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Seismic Analysis of Vertically Irregular RC Building Frame With and Without Shear Wall Using NBC 105:2020

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ABSTRACT- Buildings will always have some kind of irregularity about them. The behaviour of buildings with typical types of irregularities, including vertical and planar ones, has to be examined, especially in the context of earthquakes. The fundamental goal of earthquake engineering is to design and construct a structure in such a manner that the damage to the building and its structural components during an earthquake is minimised by taking the necessary safeguards. Seismic excitations may cause a wide range of damage to buildings. Damages in the system are not uniform nor consistent, even when accounting for the same structural structure, area, and earthquake. A building's seismic behaviour is determined by a number of factors, including the building's structural system, the nature of the earthquake, the building's quality, the soil in its location, and any repairs that have been made. The current research shows how both typical and atypical structures behave. Ten-story buildings are the focus of the current investigation. ETABS-2016 was used to create the building's model. This thesis analyses both regular and irregular schedules. For the sake of analysis, the X and Y axes are subjected to a variety of loads, including dead load, live load, and seismic load. According to NBC 105:2020, a number of load configurations are taken into account. An investigation into the seismic behaviour of buildings with regular and irregular plans is presented in this thesis. The primary goal of this study is to compare the seismic performance of buildings with regular and irregular floor plans. The current research analyses models of RCC buildings with G+9 storeys and both regular and irregular floor plans. Using the ETABS programme, we do a dynamic study of the model. Final comparisons of seismic response findings are made between various time periods; base shear, storey shear, member forces, overturning moments, displacement, stiffness, and drifts.

KEYWORDS- Base Shear; Storey Shear; Seismic Analysis; Storey Drift.

I. INTRODUCTION

The current scenario features a wide variety of abnormal building configurations, both in terms of elevation and plan. Future earthquakes could be devastating, so it's crucial to assess how well buildings can withstand earthquake-related disasters.Buildings will always have imperfections, but understanding how these imperfect structures will respond to an earthquake will allow for better safety measures to be adopted in the future. In order to properly plan for and react to earthquakes, it is crucial to understand the structural behaviour of buildings with irregularities.

It is impossible to completely eliminate imperfections in building construction.A building's ability to withstand an earthquake depends on its four main characteristics: a regular and simple layout, sufficient lateral strength and stiffness, and sufficient ductility. Buildings with simple regular geometry and consistently distributed mass and stiffness in plan as well as elevation, incur far less damage than buildings with irregular layout.

A regular building is building which performs against the earthquake. The minimum lateral strength and stiffness of the structure, as well as its straightforward, regular configuration, are required features of this building. Setback buildings are a subset of vertically irregular structures when there are discontinuities with regard to geometry. Structural analysis is the process of determining how a structure will react to a given load or set of loads. Irregularities are not avoidable in construction of Buildings. However, the behaviour of buildings with these abnormalities during earthquake has to be explored. The primary goal of Earthquake Engineering is to minimise the destruction of a building and its components during an earthquake through careful planning and construction.

Structures often use shear walls to effectively withstand lateral stresses and to actively contribute to transporting gravity loads. Commonly, they are shown as vertical plates that are anchored at the base and are only meant to withstand horizontal and vertical forces acting in the same plane. Shear walls, however, may take on a more complicated form, depending on the building's specific architectural and structural architecture. Walls may be cast between two columns to create I or dumbbell forms, or they may be made of a central core to create boxes. In earthquake-prone locations, shear walls also need to be ductile in addition to being strong and stiff. Depending on the ratio of moment to shear at each horizontal cross section of the wall, the behaviour can be controlled by shear or flexure.

II. OBJECTIVES OF THE STUDY

The primary goal of this research is to use the new Nepali building code to conduct static and dynamic analyses of multi-story R.C. building models with variations in elevation, with and without shear walls (NBC:105:2020). The purposes of the research include the following:
For use in an ETABS model of a nine-story structure with varying floor heights (G), shear walls are optional.

- Analysis of an irregular building subjected to seismic loads in accordance with NBC 105:2020
- with the intention of contrasting the structure's analytical characteristics before and after the installation of a shear wall.
- for the purpose of evaluating the seismic performance of buildings in accordance with NBC 105:2020.
- In order to examine the differences between the behavior of building with and without the shear wall, we will be comparing characteristics such as storey drifts, displacements, and base shear.

III. LITERATURE REVIEW

Acc. To Sameer Pardeshi et al. [1] - Regular, L-shaped, T-shaped, and plus-shaped models were used in their analysis of the structure based on the method of time series. During the seismic analysis, shear force was determined to be greatest on the ground floor of the building. as opposed to the little displacement shown in the T-shape.

Professor Vedantee Prasad Shukla and colleagues [2] - Analysis is performed using the Response Spectrum Method, and results are shown as storey displacement, storey drift, base shear, and time period for both regular and irregular buildings in different earthquake zones where the slope is more than 3 degrees. The normal building time period exceeds the irregular building time period. Temblors and tremors are caused by earthquakes. It was decided to use the "Push over" approach to analysis. The Base Shear and Roof Displacement Results show that the base shear of regular structures is bigger than that of irregular structures.

S. Mahesh and Others Like Him [3] - Using STADD PRO, researchers compared the analysis and design of multi-story buildings with regular and irregular configurations in different seismic zones, finding that drift is mild in regular buildings in Seismic Zone 4.

Acc to Dr.S.K.Dubey & P.D.Sangamnerkar [4] - The authors of the paper "Seismic Behavior of Asymmetric R.C. Structures" used STAADPRO to model and evaluate a framed building with five stories. It is thought that the structure houses some kind of business. The building has an open ground level with a "T" geometry and parking spaces. They did the analysis for Zone IV. 2016's Abhay Guleria: Analysis of multi-story RCC buildings with varying floor plans was presented. The earthquake loads analysed by this method have been shown to be effective. The lateral load specifications of IS 1893 (Part 1)2002 were used as the reference. Finite-element software was used for the modelling and analysis. ETABS What's more, the results of this research indicate that L-and I-shaped structures react similarly to overturning moments, tale drift, and story displacement.

Sanhik Kar Majumder and Priyabrata Guha [5] – They compared the impact of wind and seismic stress on various building types. This research will compare the standards for seismic and wind resistance found in IS 875(Part 3)1987 with IS 1893(Part 1)2002 for a location with medium soil. They came to the conclusion that irregularly shaped buildings are more likely to be severely damaged or even fall down completely in an earthquake, and that torsion is the most important factor in this regard.

Acc to G. Magliulo, G. Madaloni, and C. Petrone [6] - Three multi-story R.C. buildings were utilised to evaluate the "Influence of Earthquake Direction on the Seismic Response of Irregular Plan R.C. Frame Structures." This structural topology is quite popular in Italy. There is a rectangular building, an L-shaped structure, and a rectangular building with a court yard.

Shreyasvi.C and B.Shivakumaraswamy [7] – They evaluated the behaviour of regular and re-entrant structures in different seismic zones via the use of STAAD Pro in their modelling and analysis of (G+5) structures. It was ETABS that was used to carry out the response spectrum approach and the time history method. The time history technique relied on seismic accelerationograms from the Bhuj and Elecentro quakes. Displacements between floors, times between shakings, and shears between floors were examined for both the regular and irregular models. Uneven structures were more likely to experience drift and vertical displacement.

Shaikh and Deshmukh [8] - Both analysed the G+10 building's vertical irregularity using linear static and dynamic analysis in accordance with IS 1893:2002 (part I). A basic lump mass model was used to represent the structure, and the building's stiffness was found to be uneven at the fourth storey. The building's reaction characteristics were analysed, including drift, deflection, and shear at different stories. The results show that flaws in the building's rigidity make it structurally unstable and cause a lot of story shear.

Mahesh and Rao [9] – They shows the effects of seismic shaking on G+11 apartment buildings and how regular and irregular buildings fared were investigated. They took into account the varying seismic activity in the area and the hardness, medium, and softness of the soil. ETABS and STAAD PRO were used for the analysis.

Acc. to Gagandeep and Banga [10] - RSA and THA were used on vertically asymmetric RC frame constructions. During the Seismic Analysis of Vertical Irregular RC Building with Stiffness and Setback Irregularities, they thought about the building's mass, stiffness, and vertical geometric irregularities. They discovered that the base shear of massive irregular buildings is greater than that of comparable regular structures. Less base shear was felt and bigger inter-story drifts were seen in the structure with higher stiffness irregularity.

In addition, Raheem and Rana [11] – They examined how well vertical geometrically uneven RC frame systems withstood seismic activity. One typical frame and four nonstandard ones were studied side by side. Shear force, bending moment, storey drift, and storey displacement, among other earthquake reactions, were measured. In the end, the shear force of regular building frames is much lower than that of irregular building frames that are set back in an asymmetrical way.

IV. METHODOLOGY

Here, Using ETABS, a 10-story structure with both normal and irregular floor plans was designed for the research. The floor plans for the models are 9 by 11.3 metres. The standard model takes a story height of 3.175 m. In both the X and Y axes, you'll find a variety of storage compartments. The footing depth is measured to be 1.6 metres. In these representations, beam and column sizes are assumed to remain constant throughout all levels.

In this study following models are prepared for the study:

Model 1- Building with Regular shape
Model 2- Building with irregular shape.

a) Loads

Dead loads

Brick masonry : Unit Weight 19.2KN/m3
Finishes (Floor Finishes) : 1 KN/m2
Reinforced Concrete Elements: Unit Weight 25KN/m3
Live load: 3 KN/m2 on all floors except roof
Lateral Loads : Earthquake Loads as per NBC: 105:2020

b) Lateral load

Time periods of the modes are computed using ETABS 2016 software, and lateral forces are estimated using the equivalent static technique at each storey level in accordance with NBC: 105:2020. The lateral forces in the buildings were determined by taking into account the following factors.

Zone factor (Z) = 0.3
Importance factor (I) = 1
Response Reduction Factor (R) = 5(SMRF)
Soil Type = C

Load Combination considered in the analysis are mentioned above and for Dynamic Analysis addition combination is considered.
For Regular
DL+0.3LL+REX
DL+0.3LL+REY
For Irregular
DL+0.3LL+REX +0.3REY
DL+0.3LL+REY+0.3REX

c) Material properties

Concrete grade : M25 for beam and Slab
M25for Column Steel grade : Fe 500
Modulus of Elasticity of concrete (Ec): 5000√fck N/mm2
Modulus of Elasticity of Steel (Es) : 2x105 N/mm2

d) Element dimensions

"A 150mm thick slab is considered for all building models .Exterior wall thickness is taken as 250mm and interior wall thickness as 125 mm and all beams were taken as model 1:-355.6mm x 609.6mm model2:-355.5x609.6mm."
Seismic Load Calculation

e) Coefficient Calculation:

"Based on NBC 105 2020, Designing buildings to withstand earthquakes requires the use of the seismic coefficient technique for calculating earthquake loads."
The design horizontal seismic coefficient,

$$Cd(Ti) = \frac{C(Ti)}{R_\mu x \Omega_u}$$

Where,

C(Ti) = Elastic Site Spectra at period (Ti)
Rμ = Ductility Factor
Ωu = Over Strength Factor

It is possible to use an empirical equation to get a ballpark figure for the basic natural interval of oscillation (Ti) in seconds of moment-resisting frame structures with brick infill panels.:
Ti = 0.075*h0.75
Where,
h = Height of building in meters
Ta = 0.075*h0.75
= 0.075*34.9250.75
=1.07 sec
Time period shall be increased by 1.25.
T=1.07*1.25=1.346sec
I = 1 (for Residential building)
Z = 0.3

$$Cd(Ti) = \frac{C(Ti)}{R_\mu x \Omega_u} = \frac{0.75}{1.5x4} = 0.125$$

VB = Cd(Ti) x W
(Cs(T)=0.2*Ch(T)=0.2*0.75=0.15

$$Cd(Ti) = \frac{Cs(T)}{\Omega_s} = 0.15/1.25 = 0.12$$

$$VB = \frac{C(Ti)}{R_\mu x \Omega_u} xW$$

$T = 0.075h^{\frac{3}{4}}$ For RCC frame building

Where,
VB = Base shear
Cd(Ti) = Design horizontal acc. spectrum
Z = Zone Factor
I = Importance Factor
C(Ti) = Elastic Site Spectra at period (Ti)
Rμ = Ductility Factor
W = Seismic Weight of building
Ti = Fundamental time period of ith mode of vibration
Ωu = Over Strength Factor
h = Height of Building in m
d = Base Dimension at Plinth level

Model description

Here, figure 1 shows the plan of building for without shear wall, figure 2 shows plan of building for with shear wall,

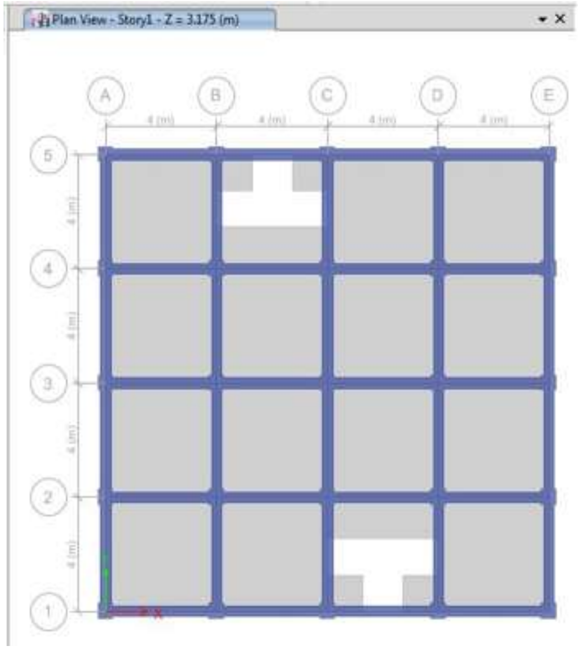

Figure 1: Plan of building for without shear wall

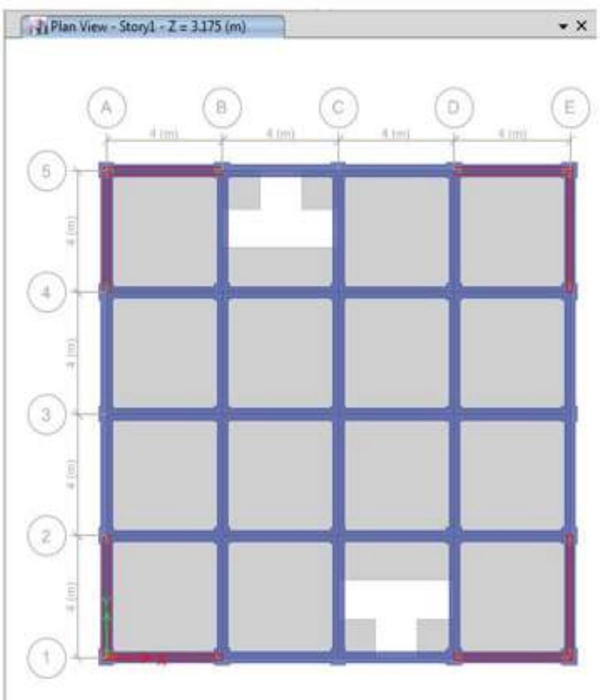

Figure 2: Plan of building for with shear wall

Here figure 3 represents the 3D view of building without shear wall, figure 4 shows the 3D view of the building with shear wall.

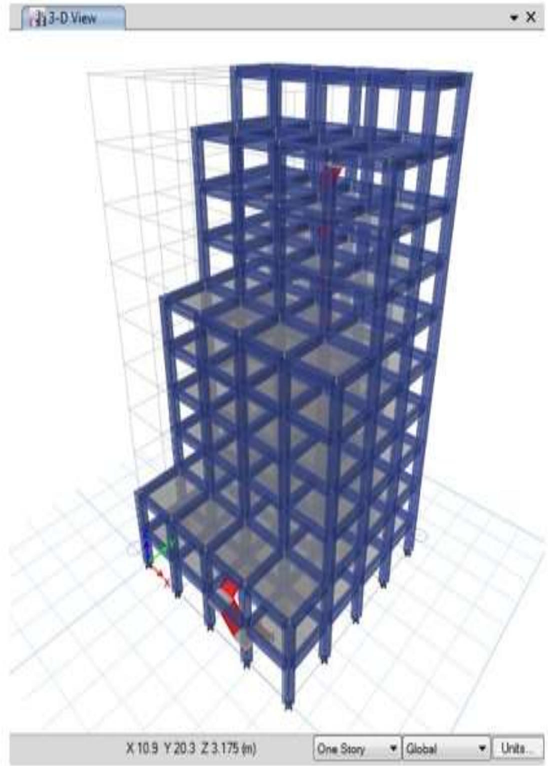

Figure 3: 3D view of the building without shear wall

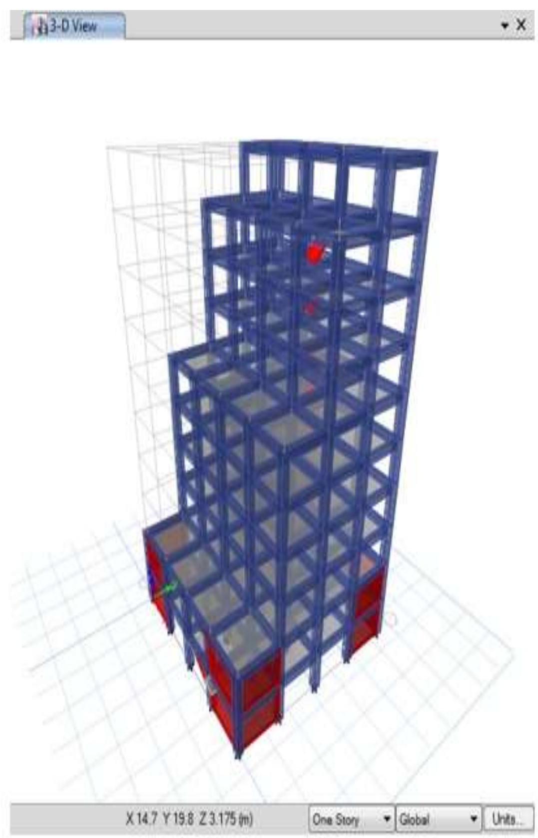

Figure 4: 3D view of the building with shear wall

Here figure 5 represents the elevation view for without shear wall, and figure 6 represents the elevation view for with shear wall.

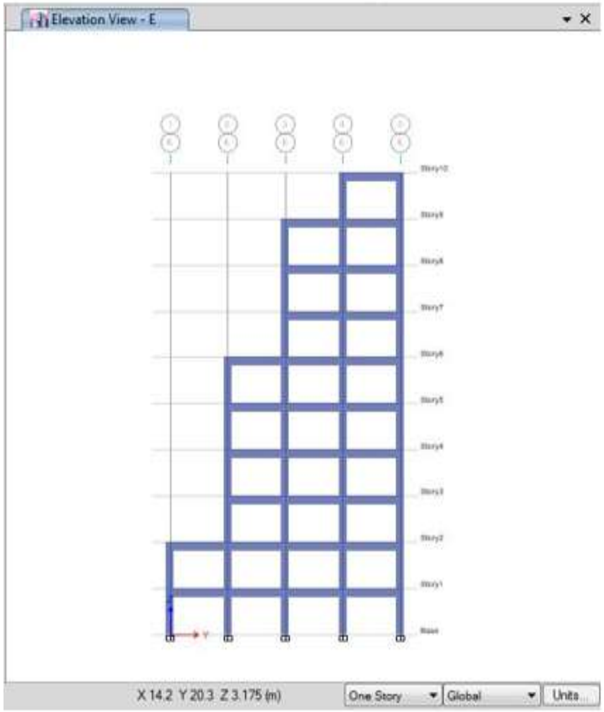

Figure 5: Elevation view of without shear wall

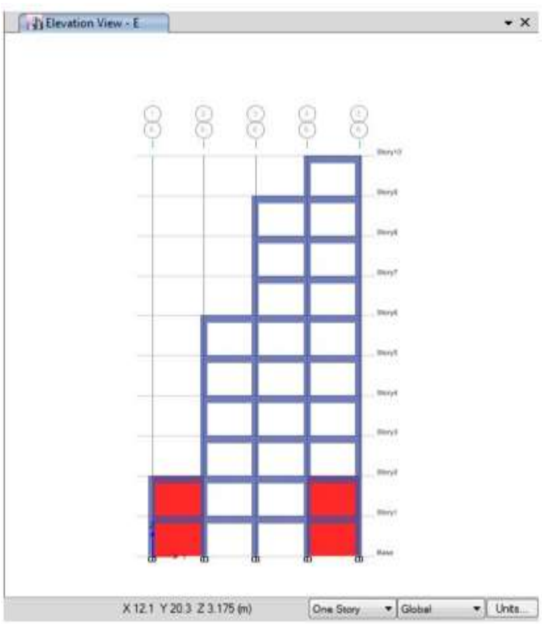

Figure 6: Elevation view of with shear wall

V. EXPERIMENTAL RESULTS

A. Displacements

The variation of displacement of different stories for all models when a response spectrum is along longitudinal direction is show in the Table 1.

Table 1: Displacements of models along longitudinal direction

	Displacement in mm	
Storey Level	Model 1	Model 2
10	61.002	69.869
9	59.041	66.886
8	55.886	62.079
7	51.263	54.983
6	45.43	45.964
5	38.799	35.584
4	31.281	23.824
3	23.125	11.409
2	14.634	1.623
1	6.239	0.599
0	0	0

figure 7 represents the Displacement of model along longitudinal direction, figure 8 represents the Displacement of model along transverse direction , figure 9 represents the Comparison of maximum Drift of each Models,

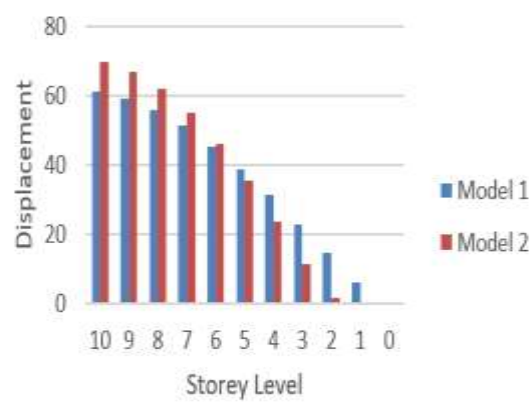

Figure 7: Displacement of model along longitudinal direction

Table 2: Displacement of model along transverse direction

	Displacement in mm	
Storey Level	Model 1	Model 2
10	68.051	85.72
9	64.86	80.917
8	60.377	73.924
7	53.867	63.773
6	46.231	51.847
5	38.986	40.025
4	30.634	26.526
3	21.529	12.312
2	12.541	1.492
1	5.268	0.541
0	0	0

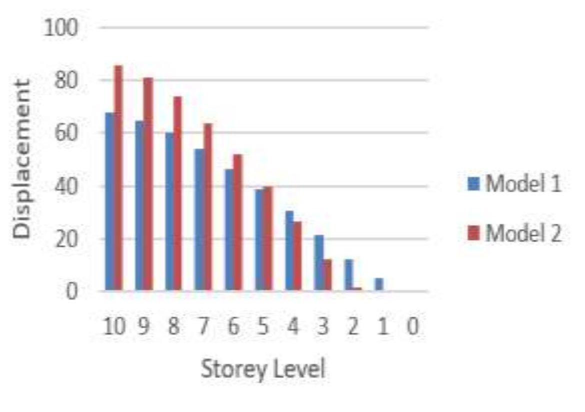

Figure 8: Displacement of model along transverse direction

B. Drift

The values of drift of different stories for all models when a response spectrum is along longitudinal direction are show in the Table 3

Table 3: Comparison of maximum Drift of each Models

Models	Drift	
	EQX(ULS)	EQY(ULS)
Model 1	0.002674	0.002868
Model 2	0.00391	0.004477

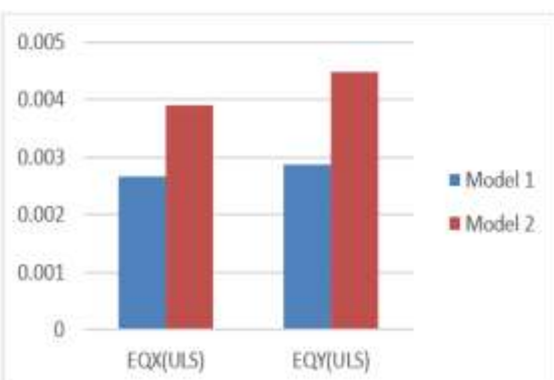

Figure 9: Comparison of maximum Drift of each Models

C. Storey shear

The values of maximum storey shear of each models when a response spectrum is along longitudinal direction and transverse direction are show in the Table 4.

Table 4: Comparison of maximum Storey shear of each models

Models	Storey shear in kN	
	Rx	Ry
Model 1	-3323.1945	-3323.1945
Model 2	-3436.4413	-3436.4413

From Figure it is observed that when a response spectrum is along longitudinal direction the values of storey shear get reduced when special shape column is used. The value of storey shear is more when a response spectrum is along transverse directions. The value of storey shear also get reduced in transverse direction case when model 2 compare to model 1, figure 10 represents the Comparison of maximum Storey shear of each models.

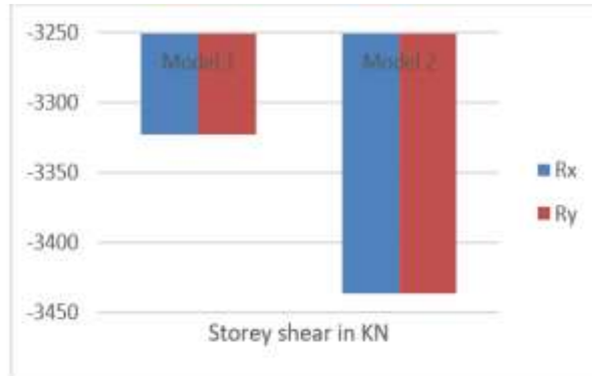

Figure 10: Comparison of maximum Storey shear of each models

D. Overturning Moments

The comparison of maximum overturning moment each model of different stories are show in the Table 5.

Table 5.Maximum Overturning moment of each models

Figure 11 shows that compared to model 1, the overturning moment in the model 2 is larger in both the longitudinal and transverse directions. Here figure 11 represents the maximum overturning moment of each models and figure 12 represents the base shear of each models.

So, in a structure on a hill slope with both a step back and a step-set back arrangement, the overturning moment is lowered when a special shape column is employed instead of a conventional (square) form column.

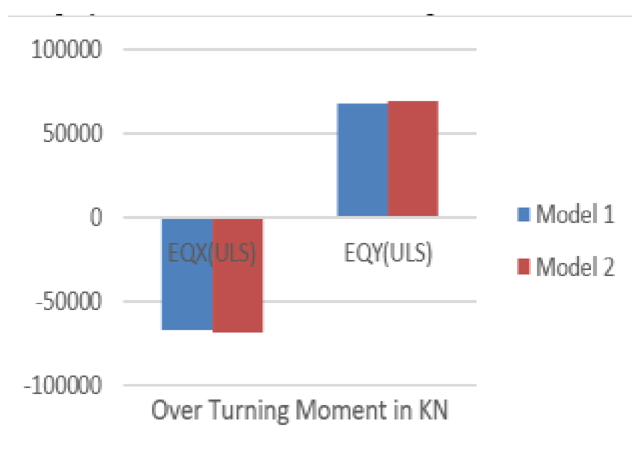

Figure 11: Maximum Overturning moment of each models

E. Base shear

Comparison of base shear for each model is shown in Table 6.

Table 6: Base shear of models

Models	Base shear in kN	
	EQX(ULS)	EQY(ULS)
Model 1	-3323.1945	-3323.1945
Model 2	-3436.4413	-3436.4413

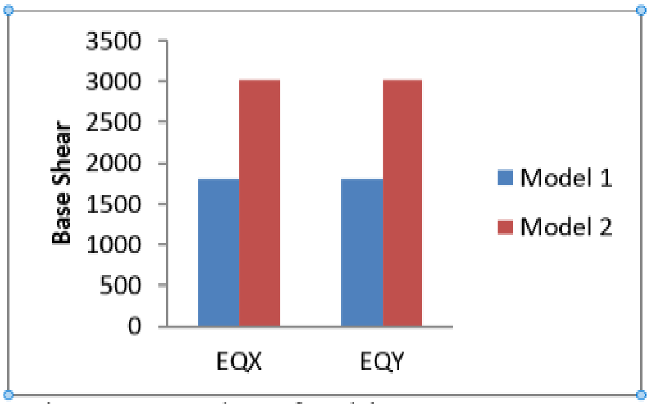

Figure 12: Base shear of models

VI. CONCLUSIONS

The following conclusions were made from the analysis:
Ten-story buildings with shear walls experience less movement than those without them.

- A shear wall may reduce the displacement of a 10-story structure by as much as 78%.
- A shear wall may reduce the storey drift of a structure by a significant amount. The case construction with the shear wall has a drift reduction of 19.35%.
- By comparison, the storey shear of non-shear-walled buildings is shown to be 9.21% lower than that of shear-walled structures.
- Shear walls reduce the basic construction time of a structure relative to those without them.
- When a shear wall is included in a model, the base shear is higher than it would be without one.
- The shear wall increases the overturning moment by 23% compared to a structure without a shear wall.

A building with shear walls is more rigid because of this.In light of the above, it may be deduced that a building with a shear wall has greater seismic performance than a one without one. Buildings with shear walls are better suited to earthquake zones because they lower basic time period, axial pressures, torsion in columns, storey shear, and floor displacement.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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