted that shear walls placed at strategic locations—such as at the building core, periphery, or corners—are more effective in controlling torsional effects and lateral deformation, while improper placement may lead to uneven stiffness distribution and increased seismic demand on certain structural elements. The study also highlighted that the optimum height of shear walls plays a crucial role in achieving an economical and efficient design, as providing shear walls throughout the full height of the building may not always be necessary or cost-effective. Instead, an optimal combination of shear wall height and location can achieve desired seismic performance with reduced material consumption. The authors concluded that careful evaluation of shear wall positioning and optimum height is essential for ensuring seismic safety, structural efficiency, and economic feasibility of high-rise buildings.

2.2.11 "Effect of Positioning and Configuration of Shear Walls on Seismic Performance of RC Building Resting on Hilly and Plain Terrain" by Anjali B. U. and Dr. Gopisiddappa (2017)- presents a comparative analytical study on the seismic behavior of reinforced concrete buildings constructed on hilly terrain and plain ground with different shear wall configurations. The authors emphasized that buildings located on hilly terrain are inherently irregular and unsymmetrical in both vertical and horizontal planes due to uneven ground profiles, leading to torsional coupling and increased vulnerability under seismic loading when compared to buildings on flat terrain. The study highlighted the importance of shear wall systems as one of the most effective lateral load-resisting mechanisms in multistorey buildings because of their high in-plane stiffness and strength, which enable them to resist large horizontal seismic forces while simultaneously supporting gravity loads. The primary objective of the research was to evaluate and compare the seismic performance of RCC buildings on hilly and plain terrain with and without the provision of shear walls and to study the influence of different shear wall configurations on overall structural response. For this purpose, G+8 storey RCC building models resting on plain ground and on hilly terrain with a slope of 10° were considered. Various shear wall configurations, including straight, T-shaped, C-shaped, and L-shaped walls, were incorporated into the structural models. Seismic analysis was carried out using the Response Spectrum Method as per relevant code provisions, and ETABS software was used for modeling and analysis. The performance of different building configurations was assessed by comparing key seismic response parameters such as natural time period, base shear, and storey displacement.

2.2.12 "Effect of Shear Wall on Seismic Behavior of Unsymmetrical Reinforced Concrete Structure" by Gaikwad Ujwala Vithal (2017)- presents a detailed analytical investigation into the role of shear walls in improving the seismic performance of horizontally unsymmetrical reinforced concrete buildings. The author emphasized that shear walls are widely used as primary lateral load-resisting elements in tall buildings to withstand earthquake-induced forces and that their effectiveness becomes even more critical in unsymmetrical structures where torsional effects dominate the seismic response. The study highlighted that damage to buildings during earthquakes is primarily caused by dynamic loads, and therefore, understanding the dynamic characteristics of structures is essential for earthquake-resistant design. Unsymmetrical buildings, which often consist of a combination of frames, shear walls, structural cores, and coupled shear walls, are particularly vulnerable due to eccentricity between the center of mass and center of rigidity, resulting in significant torsional moments under lateral loading. The main objective of the study was to reduce torsional effects, storey drift, and lateral displacement in an unsymmetrical RC structure through effective positioning and thickness variation of shear walls. For this purpose, seismic analysis was carried out using the Response Spectrum Method, and ETABS software was employed for modeling and analysis.

2.2.13 "Effect of Positioning of RC Shear Walls of Different Shapes on Seismic Performance of Building Resting on Sloping Ground" by S. P. Pawar, Dr. C. P. Pise, Y. P. Pawar, S. S. Kadam, D. D. Mohite, C. M. Deshmukh, and N. K. Shelar (2016)- presents an extensive analytical study on the seismic behavior of reinforced concrete buildings constructed on sloping ground with different shear wall shapes and positions. The authors emphasized that buildings located on hill slopes in earthquake-prone regions are inherently irregular and torsionally coupled due to varying mass and stiffness distributions along both vertical and horizontal directions. As a result, the centers of mass and rigidity do not coincide at different floor levels, leading to significant torsional effects in addition to lateral seismic forces. The primary objective of the study was to evaluate how the positioning and shape of RC shear walls influence the seismic performance of such irregular buildings resting on sloping terrain.

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The research highlighted that sloping ground buildings typically exhibit step-back or step-back–set-back configurations, where floors recede towards the hill slope, making them more vulnerable to seismic excitation. Through comparative seismic analysis, the study demonstrated that buildings on sloping ground experience higher lateral displacement and base shear than similar buildings on plain ground. It was also observed that shorter columns, commonly present on the uphill side of sloping ground structures, attract higher seismic forces and are more susceptible to damage during earthquakes. The inclusion of shear walls significantly altered the seismic response by improving lateral stiffness and reducing excessive displacements; however, their effectiveness was strongly dependent on their shape and location within the building plan.

2.2.14 "Seismic Performance of the Building Resting on Sloping Ground with Shear Wall" by Ms. Sunita D. Kamble and Dr. Surekha A. Bhalchandra (2016)- presents a focused analytical study on the seismic behavior of reinforced concrete buildings constructed on sloping ground with and without the provision of shear walls. The authors highlighted that buildings located on sloping terrain in earthquake-prone hilly regions are fundamentally different from those on flat ground due to inherent geometric irregularities, unsymmetrical configurations, torsional coupling, and non-uniform distribution of mass and stiffness. These characteristics significantly increase their vulnerability to seismic ground motion, often resulting in severe structural damage, especially in critical columns on the uphill side. The primary objective of the study was to evaluate and compare the seismic performance of buildings resting on sloping ground by incorporating shear walls as a lateral load-resisting system. Shear walls were emphasized as one of the most effective structural elements for improving seismic resistance due to their high in-plane stiffness and strength, which substantially reduce lateral sway and enhance overall structural stability. In this research, linear Time History Analysis was carried out using SAP2000 software to realistically capture the dynamic response of the building under earthquake excitation. A comparative assessment was performed between structural models with and without shear walls, focusing on key response parameters such as lateral displacement, seismic performance of critical columns, and overall stability.

2.2.15 "Effective Location of Shear Wall on Performance of Building Frame Subjected to Earthquake Load" by Mr. K. Lova Raju and Dr. K. V. G. D. Balaji (2015)- presents a detailed investigation into the influence of shear wall location on the seismic performance of multistorey building frames using nonlinear analysis techniques. The authors focused on identifying the most effective position of shear walls in a multi-storey RCC building to enhance its earthquake resistance. In the study, four structural models were considered, wherein Model I represented a bare frame structural system without shear walls, while Models II, III, and IV were dual structural systems incorporating shear walls at different strategic locations. An eight-storey RCC building was analyzed under seismic loading corresponding to seismic Zones II, III, IV, and V in accordance with IS 1893:2002, enabling a comparative assessment of structural performance across varying seismic intensities. The nonlinear static pushover analysis method was adopted to capture the inelastic behavior of the structure beyond the elastic range, and the analysis was carried out using ETABS v9.7.2 software. Pushover curves were generated and compared for all models to evaluate key seismic response parameters such as base shear capacity and lateral displacement. The results clearly indicated that buildings equipped with shear walls exhibited significantly improved seismic performance compared to bare frame structures, particularly in terms of reduced displacement and enhanced base shear resistance.

2.2.16 "Seismic Analysis of Building with Shear Wall on Sloping Ground" by Prasad Ramesh Vaidya (2014–2015)- presents a focused analytical study on the seismic behavior of reinforced concrete buildings constructed on sloping ground with different shear wall positions. The author highlighted that buildings on sloping terrain exhibit complex seismic behavior due to vertical and horizontal irregularities, unequal column heights, and non-uniform stiffness distribution, which collectively increase vulnerability under earthquake loading. The primary objective of the study was to understand the seismic response of buildings on sloping ground and to evaluate the effectiveness of shear walls placed at various locations in improving structural performance. To achieve this, four mathematical models were developed, wherein Model I represented a conventional moment-resisting frame system without shear walls, while Models II, III, and IV were dual structural systems incorporating shear walls at three different strategic positions to study frame–shear wall interaction. Seismic analysis was carried out using the Response Spectrum Method, and finite element modeling and analysis were performed with SAP2000 software. The seismic performance of each model was evaluated based on key response parameters such as lateral displacement, storey drift, and maximum forces developed in columns. The comparative results demonstrated that the inclusion of shear walls significantly reduced lateral displacement and storey drift compared to the bare frame model, thereby enhancing overall stiffness and seismic stability of the building on sloping ground.

III. RESEARCH GAP

From the extensive review of past literature, it is evident that significant research has been carried out on the seismic behavior of reinforced concrete buildings incorporating shear walls, particularly focusing on buildings resting on sloping ground, hilly terrain, and irregular configurations. Numerous studies have investigated the effect of shear wall presence versus bare frame systems, optimal positioning of shear walls, comparison of different shear wall shapes (rectangular, L, T, C, core walls), and their influence on key seismic parameters such as storey displacement, storey drift, base shear, torsion, and time period. Several researchers have also compared buildings on plain ground and sloping ground, highlighting the increased vulnerability of sloping ground buildings due to vertical and horizontal irregularities, unequal column heights, and torsional coupling. However, despite these contributions, notable research gaps still exist. Most studies are limited to a single slope angle or a narrow range of slopes, whereas real-life hill constructions involve varying and complex slope geometries. Many investigations rely predominantly on linear static or response spectrum analysis, with comparatively fewer studies employing advanced nonlinear dynamic approaches such as nonlinear time history analysis to capture realistic inelastic behavior, damage progression, and failure mechanisms in sloping ground buildings. Additionally, while individual effects of shear wall position or shape have been studied, limited research addresses their combined influence considering plan irregularity, vertical irregularity, and varying slope angles simultaneously. The majority of existing studies also focus on low- to mid-rise buildings, leaving a gap in understanding the seismic performance of tall and high-rise irregular buildings on sloping terrain. Furthermore, the interaction between shear wall configuration and mass–stiffness distribution along the height of buildings on sloped ground has not been comprehensively explored. There is also a lack of comparative studies evaluating optimized shear wall layouts that balance seismic performance with material efficiency and constructability.

CONCLUSION

Based on the extensive review of previous studies, the following conclusions are drawn:

- Buildings on sloping ground are more vulnerable to seismic forces due to irregularities and torsional effects
- Shear walls are highly effective in improving seismic performance by reducing displacement and drift
- Proper positioning of shear walls is more important than just providing them
- Central and symmetrical placement generally gives better performance
- Shape, thickness, and configuration of shear walls significantly influence structural behavior
- Advanced dynamic analysis methods provide more accurate results
- There is a strong need for further research on asymmetrical buildings and optimization techniques

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