Engineering Universe for Scientific Research and Management
ISSN (Online): 2319-3069 Vol. XVI Issue IV
April 2024

Analyzing Earthquake-Resistant Building Designs: Bracing versus Shear Wall Systems with STAADPRO Software

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Abstract

The pursuit of earthquake-resistant building designs is paramount in regions prone to seismic activity. This abstract delves into the comparative analysis of two prominent structural systems, bracing, and shear wall systems, utilizing STAADPRO software. The study aims to discern the effectiveness of each system in mitigating seismic forces and enhancing structural resilience. Through meticulous modeling and simulation, various parameters such as structural integrity, stability, and response to seismic loads are scrutinized. The research methodology involves the creation of virtual models representing buildings with both bracing and shear wall systems, subjected to simulated seismic events of varying magnitudes. By employing STAADPRO software, a comprehensive analysis of structural behavior under seismic stress is conducted, providing insights into the performance of each system. The results are then meticulously analyzed to ascertain the efficacy of bracing and shear wall systems in resisting earthquake-induced forces. Additionally, considerations are made for practical implementation, cost-effectiveness, and architectural adaptability of each system. The findings of this study contribute to advancing the understanding of earthquake-resistant building designs, aiding engineers, architects, and policymakers in making informed decisions regarding structural interventions in seismic-prone regions. Ultimately, this research endeavors to foster the development of safer and more resilient built environments, mitigating the catastrophic impacts of seismic events on communities and infrastructure.

Keywords: *Earthquake-resistant, Building designs, Bracing, Shear wall systems, STAADPRO software*.

1. Introduction

In regions characterized by seismic activity, the imperative of constructing earthquake-resistant buildings stands as a paramount challenge. The devastating consequences of earthquakes underscore the critical need for innovative structural solutions that can withstand the formidable forces unleashed by seismic events. In response to this imperative, engineers and architects have developed various strategies to enhance structural resilience, among which bracing and shear wall systems stand as prominent contenders. This introduction sets the stage for a comprehensive exploration into the comparative analysis of these two structural systems, employing advanced computational tools such as STAADPRO software. By delving into the intricate dynamics of bracing and shear wall systems, this study aims to discern their relative efficacy in bolstering the seismic resilience of buildings. Earthquakes, natural phenomena characterized by sudden and violent shaking of the ground, pose a significant threat to both life and property. The seismic waves generated by earthquakes exert immense pressure and impart dynamic forces upon structures, often leading to catastrophic structural failures. In seismic-prone regions, the design and construction of buildings capable of withstanding these forces are imperative for safeguarding human lives and preserving infrastructure. Consequently, the field of earthquake engineering has emerged, dedicated to developing innovative solutions to mitigate the impact of seismic events on the built environment.

Central to earthquake-resistant building design are the structural systems employed to distribute and dissipate seismic forces effectively. Bracing and shear wall systems represent two distinct approaches to achieving structural resilience in the face of seismic activity. Bracing systems utilize diagonal braces or trusses to stiffen the building frame, thereby enhancing its lateral stability and reducing deformation during seismic events. Shear wall systems, on the other hand, consist of vertical walls integrated within the building structure to resist lateral forces through shear deformation. Both systems offer unique advantages and challenges, prompting the need for a comparative analysis to ascertain their relative performance under seismic loading conditions. The utilization of computational tools has revolutionized the field of structural engineering, enabling engineers to conduct sophisticated analyses and simulations with unprecedented accuracy and efficiency. Among these tools, STAADPRO software stands out as a versatile platform for modeling, analyzing, and designing complex structural systems. Leveraging finite element analysis techniques, STAADPRO facilitates the simulation

Engineering Universe for Scientific Research and Management
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of structural behavior under various loading scenarios, including seismic forces. By harnessing the computational power of STAADPRO, researchers can delve into the intricacies of bracing and shear wall systems, exploring their dynamic response to seismic excitation and elucidating their performance characteristics.

2. Description of Building Structure

In this study, a detailed investigation into the seismic performance of a G+9 storey reinforced concrete building with four bays has been conducted. The building exhibits mass irregularity at the 3rd floor, a critical factor influencing its response to seismic forces. The primary focus of the study is to analyze the efficacy of different bracing configurations, including X type, V type, inverted V type, and Diagonal type bracings, along with variations in their placements within the structure. These bracing systems are strategically positioned throughout the building to assess their impact on structural behavior and seismic resistance. Additionally, the study incorporates the consideration of shear walls located at various positions within the building. By investigating the effects of these shear walls on key structural parameters such as story shear and displacement, the study aims to provide valuable insights into their role in enhancing the building's seismic performance. Through meticulous analysis and simulation, this research contributes to advancing the understanding of optimal seismic design strategies for reinforced concrete structures, ultimately fostering the development of more resilient buildings in seismic-prone regions.

The study investigates various structural configurations, including:

1. A reinforced concrete multistorey building featuring X type, V type, inverted V type, and Diagonal type bracing systems.
2. Another reinforced concrete multistorey building incorporating RCC shear walls.

Additional building specifications are as follows:

- All reinforced concrete (RC) column sizes are 500mm x 500mm.
- All RC beam sizes measure 350mm x 450mm.
- Slab thickness is uniform at 200mm.
- Bracing details conform to ISHB 250 standards.
- Grade of concrete utilized is M-30.
- Grade of steel employed is Fe-500.

3. Structural Modelling and Analysis

The seismic performance of a G+9 storey reinforced concrete building is assessed through the analysis of X type, V type, Inverted V type, and Diagonal type bracings placed at different positions within the structure. The study employs the Response Spectrum method, a linear dynamic approach, for seismic analysis. Earthquake loading is applied in accordance with the guidelines outlined in IS: 1893-2002. The building is situated in seismic zone IV of India and is assumed to rest on medium soil conditions.

A) The present study considers the following seismic parameters:

1) Zone factor for seismic zone IV = 0.24
2) Soil site factor for medium soil condition = 2
3) Importance factor for important buildings = 1
4) Response reduction factor = 5
5) Damping ratio = 0.05

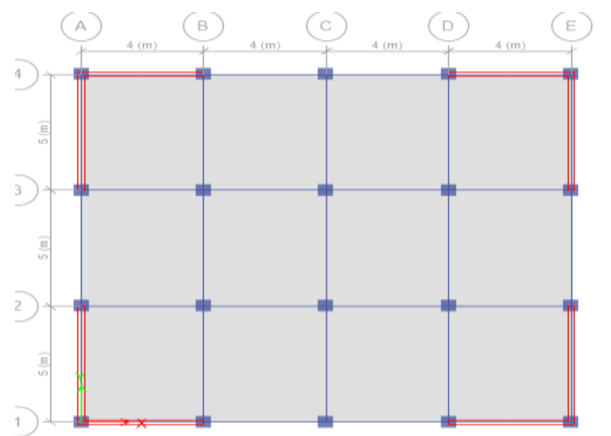
B) The structures are modeled using computer programming ETABS, with the following specifications:

1) Floor load: 5 kN/m2
2) Floor finishing load: 1 kN/m2
3) Waterproofing load: 2 kN/m2
4) Live load: 5 kN/m2
5) Additional load for mass irregularity: 10 kN/m2

Note: Load combinations adhere to the recommendations outlined in Indian standard codes.

A. This study encompasses the analysis of a total of 10 models.
B. Two models feature mass irregularity at the 3rd and 8th floors, respectively, without the inclusion of a lateral steel bracing system.
C. Four models exhibit mass irregularity at the 3rd floor, incorporating X, V, Inverted V, and Diagonal bracing systems in both the X and Y directions.
D. Additionally, four models showcase mass irregularity at the 8th floor, integrating X, V, Inverted V, and Diagonal bracing systems in both the X and Y directions.

The figures provided below depict the plan and various arrangements of X type, V type, Inverted V type, and Diagonal type bracing within the building frame, implemented in both the X and Y directions.



Engineering Universe for Scientific Research and Management
ISSN (Online): 2319-3069 **Vol. XVI Issue IV**
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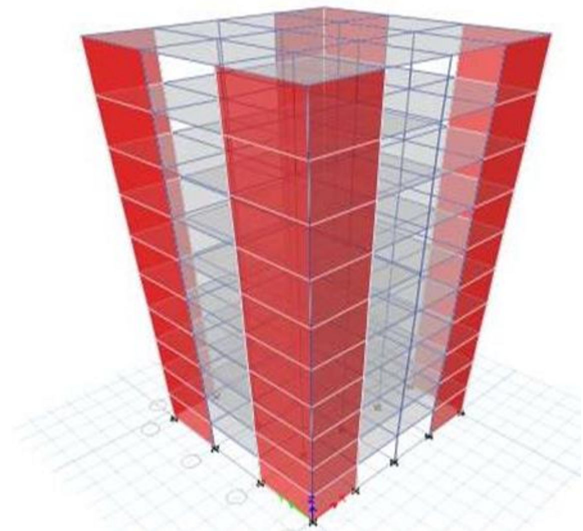


Fig. 1 plan and elevation of building showing Shear walls at corners of building

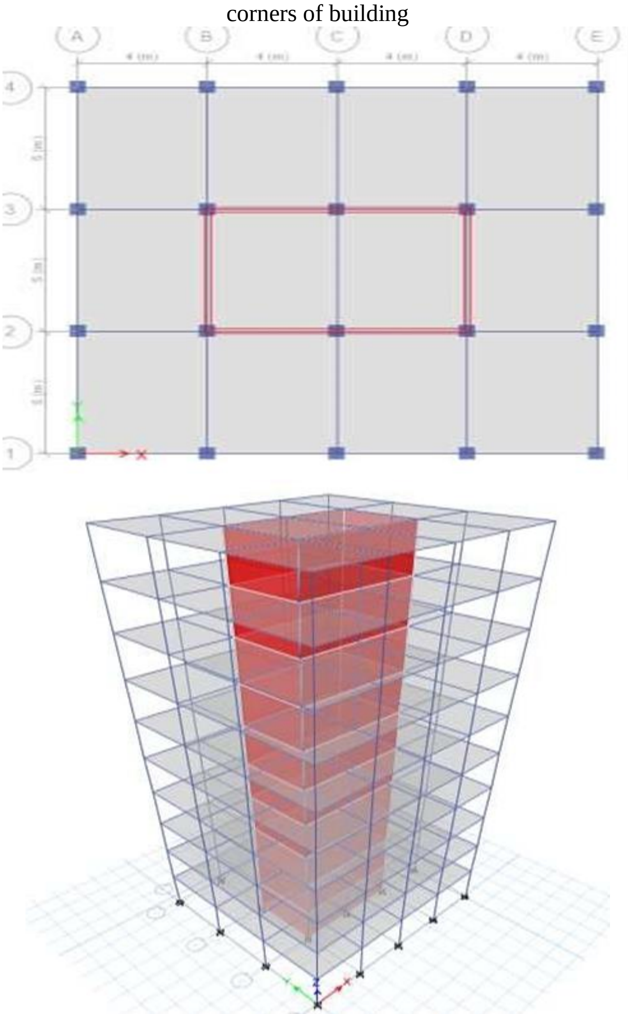


Fig. 2 plan and elevation of building showing Shear walls placed at core of building.

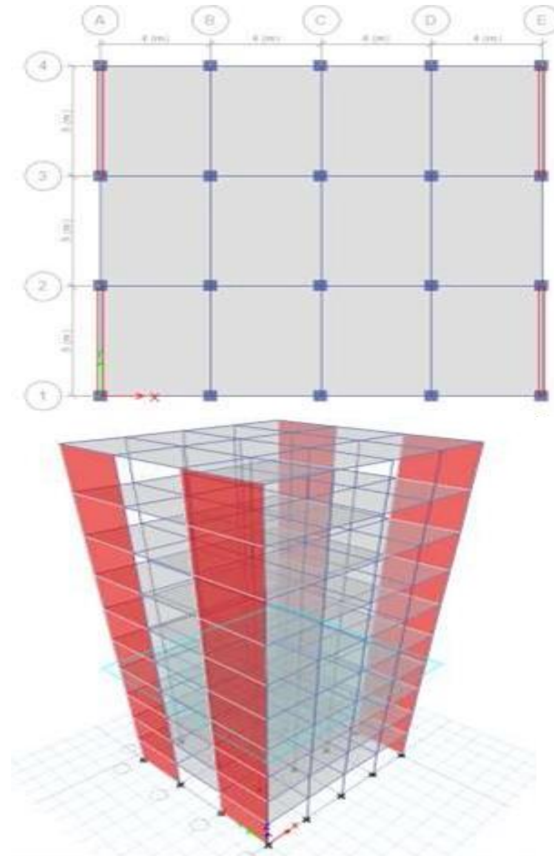


Fig. 3 plan and elevation of building showing Shear walls placed symmetrically.

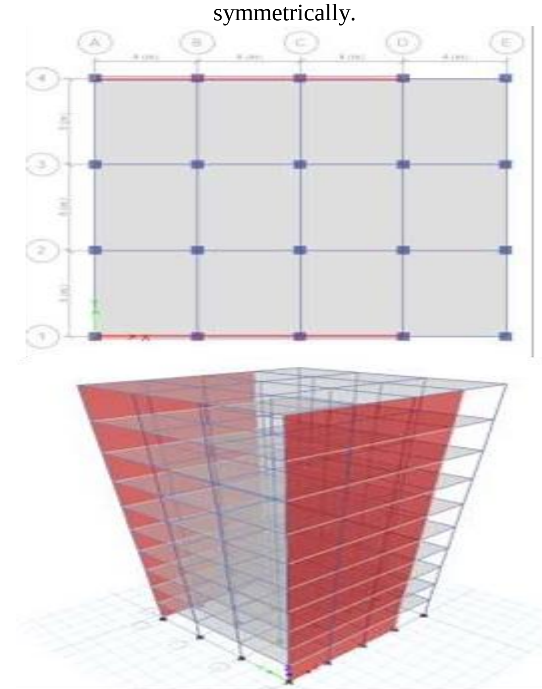
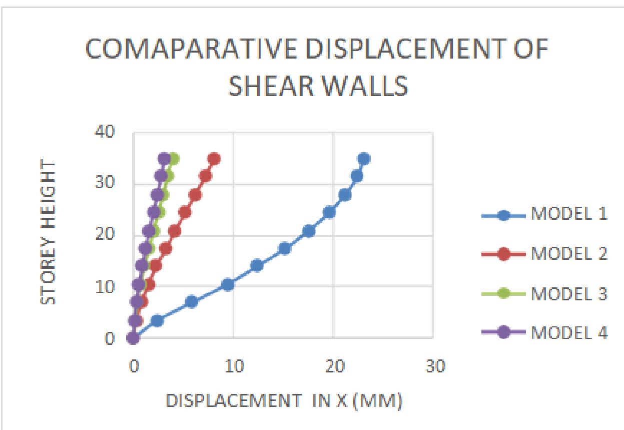


Fig. 4 plan and elevation of building showing Shear walls placed symmetrically.

4. Results

Table 1 Below shows the displacements for the Models 1,2,3,4 in X Direction

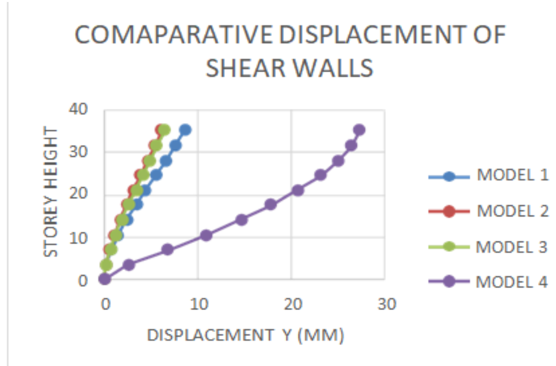
STORY	FLOOR HEIGHT	DISPLACEMENT			
		MODEL 1	MODEL 2	MODEL 3	MODEL 4
Storey 10	35	28.9	9.5	4.5	3.4
Storey 9	31.5	27.9	8.4	4	3
Storey 8	28	26.1	7.3	3.4	2.6
Storey 7	24.5	23.6	6.1	2.9	2.2
Storey 6	21	20.7	4.9	2.3	1.7
Storey 5	17.5	17.3	3.7	1.8	1.3
Storey 4	14	13.7	2.7	1.3	0.9
Storey 3	10.5	10	1.7	0.8	0.6
Storey 2	7	6.1	0.9	0.4	0.3
Storey 1	3.5	2.4	0.3	0.2	0.1
Base	0	0	0	0	0



Graph 1: Graphical representation of story height Vs Displacement

Table 2 Shows Displacement for models 1,2,3,4 in Y- Direction

STORY	FLOOR HEIGHT	DISPLACEMENT(Y-DIRECTION)			
		MODEL1	MODEL2	MODEL3	MODEL4
Storey 10	35	9.5	7.1	7.5	34.4
Storey 9	31.5	8.3	6.2	6.6	33.2
Storey 8	28	7.2	5.4	5.7	31
Storey 7	24.5	6	4.5	4.8	28.1
Storey 6	21	4.8	3.6	3.9	24.5
Storey 5	17.5	3.6	2.7	3	20.5
Storey 4	14	2.6	1.9	2.1	16.2
Storey 3	10.5	1.6	1.2	1.4	11.7
Storey 2	7	0.8	0.6	0.7	7
Storey 1	3.5	0.2	0.2	0.3	2.7
Base	0	0	0	0	0



Graph 2: Graphical representation of the displacement Vs story height

5. Discussion

The results obtained from the analysis were graphically represented to depict the actual structural behavior and assess the objectives of the study. The significance of the results is briefly discussed as follows:

The displacement graph in the x-direction illustrates that the maximum displacement occurs in model 1, where shear walls are positioned at the corners of the building. Conversely, the displacement is minimal in model 4, where shear walls are symmetrically arranged in the plan. Similarly, the displacement graph in the y-direction indicates that the structure featuring a core shear wall (model 2) exhibits the least displacement. For a 10-storey building, the maximum structural displacement is 0.0231m for the bare frame structure (model 4), while the minimum displacement of 0.0071m is observed for the structure with a shear wall at the core location. Importantly, all observed displacements fall within the specified limits outlined in IS 1893:2002 (Part I).

Figure below shows that the different types of bracing systems

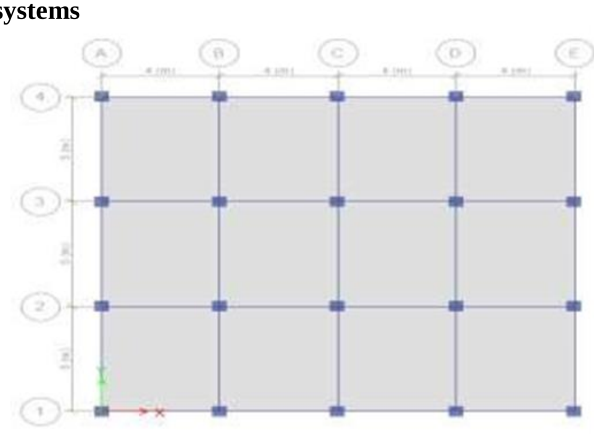


Fig. 5 Plan of building

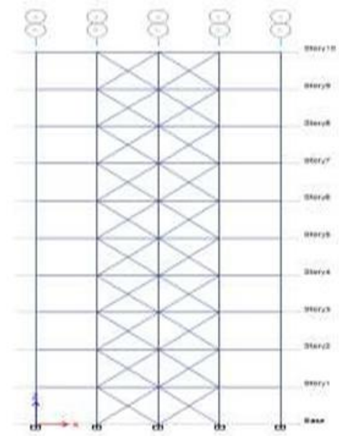


Fig.6 X- type Bracing

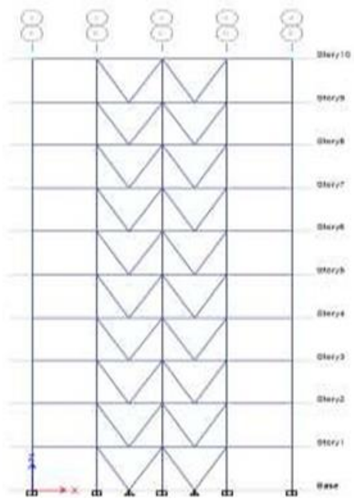


Fig. 7 V - type Bracing

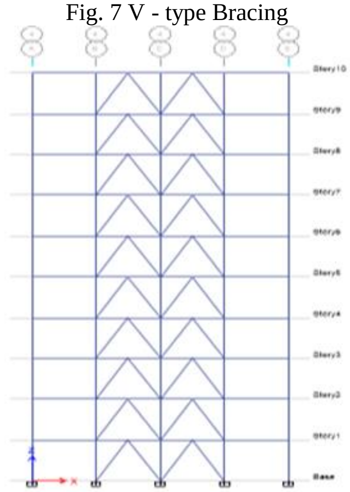


Fig. 8 Inverted v- type Bracing

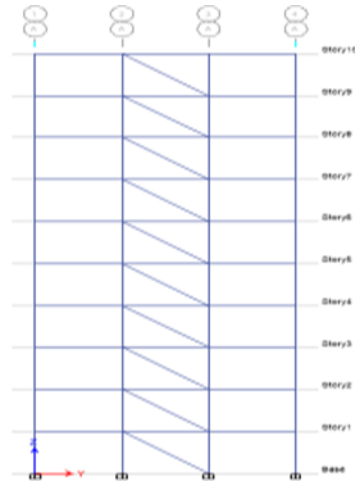
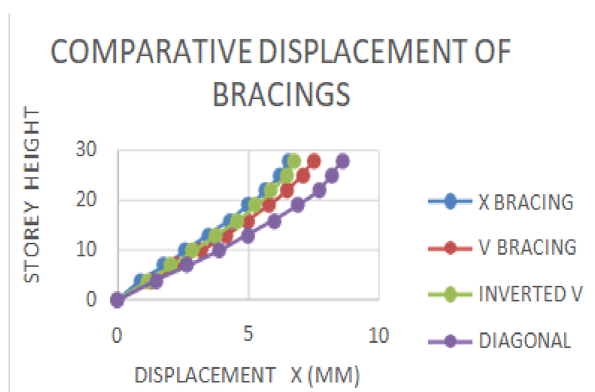


Fig. 9 Diagonal bracing

Table 3

Table III presented below displays the displacements for X-bracing, V-bracing, inverted V-bracing, and diagonal-type bracings in the x-direction.

	Storey Height	X BRACING	V BRACING	INVERTED V	DIAGONAL
Storey 9	28	6.6	7.5	6.8	8.6
Storey 8	25	6.2	7.1	6.5	8.2
Storey 7	22	5.7	6.5	5.9	7.7
Storey 6	19	5	5.8	5.3	6.9
Storey 5	16	4.3	5	4.6	6
Storey 4	13	3.5	4.2	3.8	5
Storey 3	10	2.6	3.2	2.9	3.9
Storey 2	7	1.8	2.3	2.1	2.7
Storey 1	4	0.9	1.3	1.2	1.5
Base	0	0	0	0	0

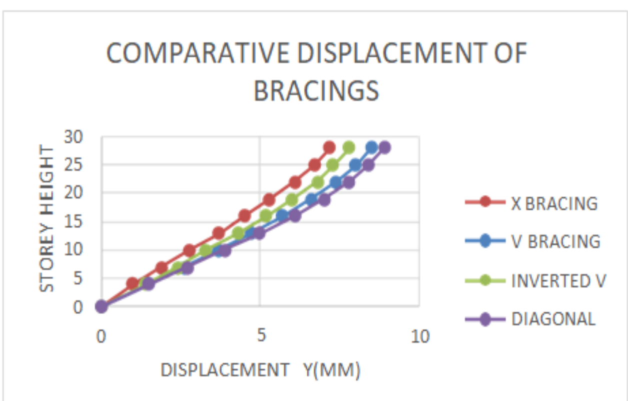


Graph3: Graphical representation of story height Vs Displacement

Table 4

Table IV provided below illustrates the displacements for X-bracing, V-bracing, inverted V-bracing, and diagonal-type bracings in the y-direction.

STO R Y	Store y Height	X BRACIN G	V BRACIN G	INVERTE D V	DIAGO NAL
Storey 9	28	7.2	8.5	7.8	8.9
Storey 8	25	6.7	8	7.3	8.4
Storey 7	22	6.1	7.4	6.8	7.8
Storey 6	19	5.3	6.6	6	7
Storey 5	16	4.5	5.7	5.2	6.1
Storey 4	13	3.7	4.7	4.3	5
Storey 3	10	2.8	3.7	3.3	3.9
Storey 2	7	1.9	2.6	2.4	2.7
Storey 1	4	1	1.5	1.4	1.5
Base	0	0	0	0	0



Graph 4: Graphical representation of story height Vs Displacement

The results were graphed to visualize the structural behavior and assess the study's objectives. Upon analysis of the graphs, it is evident that the displacement in the x-direction for X-type bracing is significantly lower compared to other bracing types such as V-bracing, inverted V-type bracing, and diagonal bracing, measuring approximately 6.6 mm. Similarly, in the y-direction, the displacement remains notably minimal. Thus, it can be inferred that X-type bracing is more effective in resisting lateral forces.

6. Conclusion

The findings of the aforementioned study unequivocally demonstrate that incorporating shear walls at the core of the structure results in significantly reduced displacements compared to other shear wall locations and various types of bracings. This observation underscores the effectiveness of shear walls in providing lateral resistance. When shear walls are strategically placed at the core of the building, they effectively distribute and dissipate lateral forces, resulting in minimal displacement and enhanced structural stability. In contrast, the displacement values associated with bracing systems, regardless of type or location, tend to be higher. Consequently, the study highlights the superiority of shear walls as a viable solution for mitigating lateral forces exerted on structures. These findings advocate for the prioritization of shear wall implementation in seismic design strategies, as they offer superior performance in enhancing structural resilience and minimizing displacement under seismic loading conditions.

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