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Seismic Performance and Shear Wall Position Assessment of the Buildings Resting on Sloping Ground

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Abstract - *In various parts of India, the ground is not flat and the lack of plain ground in hilly areas obliges construction activity on sloping terrain resulting in various significant buildings such as RC framed structures resting on hilly slopes. In such areas the constructing Structures by clearing the site, making it flat becomes uneconomical. In this present study using ETABS.v19 software, A group of buildings configurations is analyzed using Response Spectrum Method (namely Step-Back configuration) with different ground Sloping ground i.e., 15°, 20° and 25° with horizontal. These group further studied with 8 different Shear wall locations namely Shear wall at core, Shear wall at periphery of Sloping Side also along all 4 sides etc., By performing analysis Dynamic response of these buildings, in terms of Base Shear, Maximum Story displacement and Story Drifts Ratios is presented, and results are compared within the considered configuration. At the end, an appropriate building configuration to be used in Sloped terrain areas is recommended.*

Key Words: *Seismic Performance, Shear Wall, Response Spectrum Analysis, Storey Displacement, Base Shear, Storey Drifts.*

1. INTRODUCTION

The economic progress and fast urbanization in the hilly region have accelerated infrastructure development. Because of this, the inhabitants in the hilly terrain have increased rapidly. Therefore, there is demand for the construction of multi-storey buildings on hilly terrain in and around the locality. Since level or flat land in hilly regions is very inadequate, there is an insistent demand to construct buildings on the sloped ground. Therefore, the construction of multi-storey Reinforced Concrete Frame structures on a sloped terrain is the only possible choice to put up increasing demand for residential and commercial purposes. On hilly terrain, the buildings constructed are typically irregular, torsional coupled and hence, vulnerable to severe damage when subjected to Seismic ground motion. The mass and stiffness of these buildings varies along the vertical and horizontal planes, which results in the different centre of mass and rigidity on various floors, hence they demand analysis for torsional, in adding to lateral forces under the action of earthquakes. Analysis of buildings constructed on hilly areas are unlike to that of buildings on the flattened ground because, the column of hill building rests at different levels on the sloping ground. During earthquake the column which are short, i.e., short columns attract more energy and endures damage when subjected to ground motion.

Shear Wall: Shear walls are the one of the most commonly used lateral load resisting structural unit system. Shear wall has very high stiffness which can be used to resist huge gravity as well as lateral loads. The lateral stiffness, strength, and ductility as well as the resisting seismic loads carrying capacity of the building can be enhanced by well-designed and detailed RC Shear. RC Shear walls have higher lateral shear force carrying capacity as well as bending capacity under lateral loads. For the buildings on hilly terrain, the columns height below plinth level are different which affects the behaviour of the building during an earthquake takes place. Hence to improve the seismic performance of shear walls play a very important role. So, it is an essential to study the positioning of shear walls on seismic performance of buildings situated on the hilly areas.

1.1 Objectives

- To study seismic performance of building with and without shear walls resting hilly terrain.
- To study the effectiveness of different shear walls configurations on seismic action of buildings resting on hilly terrain such as Step-back.
- To compare the effect of positioning of shear walls on seismic performance of building on hilly terrain.
- To study the seismic behaviour of buildings resting on sloping terrain with different sloping angles.
- To evaluate the seismic parameters such as base shear, displacement and storey drift of the building resting on Sloping ground.

1.2 Method of Analysis

Seismic analysis is a major tool in earthquake engineering that is used to understand the response of buildings due to Response Spectrum Analysis to seismic excitations more simply. It is a part of structural analysis and a part of structural design where an earthquake is prevalent. The seismic analysis of all buildings is carried by the Response spectrum method as per IS:1893(Part 1): 2016.

2. BUILDING CONFIGURATION

The model consists of a G+5 storey RCC building having five bays in each direction, each bay is having a width of 3m. The story height for each floor height is kept as 3m. The Step back models are analysed on hilly terrain on three different slopes namely 15^0,20^0 and 25^0. Under each sloping angle, further 8 models are depending upon the shear wall locations. The frames on hilly areas under consideration for the present study is as shown below. For the analysis M30 grade concrete and Fe 415 grade steel are used

Sl.No.	PARTICULARS	SPECIFICATIONS
1	No. of storey	6
2	Base plan	15m x 15m
3	Storey height	3m
4	Depth of foundation	1.5m
5	Type of soil	Hard
6	Column size	300mm x 450mm
7	Beam size	300mm x 450mm
8	Slab thickness	150mm
9	Shear wall thickness	200mm, 150mm

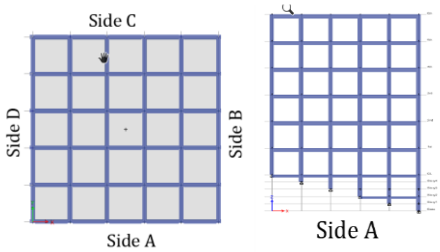

Fig-1: C0

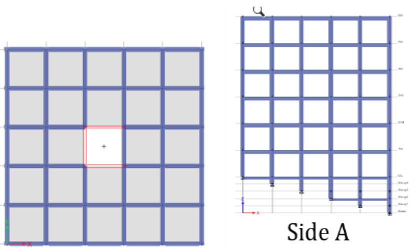

Fig-2: C1

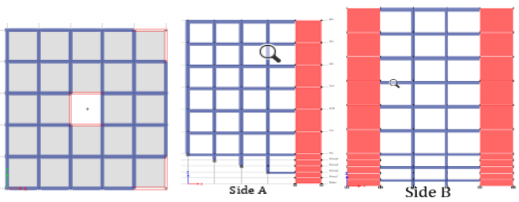

Fig-3: C2

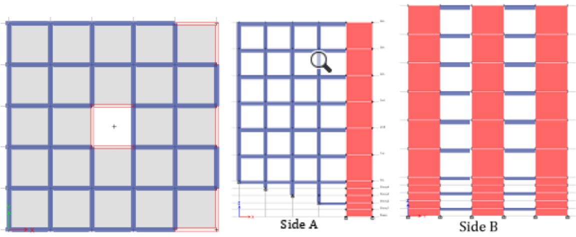

Fig-4: C3

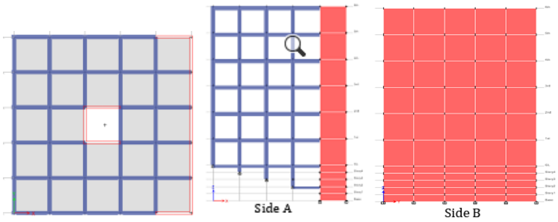

Fig-5: C4

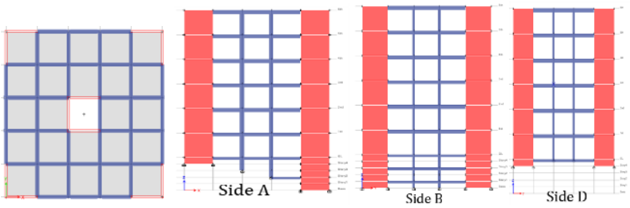

Fig-6: C5

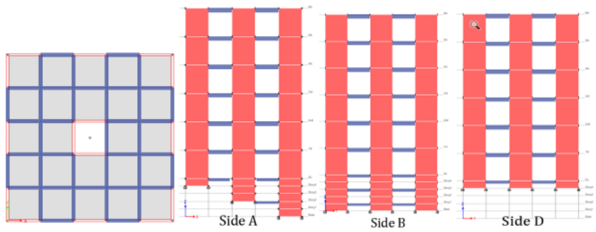

Fig-7: C6

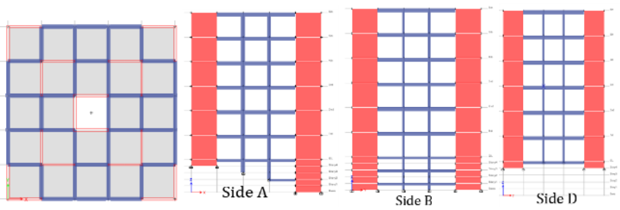

Fig-8: C7

SBC0	Without shear wall
SBC1	Shear wall at Internal Core
SBC2	Shear wall at Internal Core & corners of side B
SBC3	Shear wall at Internal Core & corners+middle of side B
SBC4	Shear wall Internal Core & along the side B
SBC5	Shear wall at Internal Core & corners of all 4 sides

SBC6	Shear wall at Internal Core & corners+middle of all 4 sides
SBC7	Shear wall at Internal Core & corners of internal frames & Exterior frames on all 4 sides

The above table shows typical representation of models with location of Shear walls is modelled with 15^0 slopes. Similarly, the analysis is done for the different locations of Shear wall for models with 20^0 and 25^0 slopes. 15^0 slope models namely 15SBC0 to 15 SBC7, 20^0 slopes has models namely 20SBC0 to 20SBC7 and 25^0 slopes has models from 25SBC0 to 25SBC7. The actual number of models are 24 with three different sloping angles.

3. LOAD CALCULATIONS

Dead load

Automatically taken by ETABS

Table 1- Super Imposed Dead Load, SIDL

Super Imposed Dead Load, SIDL as per IS 875 (part-1)			
SIDL on Intermediate Floors			
i) 50mm thick mortar for flooring		1.15	kN/m²
ii) Ceiling Plastering (say 8mm)		0.176	kN/m²
iii) Floor tiles of 12mm thick		0.12	kN/m²
Total Load on Floor except for Terrace =	SIDL =	1.446	kN/m²
SIDL on Terrace			
The density of waterproofing =		16	kN/m²
Load intensity of Waterproofing course =		1.28	kN/m²
ii) Ceiling Plastering (say 8mm)		0.176	kN/m²
Total Load on Terrace =		1.456	kN/m²

Table 2- Live Load as per IS: 875 (part-2)

Live Load as per IS: 875 (part-2)		
1) Live load on all slabs except terrace	2	kN/m²
2) For Terrace (access is provided)	1.5	kN/m²

Table 3- Seismic Loading as per IS 1893:2016

Seismic Loading as per IS 1893:2016		
Seismic Analysis Terms		
1. Seismic Zone	IV	
2. Zone Factor, Z	0.24	
3. Site Type	Type 1	For Hard Soil as per Table 4
4. Importance Factor, I	1.2	From cl.7.2.3 and Table 8
5. System	SMRF	
6. Response Reduction Factor, R	5	as per cl. 7.2.6 and Table 9
7. % of the Imposed load to be considered in Seismic Wt.	25%	as per cl. 7.3.1 and Table 10
8. Method Analysis	Response Spectrum Analysis	

4. RESULTS and DISCUSSIONS

Maximum Storey Displacement:

- Max. storey displacement along y- direction is more than that of X – direction
- It is seen that from SBC0 to SBC7, the max. storey displacement decreases in both directions.
- As the Slope of ground increases the max storey displacement will also increases.
- It is observed that, along X-direction, there is a reduction of 72.51% for 15^0 slope, 66.85% reduction for 20^0 slopes and 64.63% for 25^0 slopes in max. storey displacement from SBC0 to SBC7.
- , along Y-direction, there is a reduction of 80.42% for 15^0 slope, 67.62% reduction for 20^0 slopes and 64.63% for 25^0 slopes in max. storey displacement from SBC0 to SBC7.
- It is also observed that along X direction, compare to Y-direction just by introducing of the shear wall at core, there is huge reduction in max storey

displacement, introducing shear wall at core reduces the displacement by 33.54%, 21.03% & 18.48% for 15^0, 20^0 & 25^0 respectively.

- However, along Y-direction by introduction of Shear wall at core (SBC1) the displacement reduces by 29.08%, 4.29% & 0.2% for 15^0, 20^0 & 25^0 respectively.
- From above it is clear that along Y direction the introduction of shear wall at core is having less effect but along X direction the shear wall at core plays important role in the reduction of Displacement.
- For up to case 4 i.e., SBC0 to SBC3, there is considerable amount of reduction in displacement along X- direction whereas along Y-direction there is no much reduction in displacement. This is because the position of Shear wall is only along sloping direction(X-direction) at side B
- From case 5 onwards i.e., SBC4 to SBC7, there is considerable amount of reduction in both X & Y-direction because of the presence of Shear wall along both sloping direction and perpendicular to the sloping direction i.e., on all the sides of frames (side A, side B, side C, side D).
- It is also noted that displacement reduces with increase in number of Shear wall. Hence SBC7 shows the least displacement compare to all other cases i.e., from SBC0 to SBC6
- It is noted that for the SBC7 there is an increase of 6.735% of max storey displacement from 15^0 to 20^0 slopes, 6.98% from 20^0 to 25^0 slopes and 14.19% increase in max storey displacement from 15^0 to 25^0 slopes.

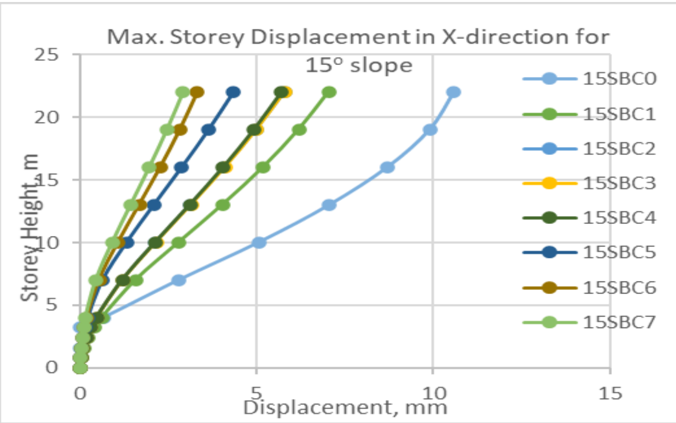

Fig. -1: Max. Storey Displacement in X-direction for 15^0 slope

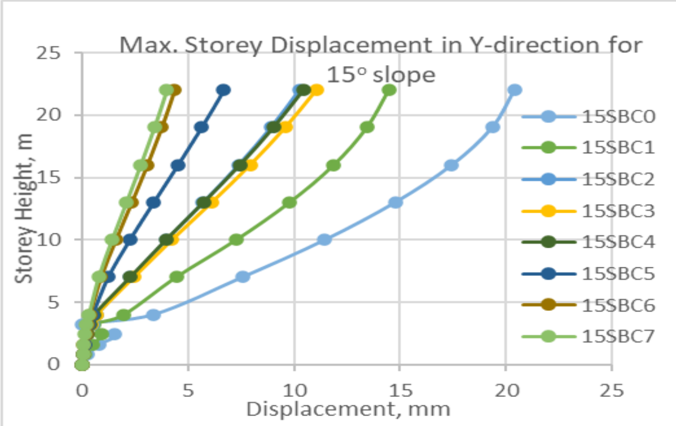

Fig. -2: Max. Storey Displacement in Y-direction for 15^0 slope

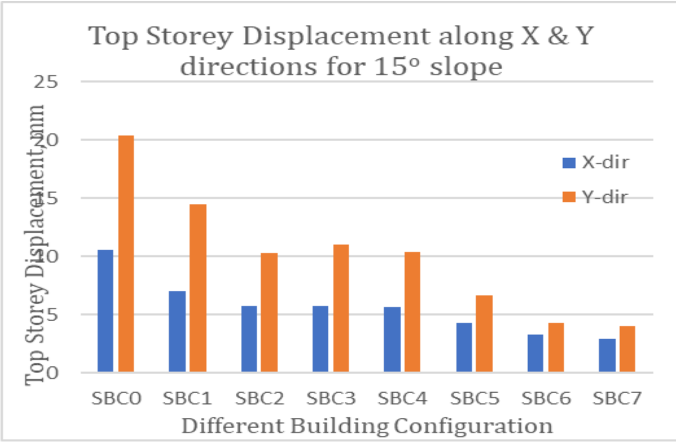

Fig. -3: Top Storey Displacement in X & Y-direction for 15^0 slope

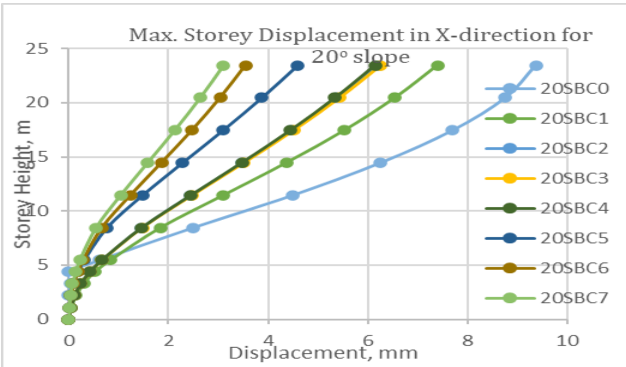

Fig. -4: Max. Storey Displacement in X-direction for 20^0 slope

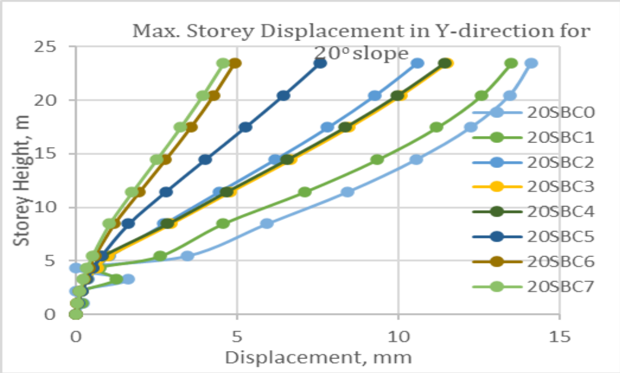

Fig. -5: Max. Storey Displacement in Y-direction for 20^0 slope

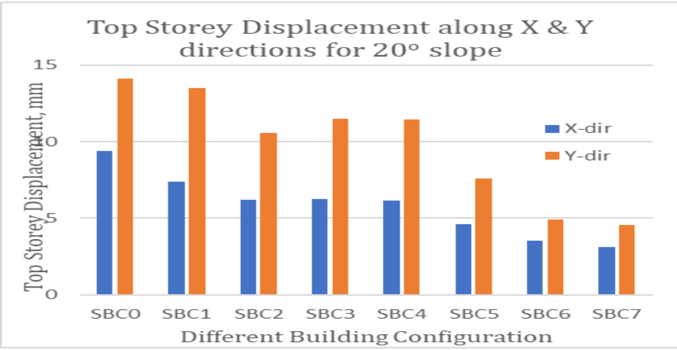

Fig. -6: Top Storey Displacement in X & Y-direction for 20^0 slope

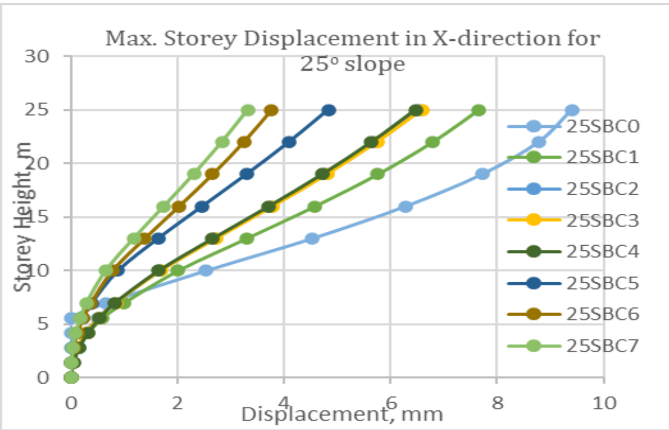

Fig. -7: Max. Storey Displacement in X-direction for 25^0

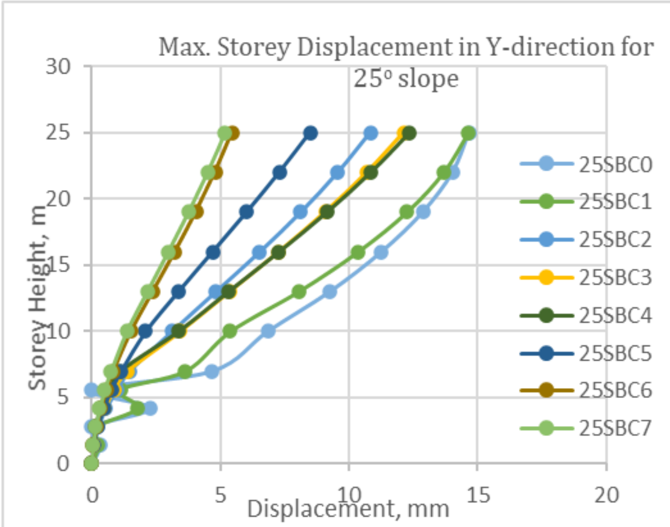

Fig. -8: Max. Storey Displacement in Y-direction for 25^0

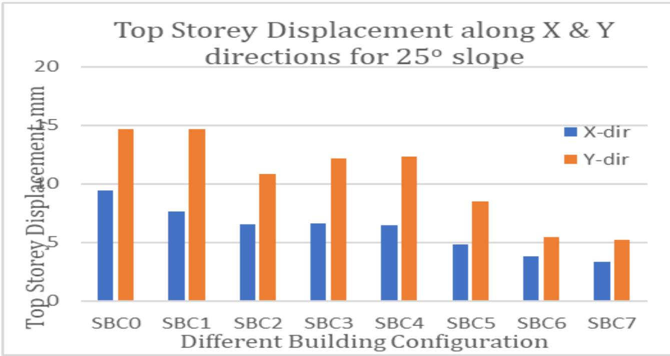

Fig. -9: Top Storey Displacement in X & Y-direction for 25^0 slope

Base Shear Reactions:

From above fig,

- As the Slope of the ground increase, the Base Shear of the building also increases (Fig-10 to 12)
- Base Shear for building without a Shear wall is less compared to that of base shear with a Shear wall, this is due to the introduction of Shear walls.
- With the introduction of Shear wall, the base shear increases (Fig-10 to 12) along both X & Y direction. This is due to increase in the dead weight of the structures.
- Considering a typical case of 20° slope (Fig-11), from SBC0 to SBC7 there is 34.125% & 86.14% increase in base shear along X & Y direction respectively.
- Along X-direction compare to Y-direction, the base shear increases for cases SBC0 to SBC4. this is due to the presence of Shear wall only along X-direction.

- In cases SBC5 to SBC7, the base shear along both the direction remains same as the structure is almost similar in plan along both X & Y direction, i.e., Shear walls are distributed uniformly on all side.
- With increase in slope (from 15º to 25º), the base shear of the structure increases for all cases i.e., SBC0 to SBC7. This is because as the slope of the increases the dead load of building will also increases.

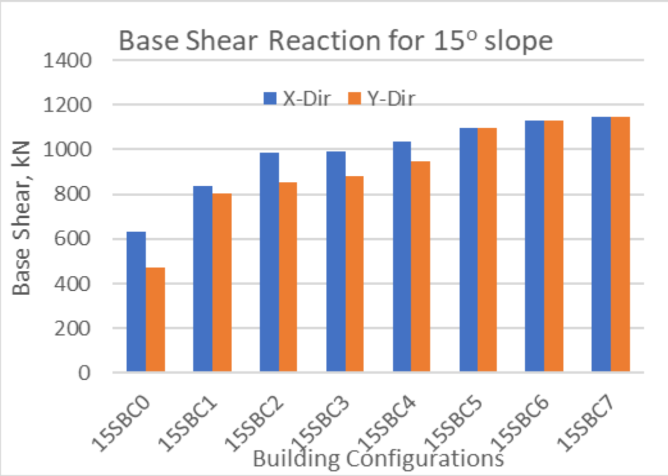

Fig. -10: Base Shear Reaction for 15^0 Slopes

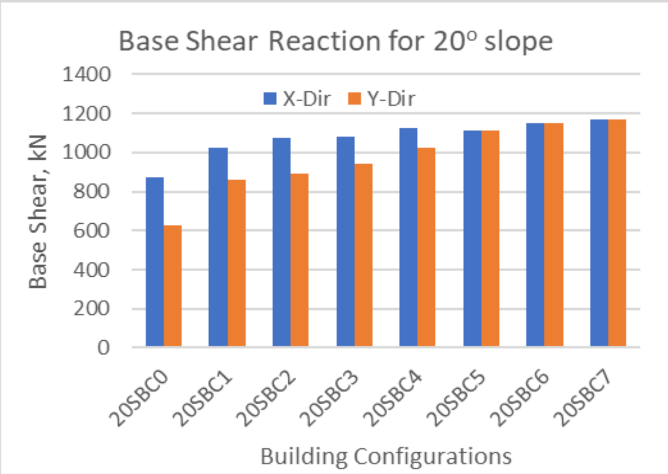

Fig. -11: Base Shear Reaction for 20^0 Slopes

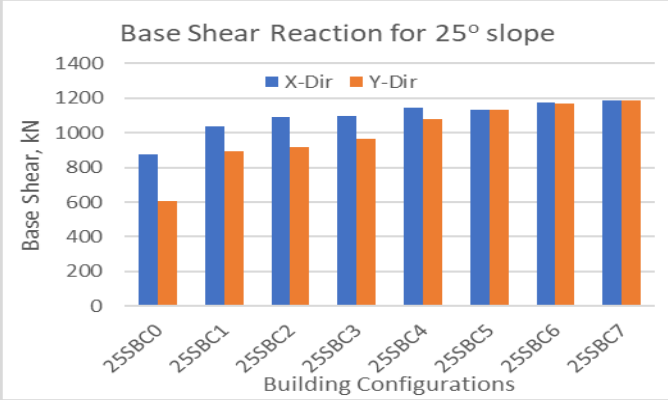

Fig. -12: Base Shear Reaction for 25^0 Slopes

Storey Drift Ratio

- Storey Drift reduces from SBC0 to SBC7
- Storey drift along X-direction is less when compared to Storey drift along Y-direction.
- Storey Drift Ratio for the first floor is very much higher compared to all other floors, this is due to the short column effect below the first floor.
- Storey drift ratios for SBC2, SBC3, and SBC4 have similar values as seen in the graphs above.
- With the introduction of Shear wall, the storey drift ratio drastically reduces particularly in the bottom stories along both X & Y direction.
- It is seen that below 1st story level, the variation in storey drift ratio is very irregular. This is been reduced considerably by introducing the Shear walls.
- However, along Y-direction, the storey drift ratio is very high and variation is highly irregular compare to that of along X -direction from SBC0 to SBC4 (irrespective of inclination of slope of the ground) this may be due to the absence of Shear wall along Y direction in those cases.
- For typical case of ground with 20o slope, the max. storey drift ratio at 1st floor level for SBC1 to SBC4 compared to SBC0 are 73.49%, 58.67%, 59.15% & 41.2% for X direction and 72.32%, 81.25%, 87.5% & 83.93% for Y direction respectively (Fig-15 & 16).
- For cases SBC5 to SBC7, the storey drift ratio considerably decreases and highly irregular variation in storey drift reduces which can seen in from Fig 13 to 18. This may be due to presence of Shear walls on both X & Y directions.

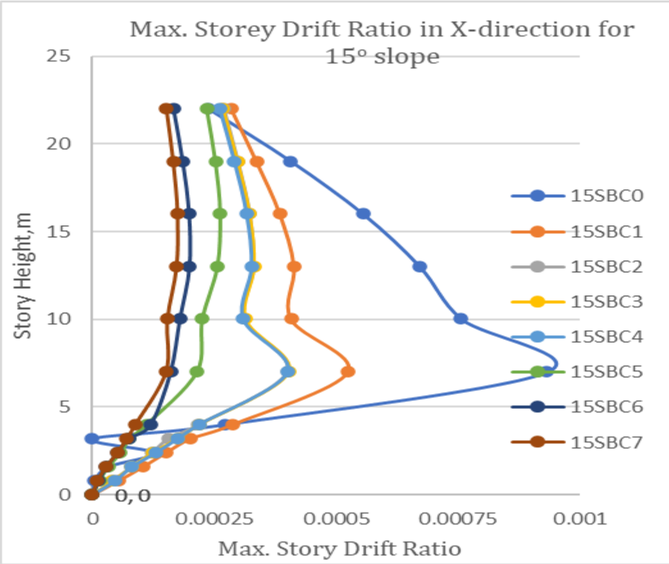

Fig. -13: Max. Storey Drift Ratio in X-direction for 15^0

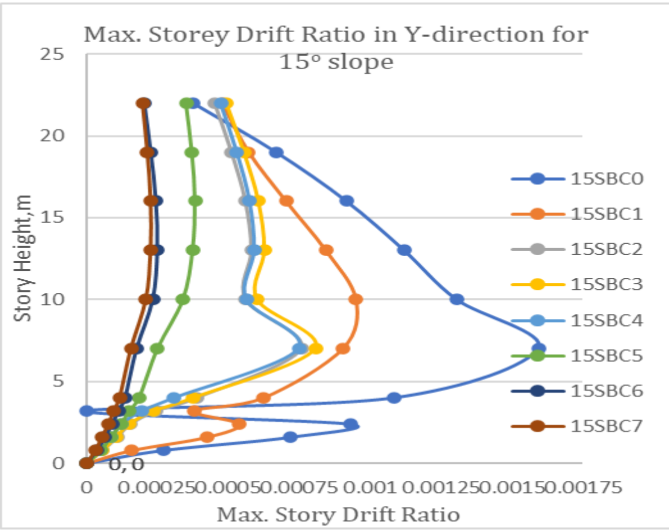

Fig. -14: Max. Storey Drift Ratio in Y-direction for 15^0

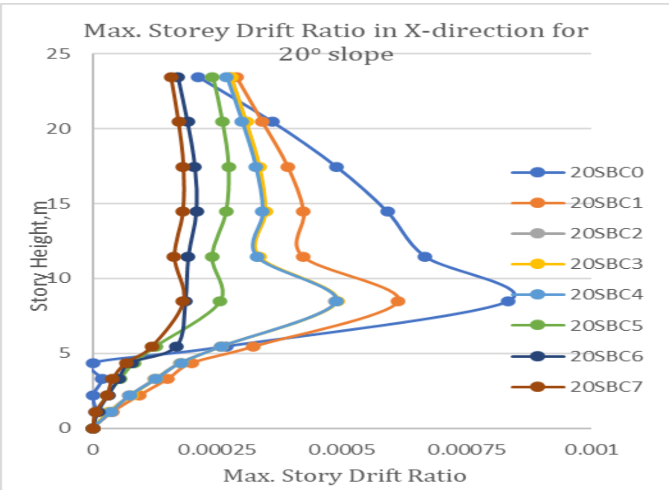

Fig. -15: Max. Storey Drift Ratio in X-direction for 20^0

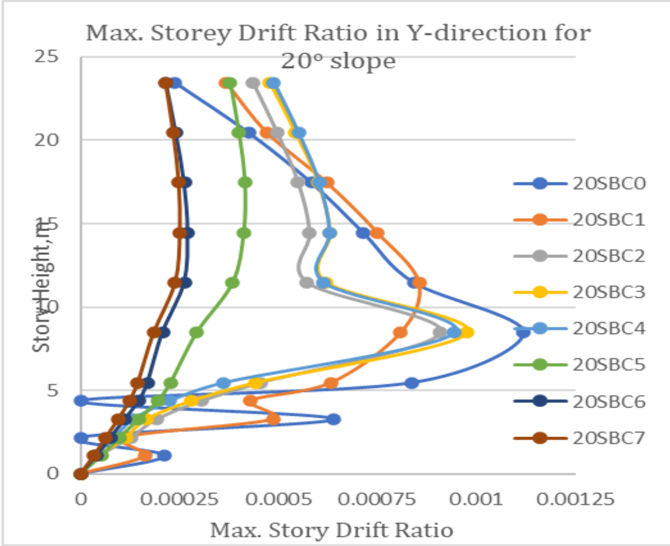

Fig. -16: Max. Storey Drift Ratio in Y-direction for 20^0

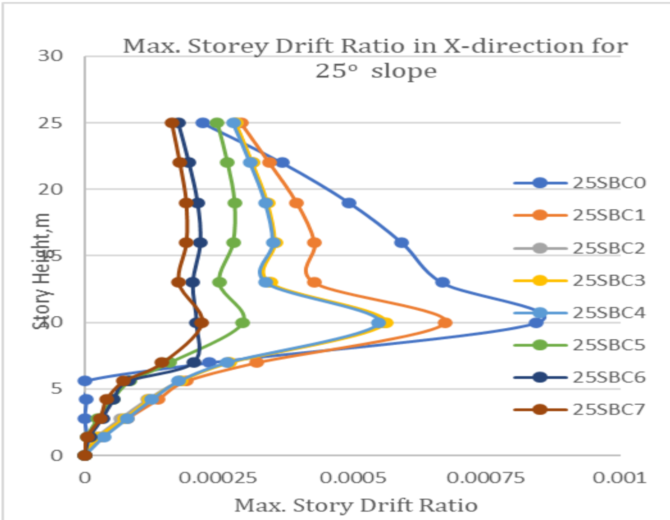

Fig. -17: Max. Storey Drift Ratio in X-direction for 25^0

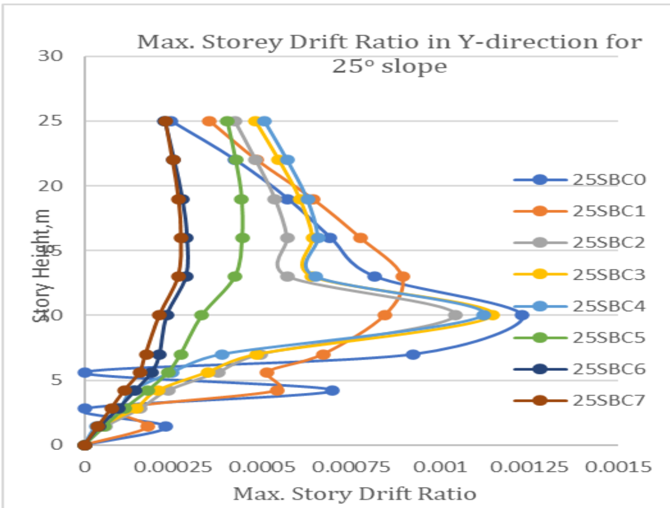

Fig. -18: Max. Storey Drift Ratio in Y-direction for 25^0

5. CONCLUSIONS

- Displacement along Y-direction is more compared to X- direction
- With introduction of Shear walls the performance of the building such as maximum storey displacement, storey drift can be enhanced drastically.
- The position of Shear walls plays a very important role in the reduction of displacement storey drifts etc.,
- By introducing the Shear walls the irregularity in the storey drift ratio can be reduced.
- By increasing the Shear walls, the base shear increases and maximum storey displacement and storey drift ratio reduces.
- When maximum storey displacement is evaluated for different shear wall locations under the same sloping terrain, we come to know that SBC7 has very little displacement compared to the other 7 cases.
- For SBC2, SBC3, and SBC4 in all 3 sloping grounds the displacement values & Storey drift ratios are almost nearer with fewer variations.
- As the Slope of the ground increase, the Base Shear of the building is also increasing.
- Base Shear for building without a Shear wall is less compared to that of base shear with a Shear wall, this is due to the introduction of Shear walls.
- It is also seen that Base shear increases from case 0 to case 7, i.e., SBC0 to SBC7
- From this, we can conclude that case 6 or case 7 i.e., SBC6 or SBC7 is best suited for buildings construction on hilly terrain.

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