International Research Journal on Advanced Engineering Hub (IRJAEH)
e ISSN: 2584-2137
Vol. 02 Issue: 03 March 2024
Page No: 574 - 578
https://irjaeh.com
https://doi.org/10.47392/IRJAEH.2024.0083

Review of Using Shear Walls & Bracings for Seismic Strengthening of High-Rise RC Structures

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Abstract

This review explores the seismic resistance of high-rise buildings through the implementation of shear wall and steel bracing systems. The use of reinforced concrete (RC) buildings with shear wall systems and steel structures with concentrated steel bracing systems has become increasingly common to mitigate seismic effects. However, the response of these systems to seismic loads varies due to differences in structural design and response factor values. Additionally, the presence of asymmetrical building designs poses a potential risk during earthquakes, necessitating a thorough examination of both new and old structures. By analyzing the dynamic properties and influencing factors of irregular RCC buildings with shear walls, this research aims to assess the impact of shear walls on factors such as base shear, torsion, story displacement, and drift. Furthermore, the study investigates the effectiveness of steel bracing systems in enhancing the performance of high-rise buildings under wind and seismic loading conditions. Different bracing configurations are evaluated to determine their ability to reduce lateral displacements and improve structural strength and stiffness. The findings will provide valuable insights into optimizing the location and design of bracing systems for enhanced structural resilience against seismic and wind forces while considering both economic and effectiveness factors.

Keywords: *Shear Wall, Bracing System, Seismic Loads, High Rise Buildings.*

1. Introduction

These days, earthquake disasters are a major worldwide concern, wreaking havoc throughout Asia and other continents. It's critical to take seismic hazards into account and implement the required precautions during design in order to lessen these unforeseen events. While different nations have different policies in place for putting these systems into place, the best ways to increase the stiffness of building frames are through the use of steel bracing systems and shear walls. In high-rise buildings, shear walls are frequently incorporated as load-bearing or lift cores, and steel bracing systems are positioned carefully to increase rigidity in particular structural regions. Bracings reduce story shears because of their lower self-weight, which allays worries about lateral load resistance even though they are less stiff than shear walls. Furthermore, the swift increase in the urban population and the requirement Because there is a shortage of land, lateral load-resisting systems like shear walls and diagrid structural systems are more crucial for taller buildings. Tall building structural and architectural designers are showing a renewed interest in diagrid systems because of their reputation for both structural efficiency and aesthetic potential. The analysis and design of

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multi-story buildings are made easier by ETABS software, which takes into account different structural forms to increase lateral stiffness and lower drift index. In multi-story buildings, steel braced frames are an efficient means of opposing lateral loads. Different bracing configurations, such as diagonal, cross, and V-bracing, have advantages and disadvantages when it comes to improving seismic performance.

2. Objectives

1. Determine the seismic resilience of high-rise structures by utilising shear walls and steel bracing.
2. Investigate the response of concentrated steel bracing systems in steel structures and shear wall systems in reinforced concrete (RC) buildings to seismic loads.
3. Analyse the effects of shear walls on irregular RCC building elements, such as displacement of stories, base shear, drift, and torsion.
4. Analyse the dynamic features and influencing factors of asymmetrical building designs to identify potential earthquake hazards.
5. Find out if steel bracing systems enhance the performance of tall buildings under wind and seismic loads.
6. Evaluate how well different bracing configurations can reduce lateral displacements and improve the structure's stiffness and strength.
7. Provide guidance on the optimal placement and design of bracing systems to optimize structural resistance while considering cost and efficacy, to wind and seismic forces.

3. Literature Review

The literature review discusses the findings of other researchers regarding shear walls and bracing. Azad S. et al. 2016 have studied on concentrated steel bracing systems commonly used in steel structures and compared with the performance of shear wall systems in reinforced concrete (RC) buildings, with a focus on seismic resistance. These systems have similar functions, but because response factors differ, they behave differently when subjected to seismic loads. The research utilizes a numerical method to illustrate the distinctions between these systems, with a new emphasis on using steel bracing to increase lateral force resistance. By means of a methodical, sequential approach, the study seeks to present distinct differences between the two systems. The study is being carried out with an emphasis on inferred findings that are relevant to East Malaysia. [1] Pandey N. et al. 2021 have researched to evaluate the seismic performance of multi-story buildings, especially those with irregular layouts that put them at risk of suffering substantial damage in an earthquake. Because of their irregularities, the current IS: 1893 (part I) - 2002 standards require three-dimensional analysis for such structures. Taking into account fixed plan irregularities, we incorporate shear walls into these structures to lessen the effects of seismic activity. The study assesses how different-shaped shear walls with a constant area affect important parameters and dynamic features like base shear, story displacement, neighboring story drifts, and excessive torsion. [2] Muley P. et al. 2021 have examined the effects of various steel bracing arrangements on the seismic and wind-induced structural performance of tall buildings. The goal is to increase strength and stiffness to more efficiently and cost-effectively support such loads. The Finite Element Analysis feature in SAP2000 V21 software is used to model a 30-story reinforced concrete building situated in Mumbai. The goal of the study is to identify the best bracing locations, taking into account both cost and effectiveness, for enhanced structural behaviour under lateral loading. [3] Li M. et al. 2009 have conducted a reliability-based assessment of the seismic performance of wood shear walls using the response surface method with importance sampling. It takes into account uncertainties about carried mass, material characteristics, earthquake ground motions, and analytical models. The study focuses on eight typical designs of shear walls in contemporary post-and-beam wood buildings that are diagonally braced and covered in structural panels. To simulate the seismic response of the shear walls, a recently developed wood shear wall model is used, which has been verified and calibrated using a reversed cyclic test database. In order to estimate failure probabilities with respect to two performance expectations, peak wall drift is chosen as the performance criterion. The results show that walls with structural panels sheathed have a higher seismic reliability than walls with diagonal bracing. [4] Hassan H. et al. 2023 have examined the possibility of using braces as a cost-effective retrofit for structures that are already in place but do not provide enough seismic resistance, as well as the possibility of using braces in place of shear walls when designing new reinforced concrete structures. The influence of different bracing systems on the structural characteristics of a square, ten-story building—including where they are placed inside the interior frames of the building—is compared with that of reinforced concrete shear walls. The results show that different bracing systems respond differently to structural properties like base shear, story displacement, and fundamental time period. These findings are helpful in determining the best bracing system to use when designing new structures and retrofitting older ones, as well as where to best place them inside the building. [5] Cao W. et al. 2002 have presented and studied a new kind of shear wall made of reinforced concrete (RC) with hidden bracing to improve building structures' seismic performance. Four medium-height specimens at a scale of 1:3 were created and thoroughly examined through experimentation. The load-carrying capacity, stiffness, ductility, hysteretic behaviour, and energy dissipation of the shear wall are among the many aspects that are analyzed in this study. The failure mechanism is clarified through experimentation, showing that the addition of hidden bracing within the wall panel can greatly improve the shear wall's seismic performance. In addition, a load-carrying capacity calculation formula and a mechanical model of the shear wall are developed. The study verifies that the theoretical and experimental results agree quite well. [6] Yaseer A. et al. 2015 have examined the seismic performance of buildings made of reinforced concrete (RC) that have undergone rehabilitation with concentrated steel bracing and shear walls. The study simulates earthquake loads on a nine-story building in zone III and assesses how well different kinds of steel bracings work in conjunction with concrete shear walls at various points throughout the structure. Metrics for evaluating performance include base shear, bending moments, lateral displacements, and story drifts. This study emphasises improvements in performance evaluation techniques and capacity design principles in seismic engineering to address the critical need to upgrade the seismic resilience of existing reinforced concrete buildings to satisfy contemporary performance-based seismic design standards. [7] Mohd A. et al. 2015 have studied a G+15 building's seismic analysis in several seismic zones using bracings and shear walls. The structure is modelled and seismic analysis is performed in accordance with IS 1893(part 1):2002 using STAAD Pro V8i software. The outcomes demonstrate how well braced frames and shear walls work to reduce earthquake damage. Performance metrics for various bracing types and orientations in columns and beams, including base shear, displacement, axial load, and moments, are displayed through tabular and graphical comparisons. [8] Dharanya A. et.al. 2017 have studied the use of shear walls and cross bracings to increase the lateral stiffness of a G+4 story residential RC building with a soft story. ETABS software is used to conduct analysis in accordance with IS 1893:2002 guidelines. Shear walls are placed at building corners, and cross bracings, like X-bracing, are placed at the outer edge of columns. The equivalent stiffness method in ETABS is used to carry out the analysis. Lateral displacement, base shear, story drift, axial force, shear force, and time period are among the important parameters that are compared. [9] Formisano A. et al. 2015 have studied into adding Metal Plate Shear Walls (MPSWs) to an existing five-story residential RC building constructed in the 1960s and 1970s to provide seismic protection. MPSWs are installed in the bays of RC-framed buildings. They are made of thin metallic plates fastened to a steel frame. Four

MPSW types are used in the retrofitting design: full steel panels, low yield steel panels, aluminium panels, and creative perforated steel plates. To ascertain which retrofitting solution is the most effective, performance and cost parameters are compared. [10] Alimohammadi H. et al. 2019 have used lightweight steel shear walls and two lateral diagonal load bracing systems to examine the seismic behaviour of light steel frame buildings. Two-dimensional shear panels are modelled and examined as lateral resistance system substitutes. Modelling is done using SAP software, and variables like base shear coefficient, added resistance coefficient, ultimate deformation, final strength level, and coefficient of hardness are compared between different shear panels. The findings point to favourable seismic performance and behaviour for these kinds of structures; lightweight steel-framed (LSF) shear walls perform better than diagonal bracing. [11] Rahman F. et al. 2020 have focused on the strengthening and stiffening of the system, which looks at seismic performance improvement strategies for buildings with insufficient lateral force resisting systems. Pushover analysis of reinforced concrete building frames is one of the research's methods for assessing variables like base shear, storey displacement, and performance point under seismic forces. Building frames are designed in accordance with Indian standards (IS 456-2000 and IS 1893-2002), both with and without bracing and shear walls. Evaluating the performance of the building and the effects of bracing and shear walls is the goal. Using SAP2000 software, pushover analysis is carried out along with a discussion of the importance of bracing and shear walls in strengthening structures. [12] Shamaa M. et al. 2023 have investigated a novel method of enhancing the lateral resistance of high-rise building structures through the integration of exterior braces and steel plate shear walls. The braces are positioned in between the shear walls in order to mitigate the problems that come with tube systems, including shear lag and architectural difficulties. The application of this system results in a notable decrease in lateral displacement, which in turn causes a notable reduction in axial forces and bending moments in columns. The suggested method shows great efficacy in improving structural performance. [13] Rahman M. et al. 2021 have concluded the results of three models' structural analyses for a ten-story building subjected to earthquake forces are compared in this study. Model 2 has L-shaped shear walls, Model 3 has an X-bracing system, and Model 1 is a generic structure without shear walls or bracing systems. The analysis incorporates parameters like displacement, base shear, story drift, and structural behaviour using SAP2000 software. At 0.041 mm, Model 2 has the least interstory drift when compared to Model 1, with a deviation decrease of 12.6 mm (34.35%). Because Model 1's story drift exceeds permitted limits, shear walls or a bracing system are required to assure structural viability. [14] Sharma S. et al. 2021 have focused to overcome the shortcomings of the current lateral load resisting systems, on combining shear walls and bracings to increase the lateral load resistance of structures. Different configurations of a hybrid structural system are assessed under seismic conditions using a numerical finite element analysis. To identify the ideal structure, various models' parameters—such as time period, base shear, overturning moment, story drift ratio, and story displacement—are compared. The hybrid structural system exhibits a reduction in fundamental time period and story displacement with negligible increases in base shear and overturning moment when compared to other configurations, according to the results. [15]

Conclusion

Shear wall placement is very important, and floor bracing orientation is less important than for vertically oriented systems, although adjustments can improve seismic resistance. location is a key factor in seismic response. Steel bracing, especially with X-bracing systems, is beneficial for minimising lateral displacements, reducing flexure and shear demands on beams and columns, and strengthening existing structures. Shear wall construction will provide large stiffness to the building by reducing the damage to the structure.

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The concept of using steel bracing is one of the advantageous concepts which can be used to strengthen or retrofit the existing structures. Steel bracings can be used as an alternative to the other strengthening or retrofitting techniques available as the total weight on the existing building will not change significantly. Compared to bracings, shear walls minimize lateral displacement and greatly shorten the structure's natural time period, which ultimately improves lateral stability more successfully. They also improve the structure's stability against earthquakes.

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