"Unveiling the Seismic Performance of High-Rise Buildings: A Comprehensive Study Using Capacity Spectrum Method and Response Spectrum Analysis"

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ABSTRACT

This research outlines the methodology for assessing the seismic performance of high-rise structures utilizing the capacity spectrum method. A three-dimensional analytical model of thirty-story buildings has been developed, encompassing regular and irregular configurations, and analyzed with the structural analysis software ETABS. The analytical model incorporates all critical elements that affect the structure's mass, strength, stiffness, and deformability. To evaluate the impact of concrete core walls and shear walls positioned at various locations during seismic events, seismic analyses employing linear static, linear dynamic, and non-linear static procedures have been conducted. The deflections at each story level have been compared through the Response Spectrum Method, which was utilized to ascertain the capacity, demand, and performance levels of the selected building models. The findings indicate that the non-linear Response Spectrum Method offers a reliable estimate of both global and local inelastic deformation demands, highlighting design vulnerabilities that may not be apparent in elastic analyses, as well as the overall performance level of the structure. The story drifts were found to be within the limits established by the relevant code (IS: 1893-2002) when applying the Response Spectrum Method.

Keywords: Shear Wall, Story Drift, Displacement, ETABS, High Rise Buildings.

1. Introduction:

To increase the earthquake resilience of reinforced concrete frameworks, shear walls are being used in the construction of numerous medium-rise residential complexes in India. For practical reasons, these shear walls may have duct spaces, windows, and door apertures. The amount, location, and size of these apertures have a major impact on the shear wall's structural behavior and stress distribution.

High-rise buildings typically use framed structures with shear walls as their structural framework. Usually, this system has several holes for stairwells, elevators, and other amenities. Shear walls and frames are typically represented by plane stress elements and beam elements, respectively, in the study of such constructions. A plane stress element must have drilling degrees of freedom. Rectangular parts, beams, and columns joined in the same plane by rigid joints make up a rigid jointed R.C. frame. The building stiffness of the columns, beams, and connections in the plane determines the lateral stiffness of such a frame. The frame could be in line with the façade or with one of the building's interior walls. The main benefit of rigid frames is their open, rectangular layout, which permits fast door and window installation and design flexibility. It appears that the rigid frame principle is inexpensive up to 15 stories for concrete framing and up to about 25 stories for steel framing. To control drift, large numbers are required above these relatively low lateral flexibilities of the frame.

For high-rise buildings, providing enough stiffness and controlling large displacements is as crucial as ensuring strength. Shear wall systems offer two key benefits: they resist large lateral loads cost-effectively and limit lateral displacements, reducing non-structural damage risk. They should be functional and fit the building's design without disrupting architecture, with lift enclosures being common. Shear walls must be positioned along both axes for lateral stiffness, especially in square buildings, and should be symmetrically placed to prevent torsion. Additionally, shear walls should extend to the foundation level.

Objective of the study

The following are the main objectives of the project.

1. To study the seismic behavior of a multi-storey building by using IS 1893:2002
2. To compare the multi-storey buildings with and without shear wall at different locations on multi storey Building with regular and irregular shapes .
3. To compare the results of Storey Drift, Shear force, Bending moment, and Building torsion of buildings without shear walls at different locations on multi-storey buildings with regular and irregular shapes.
4. To study the buildings in ETABS V9.7.4 in Response spectrum analysis.

2. Literature Review:

Shahzad Jamil Sardaar (2013) studied 25 25-storey buildings in zone V and presented some investigation, which was analyzed by changing various locations of shear wall for determining parameters like storey drift, storey shear, and displacement is done by using the standard package ETAB. Creation of a 3D building model for both linear static and linear dynamic methods of analysis, and the influence of the concrete core wall provided at the center of the building. Najma Nainan et al (2012) Structures on the earth are generally subjected to two types of load: static and dynamic. Static loads are constant with time, while dynamic loads are time-varying. Ehsan Salimi et al1 (2012) studied to determine the effect of shear wall configuration on the seismic performance of buildings. Time history analysis has been done on buildings with different numbers of stories and various configurations with the same plan. The top storey displacements have been obtained and compared to each other for all models to assess the effect of shear wall configuration on the seismic performance of buildings. Mr.K.LovaRaju, et al (2015) dealt with the non-linear analysis of the frame for various positions of shear wall in a building frame and effective location of shear wall in a multi-storey building. Varsha R. Harne et al al. (2014) find the solution for shear wall location in a multistorey building. An RCC building of six storeys, placed in NAGPUR, subjected to earthquake loading in zone-II, is considered. An earthquake load is calculated by a seismic coefficient method using IS 1893:2002. These analyses were performed using STAAD Pro. R.S. Mishra (2015). During an earthquake, RC (Reinforced Concrete) structures are subjected to lateral displacement. Most of the RC structures are designed to resist gravity loads only, neglecting the effect of lateral forces arising due to earthquakes. They concentrated on analyzing the seismic behavior of the structure.

3. Methodology:

3.1. Model Description

Two building configurations were considered:

Regular 30-story building with uniform dimensions.

Irregular 30-story building with asymmetrical layouts.

3.2. Analysis Tools

ETABS software was employed to create 3D models incorporating critical structural elements such as beams, columns, and shear walls.

3.3. Parameters for Analysis

Seismic Zone: Zone V (high seismicity).

Codes Used: IS 1893-2002, IS 456:2000.

Material Properties: M30 concrete and Fe500 steel.

Loads: Dead load, live load, and seismic load as per IS 875.

3.4. Analysis Techniques

Linear Static Analysis

Linear Dynamic Analysis (Response Spectrum Method)

Non-linear Static Analysis (Capacity Spectrum Method)

3.5. Shear Wall Configurations

Three scenarios were analyzed:

Without shear walls.

Shear walls at corners.

Shear walls at alternate positions.

Problem statement:

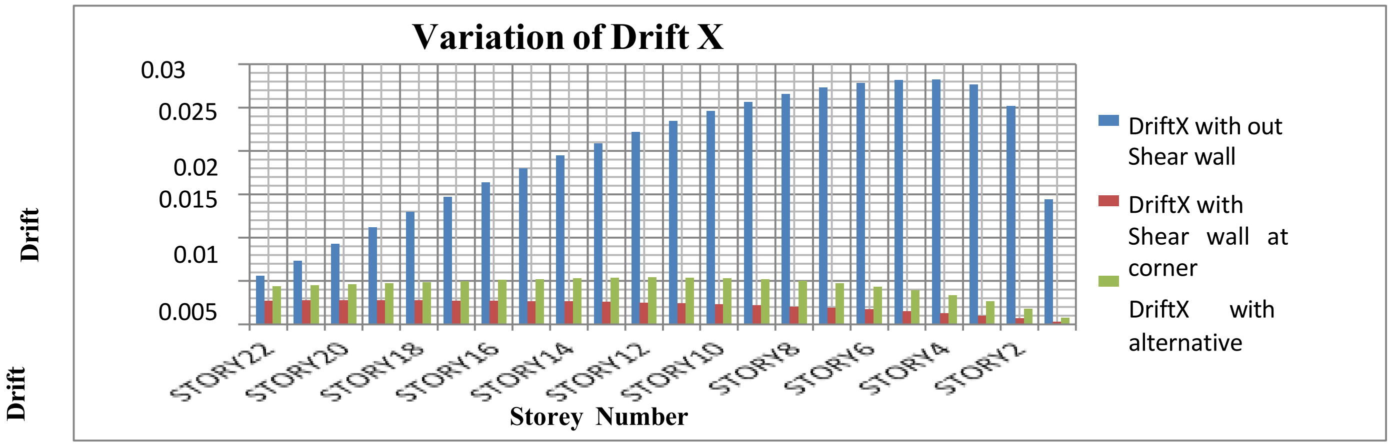
In the present study, an analysis of G+21 story building in Zone V seismic zones is carried out in ETABS. Basic parameters considered for the analysis are

1. Grade of concrete	: M30
2. Grade of reinforcing steel	: HYSD Fe500
3. Dimensions of the beam	: 230mmX300mm
4. Dimensions of the column	: 230mmX480mm
5. Thickness of slab	: 120mm
6. Height of the bottom storey	: 3m
7. Height of remaining storey	: 3m
8. Live load	3.5 KN/m^2
9. Floor load	1.5 KN/m^2
10. Density of concrete	: 25 KN/m^3
11. Seismic Zone	: Zone 5
12. Site type	: II

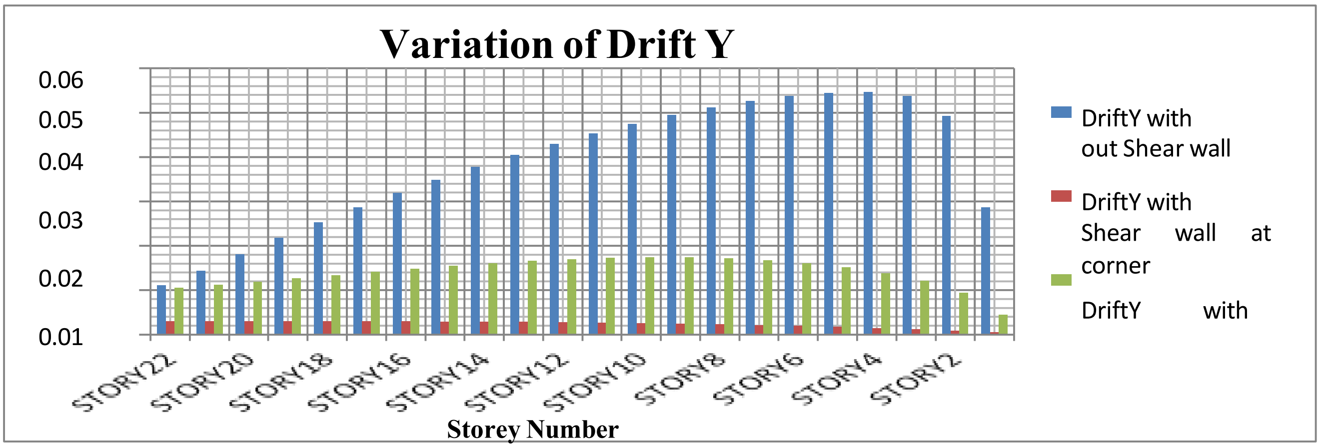
13. Importance factor : 1.5
14. Response reduction factor : 5
15. Structure class : B
16. Basic wind speed : 39m/s
17. Risk coefficient (K1) : 1.08
18. Terrain size coefficient (K2) : 1.14
19. Topography factor (K3) : 1.36
20. Wind design code : IS 875: 1987 (Part 3)
21. RCC design code : IS 456:2000
22. Steel design code : IS 800: 2007

Results and analysis:

Storey drift irregular building

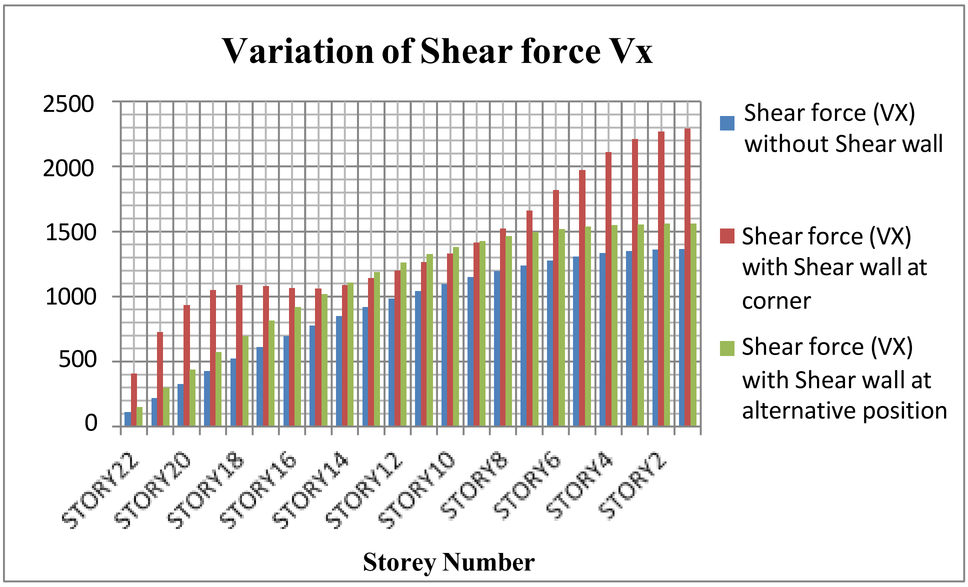


Comparison of Story drift irregular building X direction.

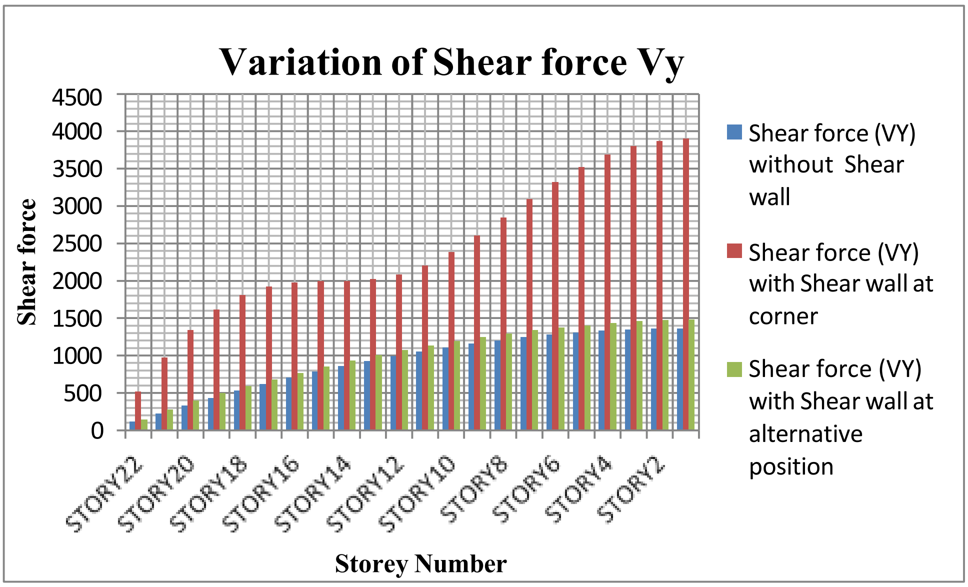


Comparison of Storey drift irregular building Y direction.

Shear Force Irregular Building



Comparison of Shear Force Irregular Building in X direction



Comparison of Shear Force Irregular Building in Y direction

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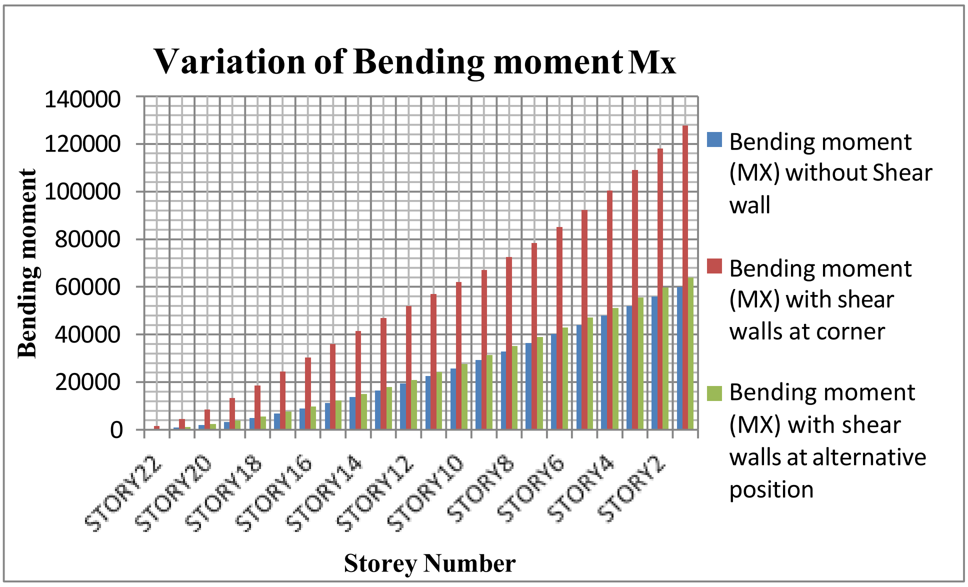
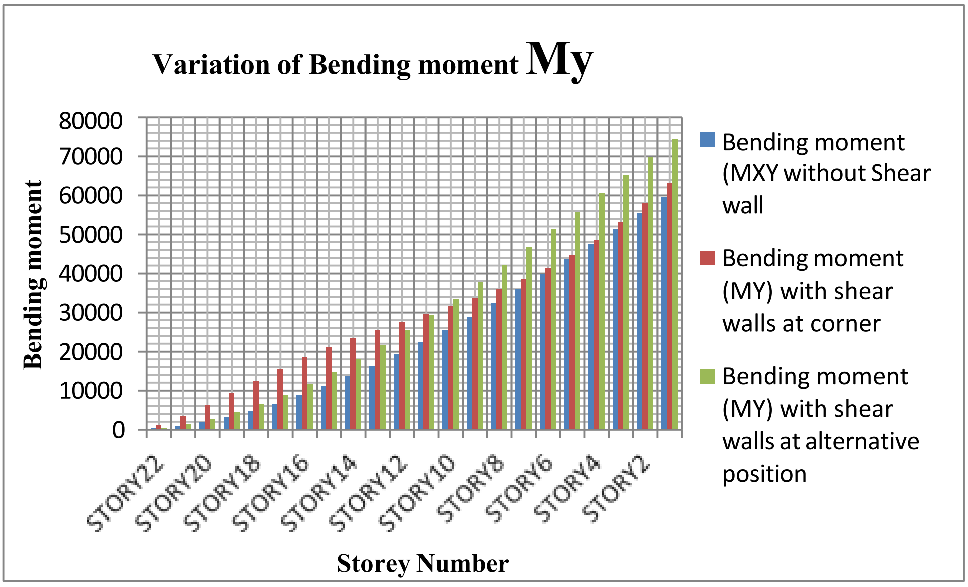
Bending Moment Irregular Building

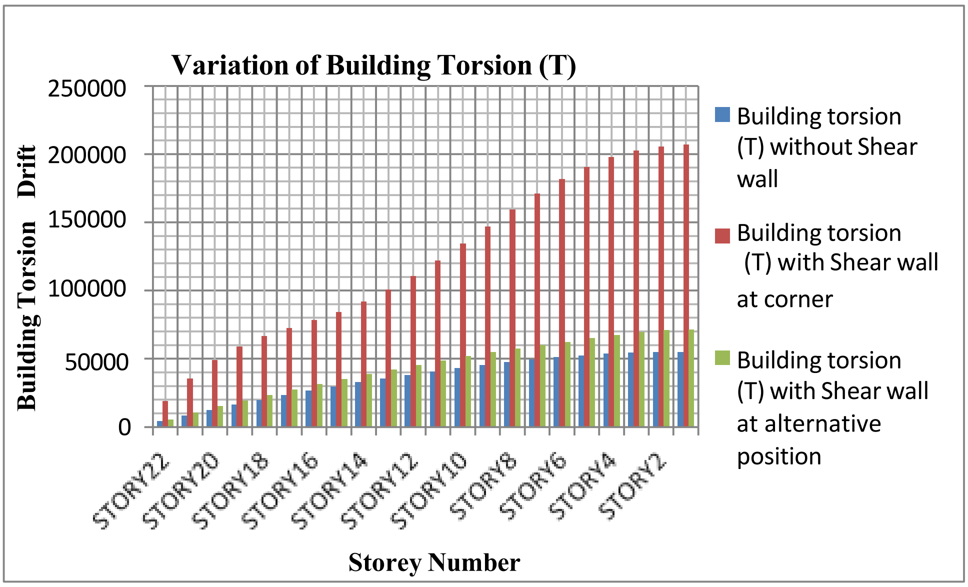


Graph 5. 5 Bending Moment Irregular Building X direction



Graph 5. 6 Bending Moment Irregular Building Y direction

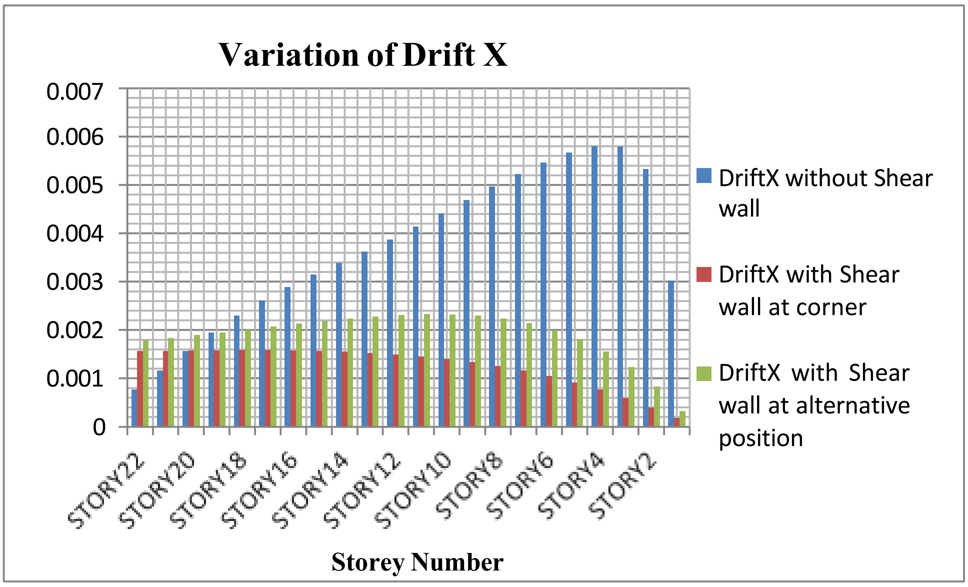
5.1 Building a torsion-irregular building



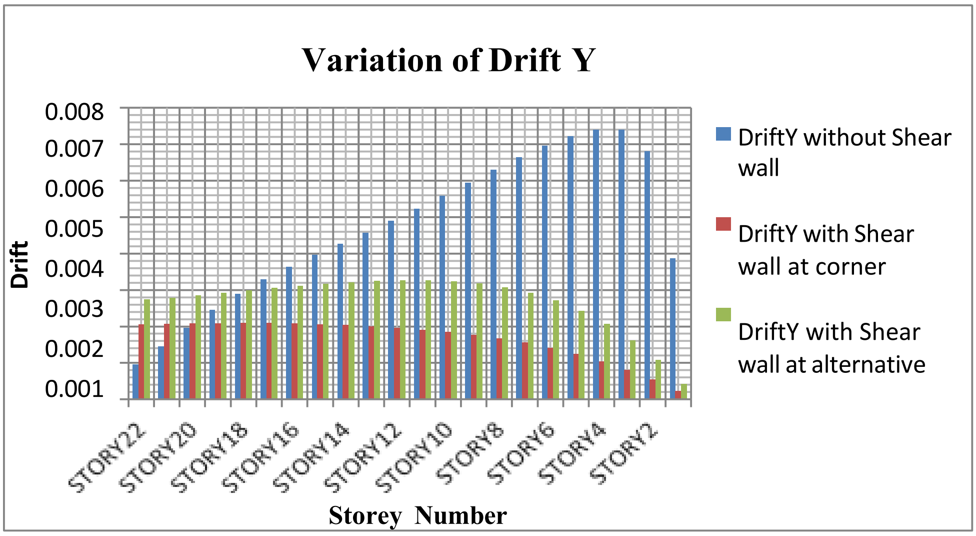
Graph 5. 7 Building torsion irregular building

Storey Drift Regular Building

X-Direction:

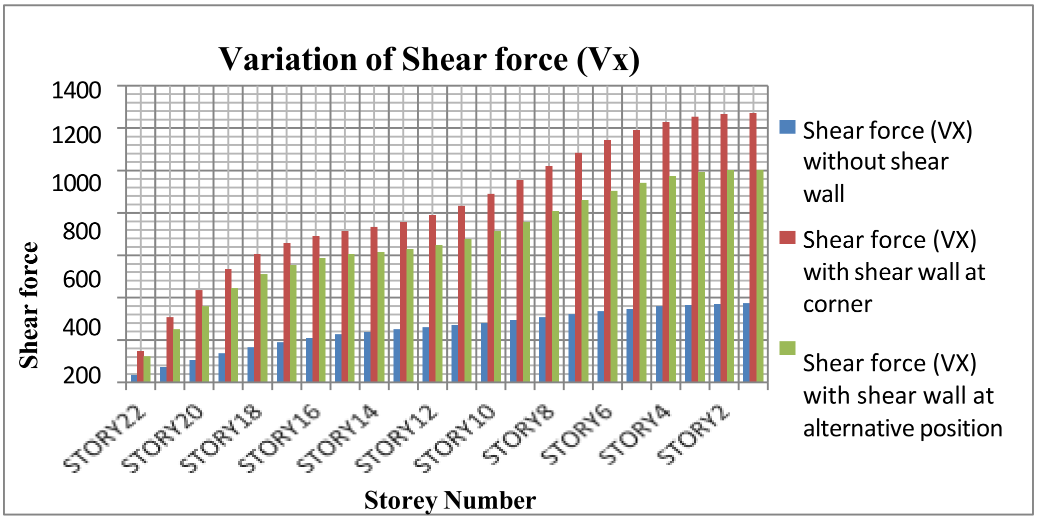


Comparison of Storey Drift Regular Building X direction

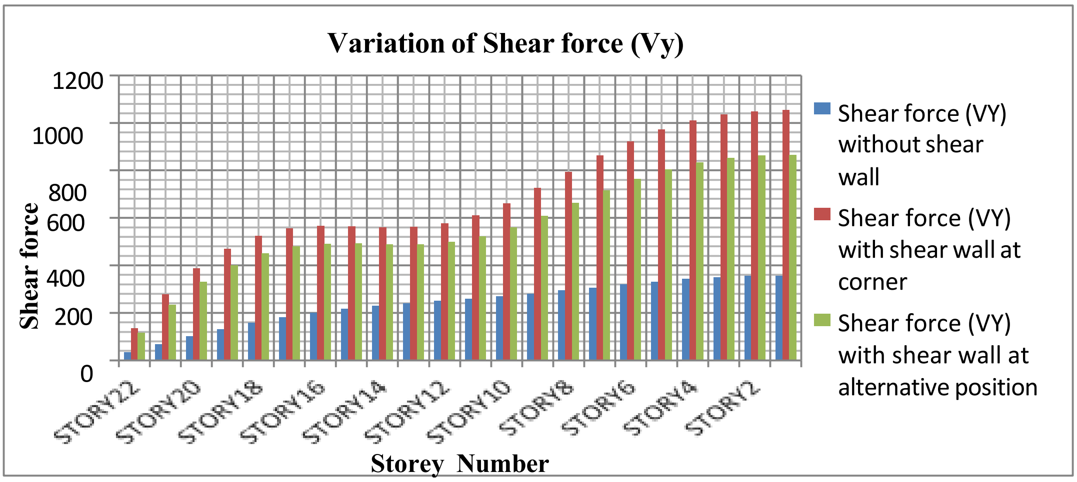


Comparison of Storey Drift Regular Building Y direction

5.1 Shear Force Regular Building



Graph 5. 10 Comparison of Shear Force Regular Building X direction



Graph 5. 11 Comparison of Shear Force Regular Building Y direction

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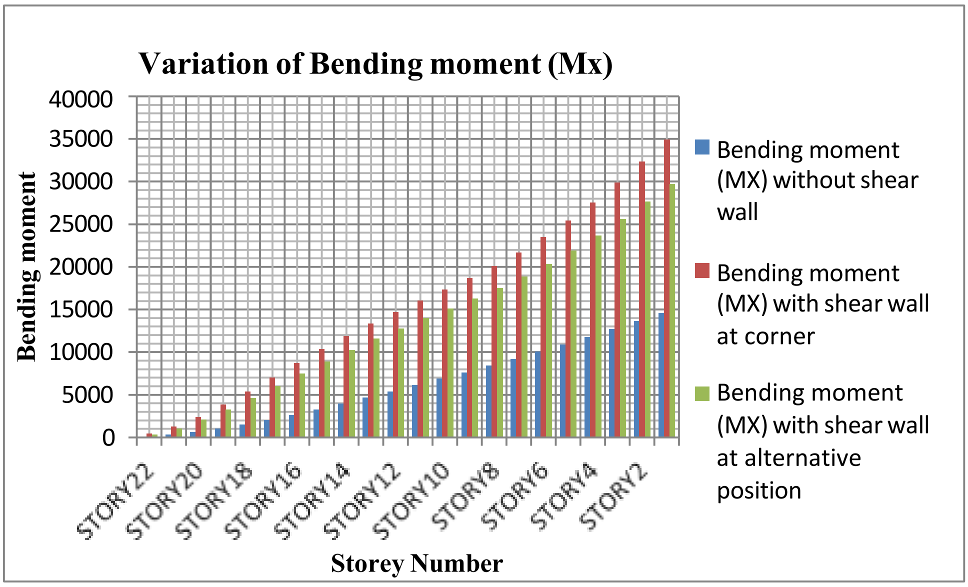
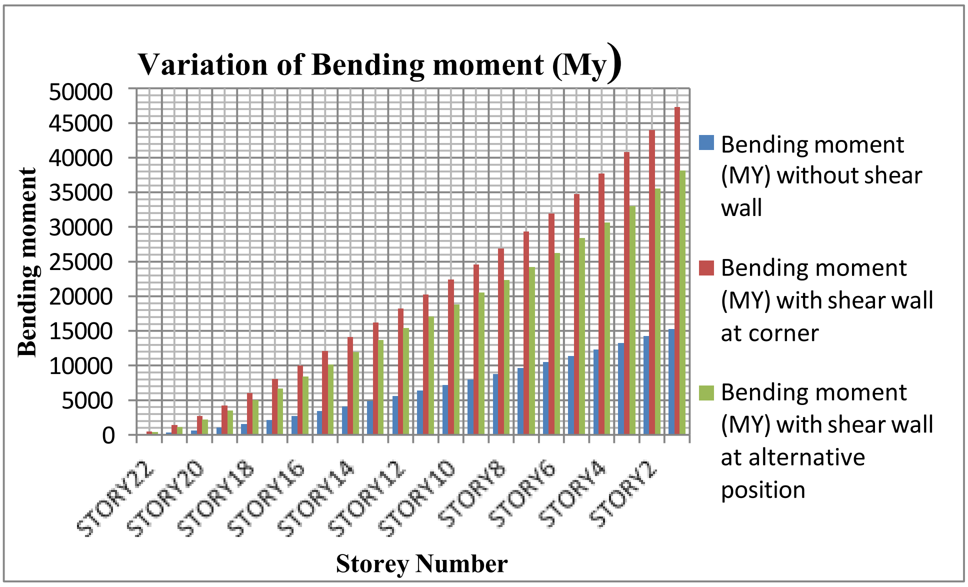
5.1 Building Moment Regular Building

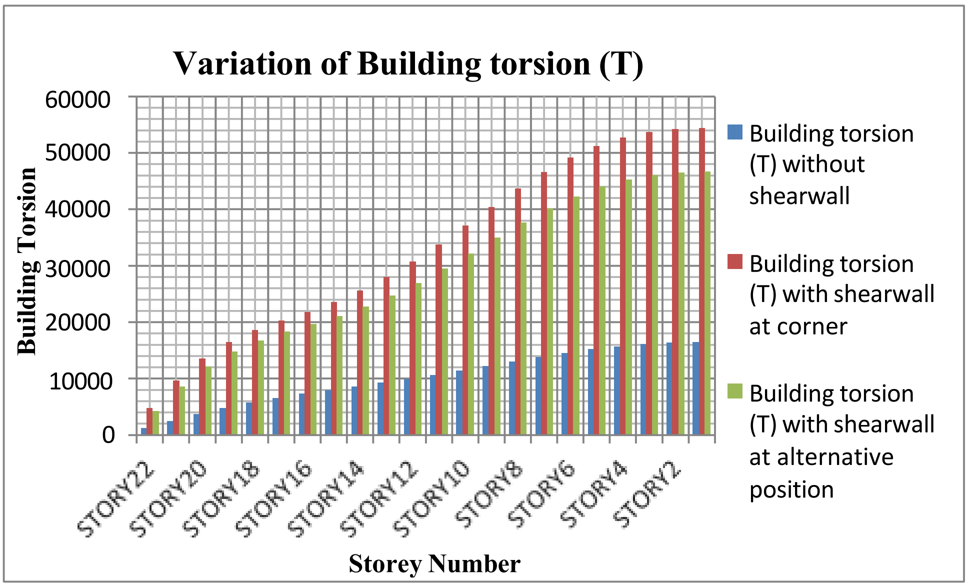


Graph 5. 12 Comparison of Building Moment Regular Building X direction



Graph 5. 13 Comparison of Building Moment Regular Building Y direction

5.2 Building Torsion Regular Building



Graph 5. 14 Building Torsion Regular Building

Conclusion:

1. For both regular and irregular buildings, the drift values in the X and Y directions are lower in structures that incorporate shear walls compared to those that do not. Additionally, shear walls positioned at the corners yield superior results compared to those placed in alternative locations for both directions.
2. The shear force values in both the X and Y directions are found to be lower in buildings without shear walls, particularly those with shear walls positioned at alternative locations and corners. Furthermore, shear walls located in alternative positions exhibit higher shear force values than those at corner positions.
3. The torsion values (T) are also lower in buildings lacking shear walls, including those with shear walls at alternative positions and corners. In this case, shear walls at alternative positions demonstrate higher torsion values compared to those at corner locations.
4. Analyzing the bending moment (M), it is evident that the values are reduced in buildings with shear walls positioned at alternative locations compared to those with shear walls at corner positions.
5. The presence of openings in shear walls significantly elevates the bending moment and shear force in the columns that are connected to those walls. When the opening is located at the top, the percentage increase in these values is less pronounced relative to the size of the opening.
6. It was noted that when the position of a specific opening in the wall is altered, there are observable changes in the structural response.
7. This study concludes that an increase in the percentage of shear walls leads to a reduction in drift while simultaneously increasing shear force, bending moment, and building torsion.

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