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Advanced Structural Analysis of Multistoried Building Resting on Sloping Ground Using Time History Method

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Abstract - *Framed structures built on slopes exhibit distinct behaviors compared to those on flat terrain. These structures are often asymmetrical, leading to uneven load distribution due to varying column heights and lengths. This study examines a multistoried building's seismic performance with different structural configurations, specifically step back set back structures and H-shaped structures. Utilizing time history analysis, seismic responses were assessed using advanced software tools. The analysis revealed that step back set back structures without shear walls perform better than H-shaped structures. However, H-shaped structures with both internal and external shear walls demonstrated superior performance compared to step back set back structures.*

Keywords: Multistorey building, Hill Slope angle, Step back set back structure (SBSB), H shape structure, Shear wall, Time history analysis(THA).

1. INTRODUCTION

Reinforced concrete (RC) framed structures face significant challenges when situated on hill slopes, particularly in seismic-prone regions. Historical seismic events like the Bhuj earthquake (2001), Chamoli earthquake (1999), and Uttarkashi earthquake (1991) have underscored the vulnerability of buildings in hilly terrain. For instance, the Bhuj earthquake resulted in a staggering loss of over 35,000 lives and extensive structural damage, while the Chamoli earthquake caused 103 fatalities and the Uttarkashi earthquake claimed over a thousand lives, causing widespread devastation in the Garhwal Himalayas. To address seismic risks, various bracing techniques such as moment frames, shear walls, and braced frames are utilized. Step-back and setback configurations have demonstrated superior performance on sloping terrains compared to conventional designs. However, despite their potential advantages, there remains a dearth of comprehensive studies on multistoried buildings on slopes, especially those incorporating shear walls in diverse locations. Further research is imperative to deepen our understanding of the behavior of these structures and to formulate effective design strategies.

I. OBJECTIVE OF THE STUDY*

1. To analyze the seismic performance of different structural configurations, including step back set back and H-shaped structures, on sloping ground.
2. To investigate structural parameters such as storey shear, base shear, and story stiffness in response to seismic forces on slopes.
3. To identify the most suitable structural configuration for multistoried buildings on sloping ground by evaluating various design options and considering seismic performance, stability, and structural integrity.

II. DESCRIPTION OF BUILDINGS*

A study was conducted to analyze the seismic behavior of buildings situated on hill slopes, incorporating various configurations as illustrated in Figures 1 to 4. The slope angle was fixed at 28.07 degrees, while the plan dimension of the building was 6.0 meters by 5.0 meters, with each story having a height of 3.2 meters. This investigation aimed to understand how different structural arrangements and slope conditions affect the response of buildings to seismic forces, providing valuable insights into the design and construction of structures in hilly terrain.

Building Height	Column Size mm x mm	Beam Size mm x mm
27.2 m	600 X 600	300 X 600

Table 1 presents the sizes of RCC beams and columns used.

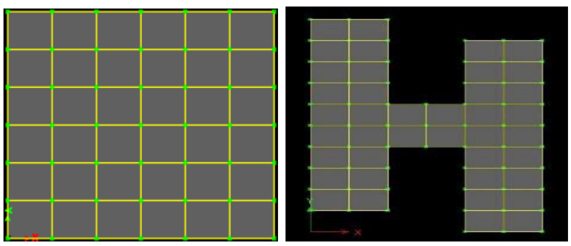


Figure 1 illustrates the plan of two types of structures: SBSB (Step-Back Setback) Structure and H-Shape Structure, both without shear walls.

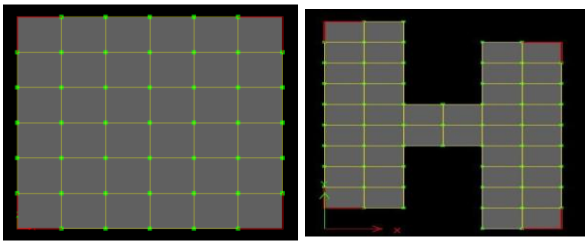


Figure 2 displays the plan of the same structures, but with a shear wall positioned at the corner.

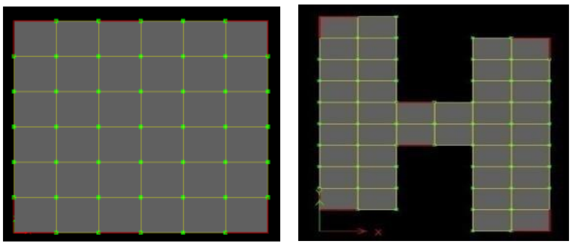


Figure 3, the plan shows the structures with shear walls placed at both the corner and the middle

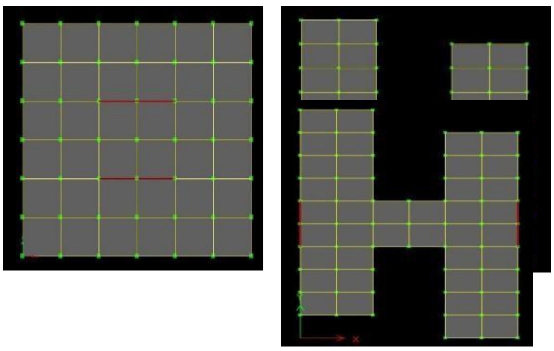


Figure 4 presents the plan of the structures with a shear wall positioned at the middle

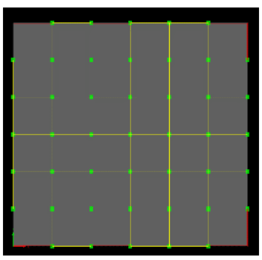


Figure 5 depicts the plan of the structures with shear walls located at adjacent ends. These figures provide visual representations of different configurations studied in the seismic behavior analysis of buildings on slopes, aiding in the comprehension of structural responses under seismic loading conditions.

2. METHODOLOGY

This research investigates the basaltic conduct of differing structural setups, containing shrink away delay and H-formed structures, in a multistoried construction circumstances. Using ETABS program, the study adhered to IS 1893:2016 flags, engaging Time History Analysis. Seismic dossier from notable upheavals (Bhuj, Uttarkashi, Chamoli) were secondhand. Shear wall configurations were resolved for two together extrinsic corner divider (Shear Wall 1) and additional within divider (Shear Wall 2) as proved in Figures 2-4.The key limits used for the reasoning are particularized beneath

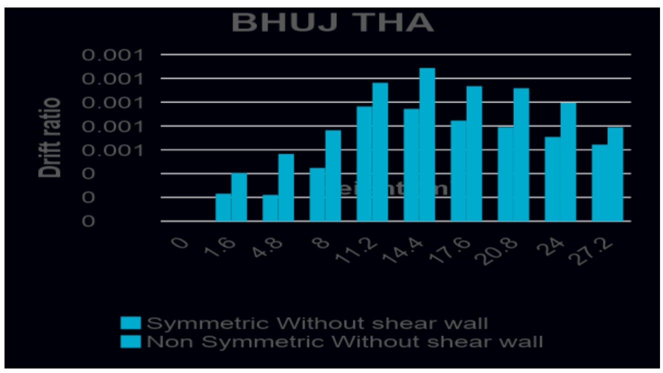
Parameters	Values
Soil type	Hard
Importance Factor	1.2
Zone Factor	IV
Damping Ratio	0.05
Reduction Factor	5
Live Load	$3kN/m^2$
Floor Finish	$1.5kN/m^2$
Wall Load	13.00kN/m

Table 2 Parameters used

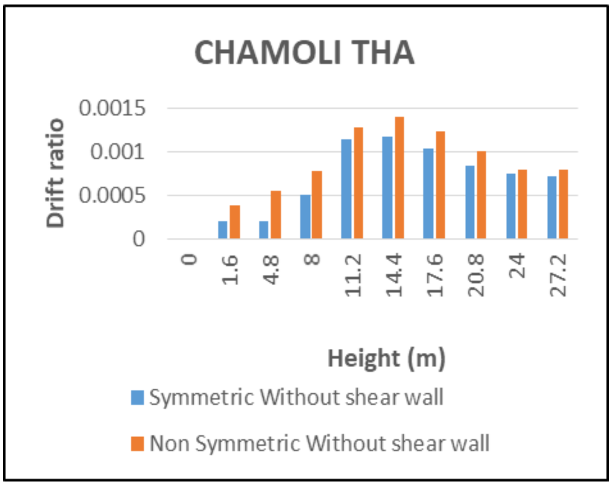
3. RESULTS AND DISCUSSION*

I. Drift Ratio:

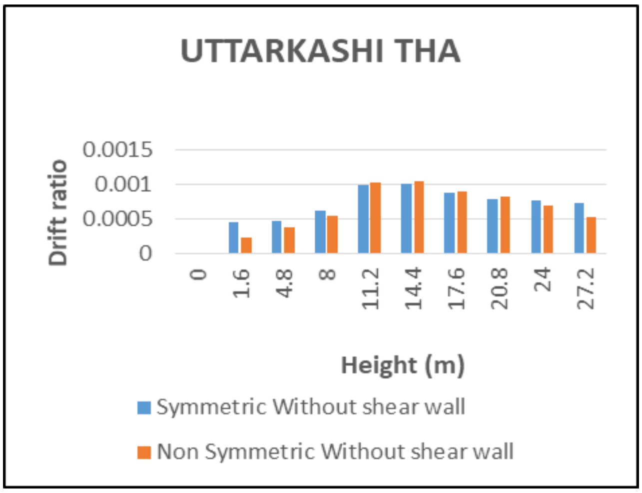
The drift ratio, indicating the lateral displacement of a building's top relative to its height, was evaluated. Buildings with lower stiffness exhibited higher drift ratios. The highest drift ratio was observed in the step back set back structure with shear walls during the Chamoli earthquake.



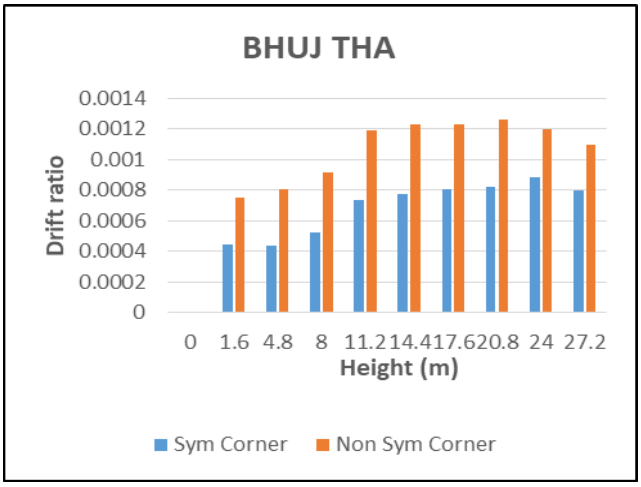
Drift ratio of H Shaped & SBSB structure without SW for BHUJ THA(Graph-1)



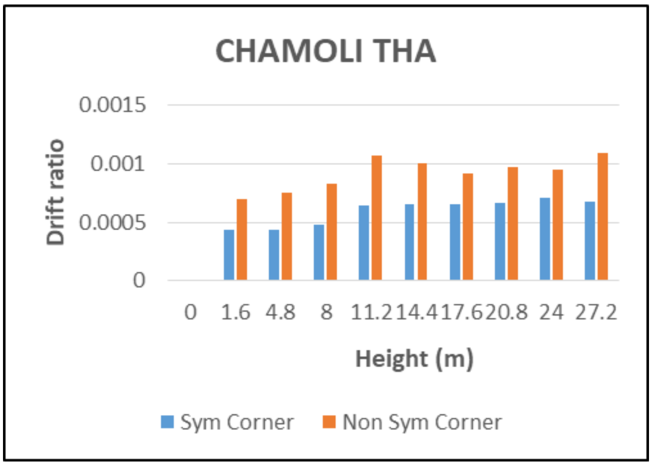
Drift ratio of H Shaped & SBSB structure without SW For CHAMOLI THA (Graph-2)



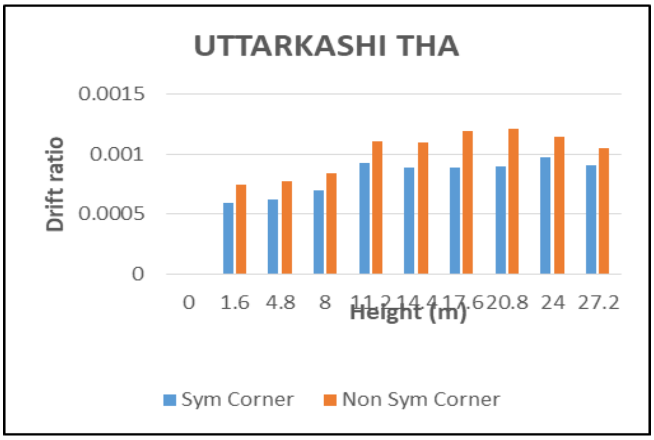
Drift ratio of H Shaped & SBSB structure without SW for UTTARKASHI THA (Graph-3)



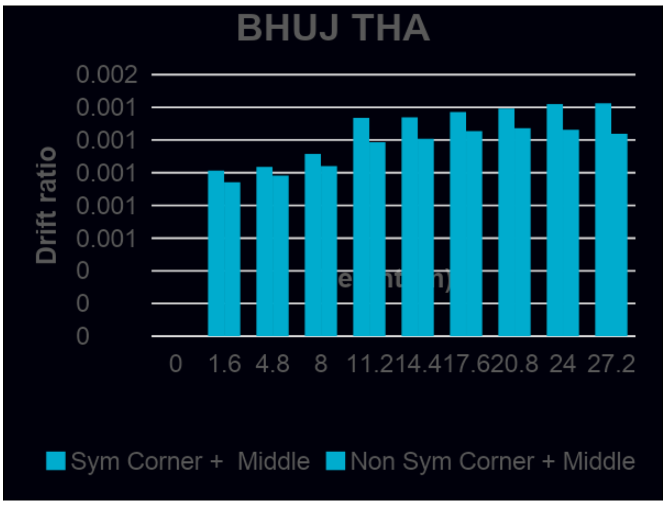
Drift ratio of H Shaped & SBSB structure with SW at corner for BHUJ THA (Graph-4)



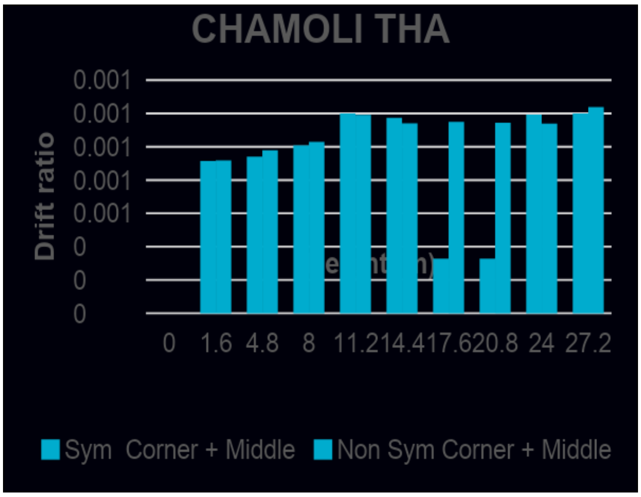
Drift ratio of H Shaped & SBSB structure with SW at corner for CHAMOLI THA (Graph-5)



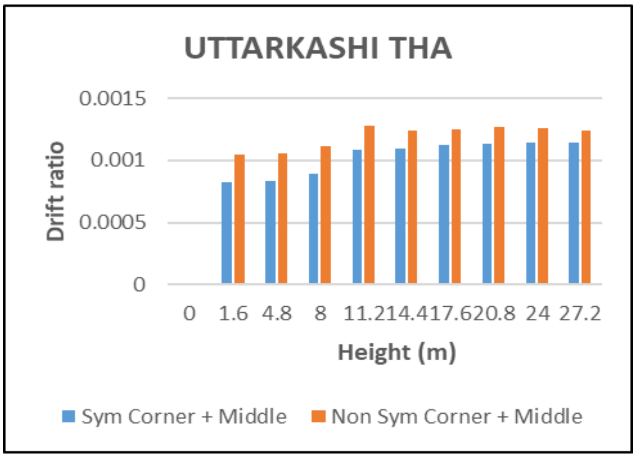
Drift ratio of H Shaped & SBSB structure with SW at corner for UTTARKASHI THA (Graph-6)



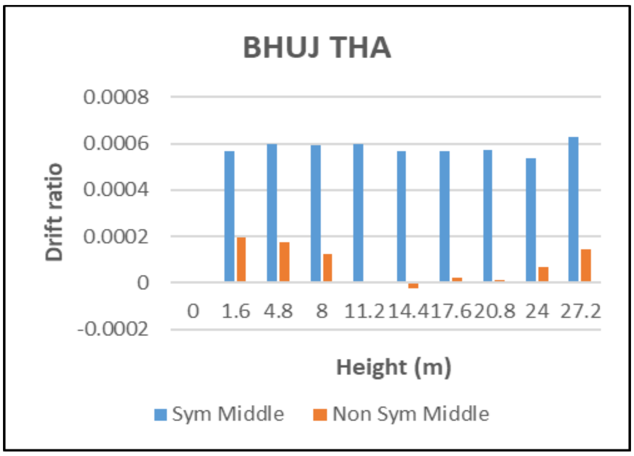
Drift ratio of H Shaped & SBSB structure without SW at Corner + middle for BHUJ THA (Graph-7)



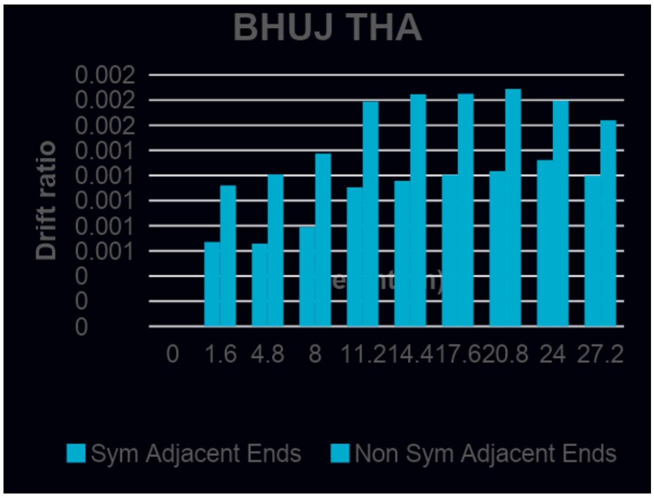
Drift ratio of H Shaped & SBSB structure without SW at Corner + middle for CHAMOLI THA (Graph-8)



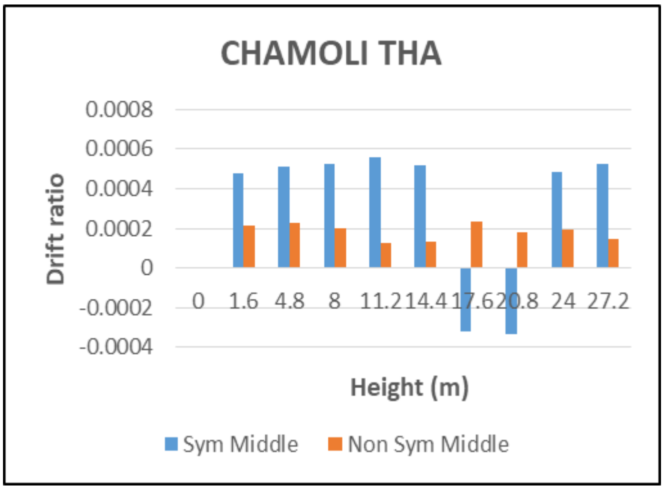
Drift ratio of H Shaped & SBSB structure without SW at Corner + middle for BHUJ THA (Graph-9)



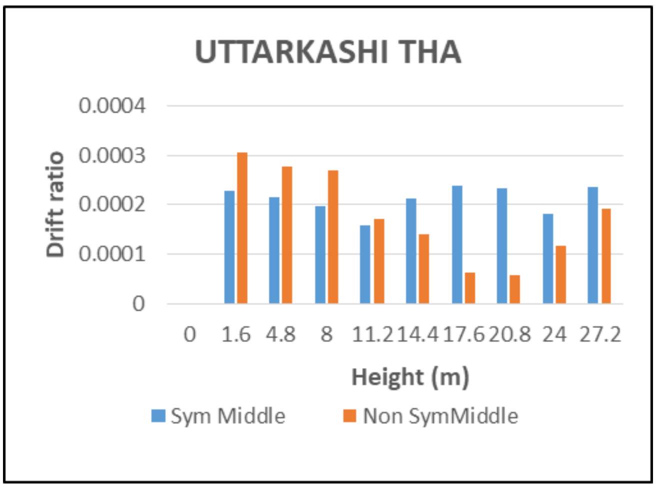
Drift ratio of H Shaped & SBSB structure with SW at middle for BHUJ THA (Graph-12)



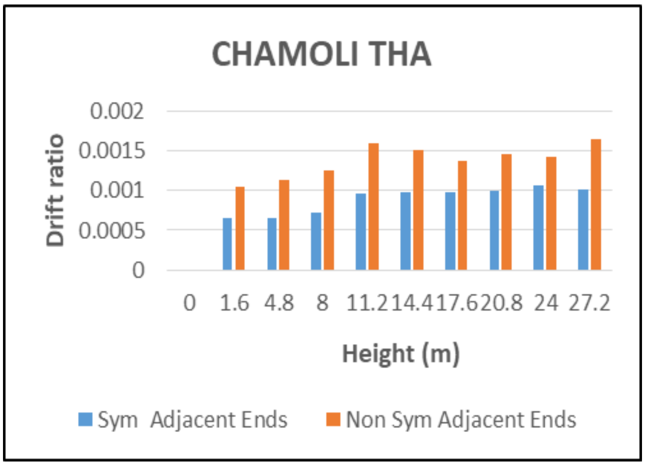
Drift ratio of H Shaped & SBSB structure with SW at middle for BHUJ THA (Graph-10)



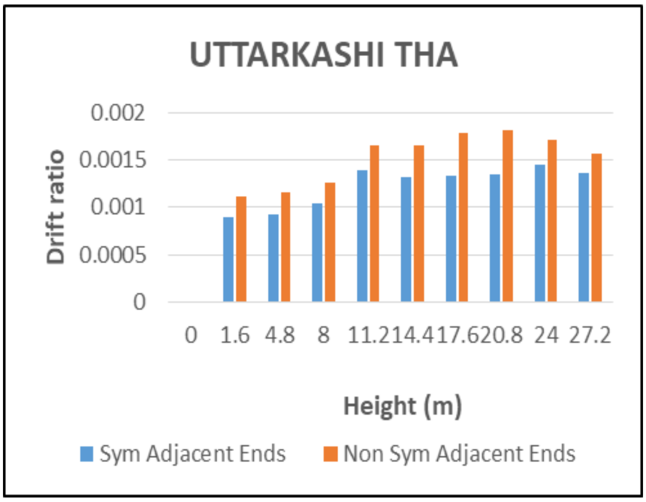
Drift ratio of H Shaped & SBSB structure with SW at middle for CHAMOLI THA (Graph-11)



Drift ratio of H Shaped & SBSB structure without SW at Adjacent ends for BHUJ THA (Graph-13)



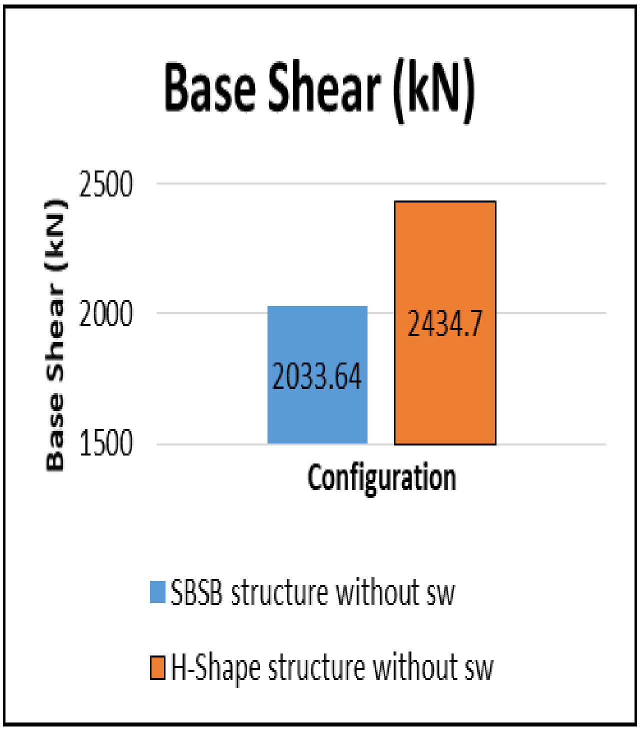
Drift ratio of H Shaped & SBSB structure without SW at Adjacent ends for CHAMOLI THA (Graph-14)



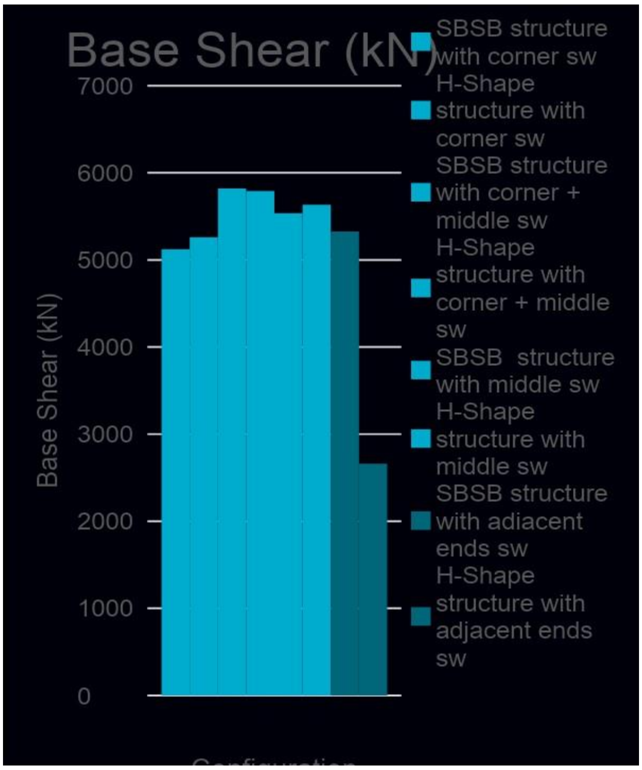
Drift ratio of H Shaped & SBSB structure without SW at Adjacent ends for UTTARKASHI THA (Graph-15)

II. Base Shear:

Base shear, the force generated at the structure's base due to seismic activity, was analyzed. Step back set back structures without shear walls showed lower base shear compared to H-shaped structures without shear walls. However, H-shaped structures with both internal and external shear walls demonstrated lower base shear compared to step back set back structures with similar shear wall configurations.



Base Shear comparison without Shear Wall (Graph-16)



Base shear comparison with Shear Wall (Graph-17)

	Bhuj Time History				
Types of configurations	**Top Storey Displacement**	**Drift Ratio**	**Storey Shear**	**Storey Stiffness**	**Base Shear**
H Shape Structure	17.00	0.0011	1540.50	3668052	2434.7
SBSB structure	15.45	0.001	1403.64	4238702	2033.69
	Chamoli Time History				
H Shape Structure	18.39	0.0014	1539.50	3668052	2434.7
SBSB structure	18.69	0.0012	1498.48	4238702	2033.69
	Uttarkashi Time History				
H Shape Structure	15.73	0.0011	1782.60	3668052	2434.7
SBSB structure	11.51	0.001	1157.66	4238702	2033.69

Table 3 Variations in Seismic Parameters of Structure without Shear Wall using Time History Analysis

	Bhuj Time History				
Types of configurations	**Top Storey Displacement**	**Drift Ratio**	**Storey Shear**	**Storey Stiffness**	**Base Shear**
H Shape Structure	17.00	0.0011	1540.50	3668052	2434.7
SBSB structure	15.45	0.001	1403.64	4238702	2033.69
	Chamoli Time History				
H Shape Structure	18.39	0.0014	1539.50	3668052	2434.7
SBSB structure	18.69	0.0012	1498.48	4238702	2033.69
	Uttarkashi Time History				
H Shape Structure	15.73	0.0011	1782.60	3668052	2434.7
SBSB structure	11.85	0.00182	5512.22	13073943	5326

Table 4 Variations in Seismic Parameters of Structure with Corner Shear Wall Location using Time History Analysis

	Bhuj Time History				
Types of configurations	**Top Storey Displacement**	**Drift Ratio**	**Storey Shear**	**Storey Stiffness**	**Base Shear**
H Shape Structure	12.58	0.00127	4833.50	9955435.8	5792
SBSB structure	9.58	0.00142	5208.93	8671598.1	5820
	Chamoli Time History				
H Shape Structure	7.94	0.00094	3090.18	9955435.8	5792
SBSB structure	7.92	0.00081	4775.61	8671598.1	5820
	Uttarkashi Time History				
H Shape Structure	8.60	0.00115	4898.45	9955435.8	5792
SBSB structure	8.41	0.00115	5233.8531	8671598.1	5820

Table 5 Variations in Seismic Parameters of Structure with Corner+Middle Shear Wall Location using Time History Analysis

	Bhuj Time History				
Types of configurations	**Top Storey Displacement**	**Drift Ratio**	**Storey Shear**	**Storey Stiffness**	**Base Shear**
H Shape Structure	8.3	0.00043	4788.474	1925046.7	5632
SBSB structure	8.381	0.00049	5168.934	759966.79	5536.7
	Chamoli Time History				
H Shape Structure	6.343	0.00035	3050.178	1925046.7	5632
SBSB structure	6.718	0.00035	4735.609	759966.79	5536.7
	Uttarkashi Time History				
H Shape Structure	7	0.0003	4858.452	1925046.7	5632
SBSB structure	7.21	0.00024	5193.853	759966.79	5536.7

Table 6 Variations in Seismic Parameters of Structure with Middle Shear Wall Location using Time History Analysis

	Bhuj Time History				
Types of configurations	Top Storey Displacement	Drift Ratio	Storey Shear	Storey Stiffness	Base Shear
H Shape Structure	19.56	0.00252	5614.38	1373203.5	2661.3
SBSB structure	13.8	0.00176	4964.98	13073943	5326
	Chamoli Time History				
H Shape Structure	9.85	0.00142	3836.02	1373203.5	2661.3
SBSB structure	9.49	0.00219	3412.5	13073943	5326
	Uttarkashi Time History				
H Shape Structure	14.49	0.00125	4961.98	1373203.5	2661.3
SBSB structure	11.85	0.00182	5512.22	13073943	5326

Table 7 Variations in Seismic Parameters of Structure with Adjacent ends Shear Wall Location using Time History Analysis

4. CONCLUSION:

1. H-shaped structures without shear walls exhibit higher drift ratios compared to step back set back structures across multiple seismic events.
2. Step back set back structures without shear walls demonstrate lower base shear compared to H-shaped structures without shear walls.
3. Incorporating both internal and external shear walls in H-shaped structures reduces drift ratios compared to configurations with only external shear walls.
4. H-shaped structures with both internal and external shear walls experience lower storey base shear than step back set back structures with similar shear wall configurations.
5. Configurations with shear walls at both external and internal locations outperform those with only external shear walls, highlighting the importance of shear wall placement in optimizing structural performance.

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13. Ahmad and Modani (2020) conducted a comparative analysis of the seismic performance of RC buildings resting on plain and sloping ground.