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The Impact of Shear Wall Locations on the Seismic Resilience of Multistorey Buildings: A Review

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A B S T R A C T

This literature review synthesizes the findings of multiple studies focused on seismic analysis and structural resilience of various building types and configurations. It explores the effectiveness of different methodologies, including the use of advanced software tools like ETABS and STAAD Pro, in evaluating seismic performance. Key aspects examined include the role of shear walls and structural configurations in mitigating seismic impacts. The review highlights the importance of strategic design choices, such as the implementation of shear walls, and optimized designs in enhancing structural stability. It also addresses the influence of building height on seismic performance. By comparing different seismic analysis methods and the impact of regulatory codes, the review underscores the necessity for accurate modeling and compliance with standards to ensure the safety and resilience of buildings. The findings contribute to the ongoing development of more robust and sustainable structural designs capable of withstanding seismic events.

Keywords: Multi-Storey,

Introduction

A multi-storey building is a structure that consists of multiple floors or levels, designed to accommodate various functions and activities within a vertical space. These buildings are characterized by their ability to maximize land usage efficiently, making them a common feature in urban environments where space is often limited. The construction of multi-storey buildings involves the use of a framework or skeleton that supports the weight of the structure and distributes it evenly across multiple floors. Common materials for construction include reinforced concrete, steel, and sometimes a combination of both. The design and engineering of multi-storey buildings require careful consideration of factors such as load-bearing capacity, structural stability, and safety measures. Multi-storey buildings serve diverse purposes, ranging from residential apartments and condominiums to commercial offices, hotels, educational institutions, and healthcare facilities. The vertical arrangement of floors allows for optimal utilization of space, providing a solution to the challenges posed by increasing population density in urban areas.

A shear wall is a vertical structural element in a building that is designed to resist lateral forces, such as those caused by wind, seismic activity, or other horizontal loads. The primary purpose of shear walls is to provide stability and prevent the building from swaying excessively or collapsing during these lateral forces. Shear walls are typically constructed from materials like reinforced concrete, masonry, or wood. They are strategically placed throughout a building, often at the perimeter or core, to create a continuous vertical barrier. When lateral forces act on a building, the shear walls transfer these forces to the foundation, helping to distribute and dissipate the loads.

Shear walls serve several important functions in a building's structural design, primarily related to resisting lateral forces and providing overall stability.

- Shear walls must provide the necessary lateral strength to resist horizontal earthquake forces. When shear walls are strong enough, they will transfer these horizontal forces to the next element in the load path below them.
- Shear walls also provide lateral stiffness to prevent the roof or floor above from excessive side sway.
- When shear walls are stiff enough, they will prevent floor and roof framing members from moving off their supports. Also, buildings that are sufficiently stiff will usually suffer less non-structural damage.
- Shear walls provide large strength and stiffness to buildings in the direction of their orientation, which significantly reduces lateral sway of the building and thereby reduces damage to structure and its contents. Since shear walls carry large horizontal earthquake forces, the overturning effects on them are large.

Literature Review

The reviewed studies provide a comprehensive understanding of various methodologies and their effectiveness in seismic analysis and structural response. The findings highlight significant advancements and practical implications in the field of structural engineering.

Chandurkar and Pajgade (2013) examined a reinforced concrete building with 15 storeys, analyzing it both without shear walls and with shear walls. The building's plan dimensions were 36m x 36m, with each floor having a height of 3.2m. The construction included 230mm thick brick walls and 200mm thick shear walls. The structural elements such as columns (450mm x 350mm), beams (400mm x 300mm), and slabs (180mm thick) were specified, using M25 grade concrete for slabs and M30 grade concrete for beams and columns, along with Fe415 grade steel.

Akbari et al. (2014) the assessment of seismic vulnerability for both steel X-braced and chevron-braced RC frames involved the creation of analytical fragility curves. Various parameters, including frame height, the P-Δ effect, the proportion of base shear designed for the bracing system, and the bracing system type, were examined.

Chavan and Jadhav (2014) studied the most effective strategy for enhancing the resistance of reinforced concrete frames to lateral loads involves employing a steel bracing system. The utilization of steel bracing offers notable advantages compared to alternative approaches, such as increased strength and stiffness, cost-effectiveness, minimal space requirements, and a lighter impact on the existing structure.

Harne (2014), analysed a six-storey building subjected to earthquake loading in zone II using STAAD Pro and calculated earthquake load using seismic coefficient method (IS 1893 Part II). Four different cases were analysed comprising of a structure without shear wall, structure with L type shear wall, structure with shear wall along periphery, structure with cross type shear wall.

Marsono and Hatami (2015), this paper gave the evaluation of coupling beams behaviour of concrete shear wall with rectangular and octagonal openings. This research suggests addition of haunches to the corners of rectangular openings and to form octagonal openings to increase the strength of coupling beams.

Yarnal et. al. (2015), in this research paper seismic analysis of shear wall building in zone III (IS 1893: Part 1, 2002) and study for shear walls with various percentages of openings were done. Analytical results obtained for fundamental frequency, base shear, storey drift, shear forces and stiffness.

Kumar et al., (2016), studied, the response of multistoried building with different elevations such as G+10, G+11, G+23 and G+29 of regular configuration under seismic and wind loads were observed. The parameters considered for this study are storey displacements and storey drifts.

Gupta and Sawant (2018) studied the normalized tensile reinforcement force for the seismic stability of reinforced soil walls using some rigorous methods considering the pseudo-static seismic forces is mostly used by the earlier researchers in the design of retaining walls backfilled with cohesive soil. Few studies have been presented using horizontal slice method without taking effect of the seismic acceleration in vertical direction.

Singh, et al., (2019), presented the building structure is not properly designed and constructed according to IS codal provisions, it causes more damages and destruction of the human property, and also loss of living creatures. It is recommended that the structure should be properly analyzed, designed, and constructed with good quality material, so it's become safe to resist the earthquake load. Seismic analysis of the building structure is carried out to determine the seismic response of structure by using Time history analysis method.

Singh et al., (2019) studied with constructing different types of structures with ensuring safety, durability and serviceability. Now days "earthquake "is phenomena that affects the structures with their safety and serviceability. The amount of damage that earthquake can done to structures is depend on Type of building, Type of soil, Technology used for earthquake resistance, and last but not the least Location of building.

Deoda, et al., (2020) attempted to study the seismic behaviour of two earthen dams, viz. Chang and Kaswati dam, located in Gujarat, India for different sets of time histories. Each set comprises eight earthquake time histories, where one time history set is compatible to Indian Standard IS-1893(1)-2016, Type-II spectrum (SC) and another time history set is compatible to Conditional Mean Spectrum (CMS) as per the recent state-of-art related to selection of time histories for dynamic analysis.

Gupta and Srivastava (2020) studied to other types of structure the simplified methodology proposed by Constant opoulos et al. (1979) for the seismic design of tunnels. As a practical example, a large structure of reinforced concrete, of box shape and totally embedded in soil, is analyzed. The dynamic pressures acting on walls, roof and floor, due to body and surface waves, are considered in the analyses. A set of seismic load combination hypotheses are proposed to account for the different polarization planes of the seismic.

Prashant et al., (2020), presented a water tank simply means a container to store water in huge amount of capacity. As known from very upsetting experiences, liquid storage tanks were collapsed or heavily damaged during the earthquakes all over the world. The economic lifetime of ESR is generally around 40 to 65 years. Damage or collapse of the tanks causes some unwanted events such as shortage of drinking and utilizing water, uncontrolled fires etc.

Rahman et al., (2021) studied the three different existing buildings of 8, 10 and 13 storeys are selected. The parameters considered for the study are base shear, storey shear and storey drift. The obtained results were compared for the above parameters.

Suthar and Goyal (2021) presented a comparison of wind loads for a G+11 building for wind load as per Indian Standard Wind loads i.e., IS 875 (Part-3)-1987 and IS 875(Part3)- 2015 is carried out. The parameters considered are the comparison of deflection and base shear. The obtained results are compared according to the above mentioned IS codes.

Sofi and Kumar (2022) presented the loads (mainly shear) from the beams are then transferred to the columns. For designing columns, it is necessary to know the moments they are subjected to. For this purpose, frame analysis is done by Moment Distribution Method.

Parveen and Hegde (2022), studied on Pre-Engineered Buildings (PEBs) are the building components that are manufactured at a factory and assembled on site. Usually, PEBs are steel structures and can be an alternative to conventional structural steel buildings. PEB structural components are fabricated at the factory to the exact size, transported to the site, and assembled at the site, usually with bolted connections.

Bhanudas and Shivraj (2023) attempted to understand the structural analysis and designing of G+6 apartment thereby depending on the suitability of plan, layout of beams and positions of columns are fixed. Dead loads are calculated based on material properties and live loads are considered according to the code IS 875-part 2, footings are designed based on safe bearing capacity of soil.

Sagar et al., (2023) compared the variation of steel percentage, maximum shear force, maximum bending moment and maximum deflection in different seismic zone. Variations are drastically higher from zone II to zone V. The steel percentage, maximum shear force, maximum bending moment, maximum deflection is increases from zone II to zone V. The computation of the response of a structure subjected to earthquake stimulation is known as seismic analysis.

Rajak and Choudhary (2023) studied uses the Staad Pro program and the considerably simpler comparable static approach to investigate the seismic resistance of a G+10-story building. By combining a dead load and super load, the seismic and non-seismic analyses of a comparable structure are further compared. It was observed that, in comparison to the non-seismic study, the seismic results exhibited far larger maximum moments and shear forces.

Chiluka (2023) focused on the seismic analysis and design of G+10 storey building with floating columns under low seismic zone parameters and compared the results with same G+10 storey building without floating columns (conventional structure) adopting Equivalent Static analysis of structure using IS code provisions and software tools such as STAAD PRO CONNECT EDITION, RCDC which will develop the structural drawings for site execution.

Abdulaziz et al., (2023) investigated on the interactions between neighboring structures' soil properties are reviewed. These studies are divided into two groups: theoretical/numerical studies of SSI and experimental studies of SSI.

Table 1. Literature review

S. No.	**Author**	**Methodology**	**Finding**
1.	Chandurkar and Pajgade (2013)	Response Spectrum Method using ETABS, Indian Standard Code	Max shear wall moments, max deflections, story drift
2.	Akbari et al. (2014)	Analytical fragility curves, HAZUS descriptions	Reduced damage likelihood with chevron bracing system
3.	Chavan and Jadhav (2014)	Equivalent static analysis using Staad Pro V8i, IS 1893:2002	X type bracing enhances stiffness and reduces interstorey drift
4.	Harne (2014)	Seismic coefficient method (IS 1893 Part II) using STAAD Pro	Periphery shear walls reduce lateral deflection most efficiently
5.	Marsono and Hatami (2015)	Experimental comparison under cyclic load	Octagonal openings provide stronger coupling beams
6.	Yarnal et al. (2015)	ETABS 2013, IS 1893: Part 1, 2002	Storey drift, base shear, stiffness comparison
7.	Kumar et al. (2016)	Comparative study on storey displacements and drifts	Various elevations (G+10, G+11, G+23, G+29)
8.	Gupta and Sawant (2018)	Pseudo-static equilibrium method	Seismic stability of reinforced soil walls
9.	Singh et al. (2019)	Time history analysis using ETABS and MATLAB	Base shear, displacement, storey drift comparison
10.	Singh et al., (2019)	Study on building type, soil type, earthquake resistance technology	Importance of soil type and earthquake resistance
11.	Deoda et al. (2020)	Numerical simulation using Geo studio 2012	Horizontal/vertical displacements, ground motion amplification

12.	Gupta and Srivastava (2020)	Analysis of dynamic pressures, seismic load combinations	Influence of neighbouring buildings on soil stress
13.	Prashant et al. (2020)	STAAD.PRO, IS 1893 PART2-2014	Circular tanks more economical/preferable than rectangular tanks
14.	Rahman et al. (2021)	Comparative study on base shear, storey shear, storey drift	Results compared for different building heights
15.	Suthar and Goyal (2021)	IS 875 (Part-3) - 1987 and 2015 comparison	Deflection, base shear comparison
16.	Sofi and Kumar (2022)	Frame analysis by Moment Distribution Method	Axially loaded columns with uniaxial bending
17.	Parveen and Hegde (2022)	STAAD Pro software analysis, IS 875 codes	Seismic load analysis
18.	Bhanudas and Shivraj (2023)	STAAD PRO v8i software	Maximum shear force, bending moment, storey displacement
19.	Sagar et al. (2023)	STAAD.Pro software, Equivalent Static Method	Steel percentage, shear force, bending moment, deflection
20.	Rajak and Choudhary (2023)	STAAD Pro, IS codes 1893, 875, 456:2000	Comparison of seismic and non-seismic results
21.	Chiluka (2023)	Equivalent Static analysis using STAAD PRO CONNECT EDITION	Lateral displacement, storey displacement, storey drifts
22.	Abdulaziz et al. (2023)	Theoretical/numerical and experimental studies	Displacement and time course of building frame's base

Conclusion

The studies reviewed provide a detailed examination of various methods and structural configurations aimed at enhancing seismic resilience in buildings. The findings underscore the critical role of advanced analytical tools and strategic structural designs in mitigating earthquake impacts. Shear walls are crucial in reducing maximum shear wall moments, deflections, and story drift. The placement and type of shear walls, such as those along the periphery or in cross configurations, significantly influence their effectiveness in improving structural stability. he response of multistoried buildings to seismic loads varies with elevation. Higher buildings experience greater storey displacements and drifts, necessitating careful consideration of height in seismic design. Overall, the continuous development and refinement of seismic analysis methodologies and structural designs are crucial for enhancing the resilience of buildings and infrastructure. The integration of advanced analytical tools and strategic design choices leads to safer and more sustainable structures capable of withstanding the challenges posed by seismic activities.

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