# SEISMIC BEHAVIOUR OF RC BUILDINGS IN SLOPING GROUND

**Er. Prakash Regmi*; Prof. Dr. Govind Prasad Lamichhane****

*Graduate School of Engineering,
Mid West University
Surkhet, NEPAL
Email id: prakashregmi668@gmail.com

***School of Engineering,*
*Pokhara University* Kaski, NEPAL
Email id: govindkhec@gmail.com

**DOI: 10.5958/2278-4853.2023.00041.1**

**ABSTRACT**

*This thesis is the study of seismic behavior of RC building in hilly areas i.e sloping grounds. The study of dynamic response of structure on hilly areas has been done. Two combo building ( half of building lies in sloping ground anf half portion lies on plain ground) are considered for analysis on sloping ground of uneven slope without changing existing ground profile with considering and without considering shear wall. All considered configuration of building is modeled using ETABS v20.0.0 and IS 1893:2016 and analysed by using equivalent static analysis and response spectrum methods. Then considered buildings has been compared in terms of base shear, Fundamental time period and top storey displacement, Storey stiffness, Storey drift and overturning moments.*

**KEYWORDS:** *Combo Building, Storey Displacement, Storey Drift, Storey Stiffness, Overturning Moments.*

## 1. INTRODUCTION

### 1.1 Background

The Federal Democratic Republic of Nepal lies in one of the active continental collision zone of the world, the Himalaya, where the probability of Earthquake occurrence is very high. Many destructive Earthquakes have been reported in the historical records within the Himalayan arc. Out of which the 1934 Bihar-Nepal Earthquake and 2015 Gorkha Earthquake Mw 7.6 (Mw 7.8) occurred in the Nepal Himalaya (NEMRC, 2023).

Due to lack of plain areas in hilly areas steep ground adds additional challenges to seismic analysis of RC building because it may affect the stability and performance of the building during seismic activities. Due to steep nature of ground building are irregular and unsymmetrical in horizontal and vertical planes.

After the federalism in the country economic activities and rapid urbanization in hilly area has been increased. . So after the federalism, demand and necessity of construction of multi storey building in hilly areas has been increased. These needs and demands should be addressed with the proper study of seismic behavior of RC building in sloping areas.

**1.2 Objective of Study**

To evaluate seismic response (Fundamental time period, Base shear, Top storey displacement,

Storey drift, Storey Stiffness and Overturning Moments) of various RC buildings on uneven slope without changing it's existing ground profile by seismic coefficient method and response spectrum method.

**1.3 Scope and limitation of study**

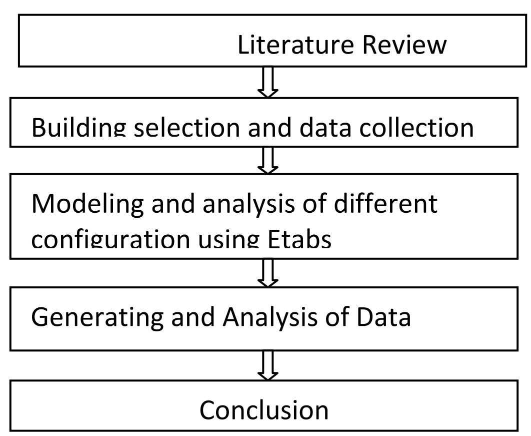
Two combo buildings of 4 storey on sloping ground of uneven slope without changing it's existing ground profile are analysed, one is building without shear wall and another is with shear wall. Equivalent static and response spectrum analysis are carried out to find the response of considered building in the form of Base shear, Fundamental Time Period, Top Storey Displacement, Storey Drift, Storey Stiffness, Overturning Moments and comparison is done. Finally Building configuration suitable in sloping ground of uneven slope is suggested based on finding of work.

This study does not consider the effects of other natural hazards such as floods, landslides etc. This work does not include detail study about effect of SSI on seismic performance of considered building.

**2. Research Methodology**

**2.1 Conceptual Framework of Research Design**

For seismic analysis of all considered building in ground of uneven slope without changing its existing ground profile, it is required assess all the point of the study area based on the set of selected criteria .overall methodology is shown in flowchart.

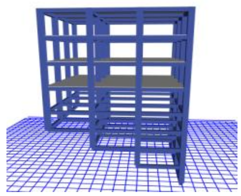
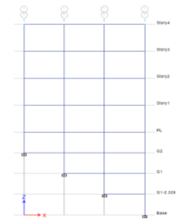



**Building Frames**

**Step back (SB) frames**

In this building configuration horizontal plane remains same but on the lower part it will maintain slope as per terrain or topography of the area. In these types of buildings the foundation of different grid columns are at different level.

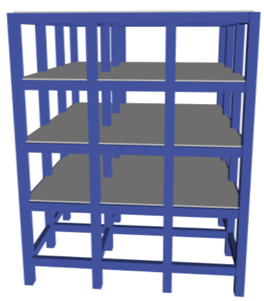
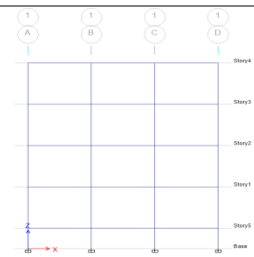
**TABLE 1 3D FRAME AND ELEVATION OF STEP BACK BUILDING**

| 3D Frame | Elevation |
|---|---|
|  |  |

**Building on plain land:**

This types of building is normally constructed on plain land. They are regular structure with symmetry in both x and y direction.

**TABLE 2 3D FREAME AND ELEVATION OF BUILDING ON PLAIN LAND**

| 3D Frame | Elevation |
|---|---|
|  |  |

**Combo Building in Uneven Slope**

This is the combination of step back building in slope and normal building in plain areas. It considered all factor considered on both step back building in slope and normal building in plain. In this building configuration half of the structure is arranged in stepping pattern in slope and half is like normal building in plain areas so the horizontal plane is not remains same along with lower part of the structure. In these type of structure the foundation level of different grids columns are at different level in sloping region but in plain region foundation level are at same level.

**TABLE 3 3D FRAME AND ELEVATION OF COMBO BUILDING**

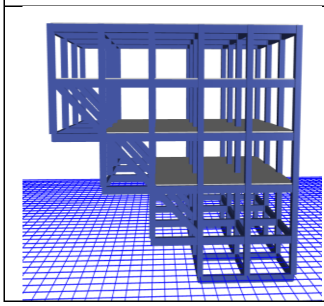
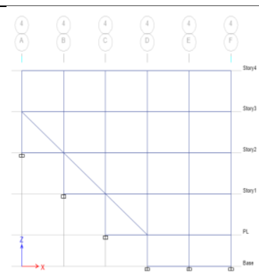
| 3D Frame | Elevation |
|---|---|
|  |  |

**TABLE 4 3D FRAME AND ELEVATION OF BUILDING WITH SHEAR**

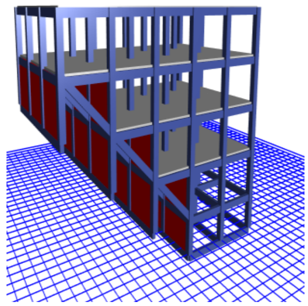
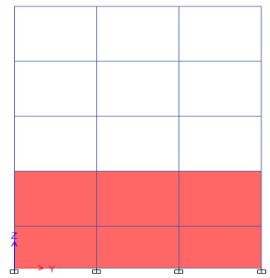
| 3D Frame | Elevation |
|---|---|
|  |  |

**TABLE 5 SIZES OF BEAM AND COLUM**

| Building Types | Column size | Beam size |
|---|---|---|
| All | 500*500 mm | 300*450 mm |

**TABLE 6 SPECIFICATION OF BUILDING**

| | |
|---|---|
| Seismic zone | V |
| Zone factor | 0.36 |
| Response reduction factor | 5 |
| All general buildings | 1.5 |
| Damping ratio | 5% |
| Structure type | RC frame building |
| Soil type –medium | II |
| Concrete grade | M20 |
| Steel grade | Fe500 |
| Floor height | 3 m |
| Depth of Foundation | m |

### 2.2 Data Analysis Procedure

For the analysis of data, Analysis methods are widely characterized as linear and nonlinear, static and dynamic. Data analysis procedures adopted in research work are as follow:

1. Linear static Analysis (Equivalent Static Analysis)
2. Linear Dynamic Analysis (Response Spectrum Analysis)

IS 1893 (part 1) : 2016 is used for analysis of building by above mentioned methods.

### 2.3 Load C0mbination

Load Combinations are taken as per IS 1893:2016 code and are as follows:

1. 1.5( DL+LL)
2. 1.2( DL+LL±EL)
3. 1.5( DL±EL)
4. 0.9DL± 1.5EL
5. $\pm EL_x \pm 0.3\ EL_y \pm 0.3\ EL_Z$
6. $\pm 0.3\ EL_x \pm EL_y \pm 0.3\ EL_Z$
7. $\pm 0.3\ EL_x \pm 0.3\ EL_y \pm EL_Z$

## 3. Results and Discussions

For analysis of all considered building seismic load is considered along with accidental eccentricity. Data of combo building in uneven slope without changing it's existing ground profile with and without considering shear wall on building are presented and interpretation of data is done simultaneously.

### 3.1 Base shear

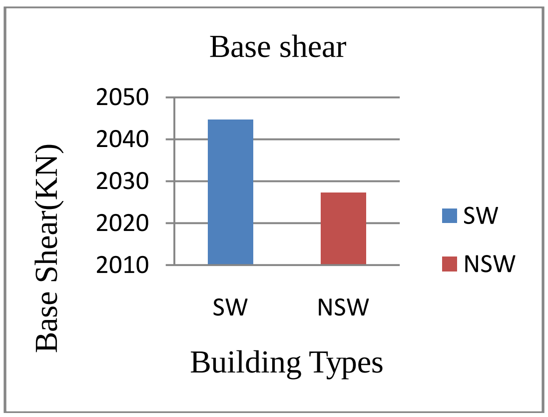



**Figure 1 Base Shear of Buildings**

From the chart we can see that addition of shear wall on building increase the value of base shear by 17.36

KN. This is due to load of shear wall greater than wall load.

### 3.2 Time Period

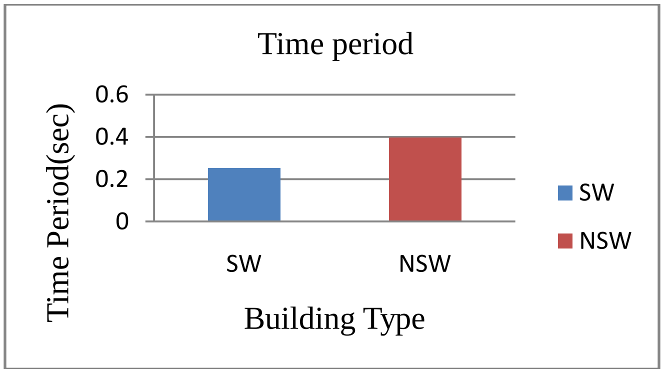



**Figure 2 Time Period Of Buildings**

From the Chart, Fundamental time period of building with provision of shear wall decrease by 36.20 %. It is due to rigidity provided by shear wall on building.

### 3.3 Storey Drift

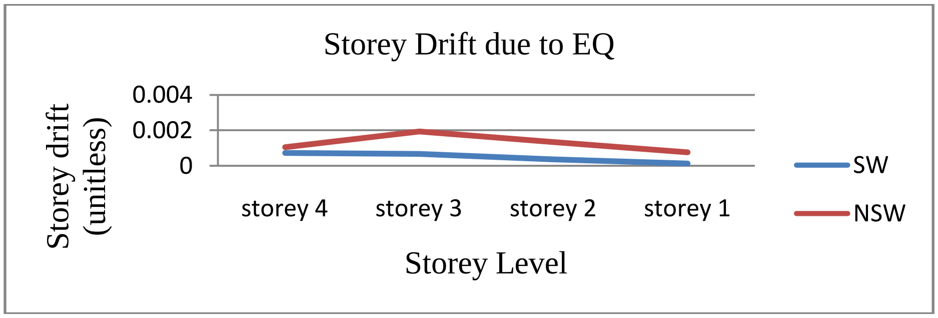



**Figure 3 Storey Drift in building due to earthquake**

From above graph it is seen that storey drift decreases with addition of shear wall on building. Average storey drift decrease by 30.29%, 64.76%, 71.64% and 81.75% in step 4, step 3, step 2 and step 1 respectively after the provision of shear wall. This is due to rigidity provided by shear wall.

### 3.4 Storey Stiffness

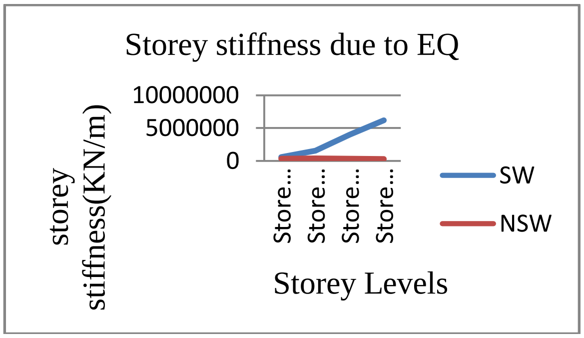



**Figure 4 Storey Stiffness of Buildings**

From the figure given above, we can see that storey stiffness increase in building after addition of shear wall on building. Lower storey shows high degree of stiffness than upper stories.

**3.3 Storey Stiffness**

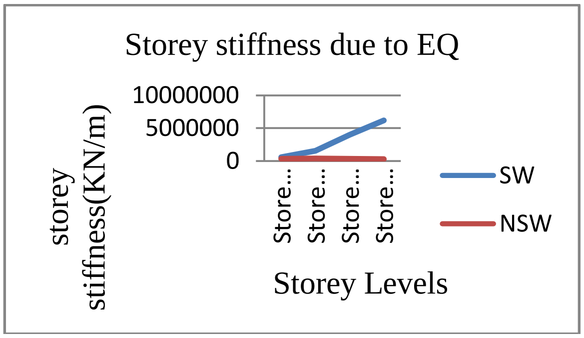



**Figure 5 Storey Stiffness of Buildings**

From the figure given above, we can see that storey stiffness increase in building after addition of shear wall on building. Lower storey shows high degree of stiffness than upper stories.

**3.4 Top storey Displacement**

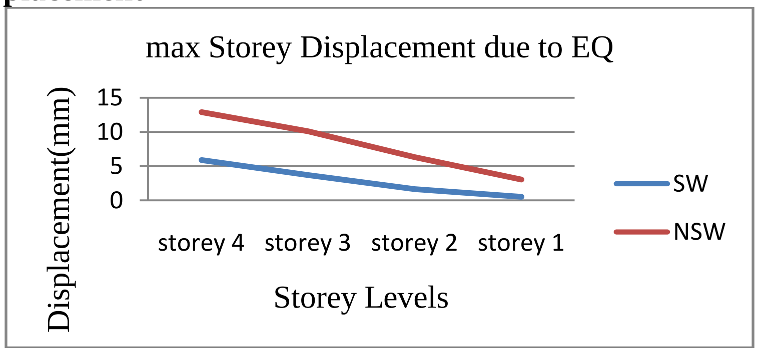



**Figure 6 Top Storey Displacement in Buildings**

From above figure, we can see that top storey displacement decreases after addition of shear wall. Here top stories decrease by 54%, 63.65%, 73.99% and 83.30% respectively in step 4, step3, and step 2and step 1 respectively.

**3.5 Overturning Moments**

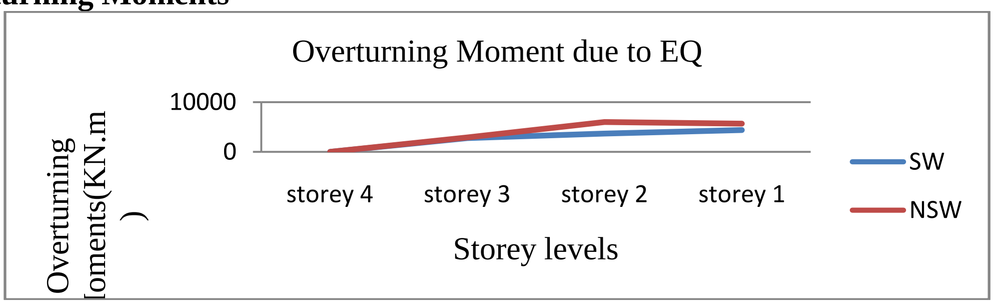



**Figure 7 Overturning Moments in Buildings**

From above figure, we can see that overturning moments reduces by addition of shear wall in building. The average reduction on overturning moments in building after addition of shear wall is 21.12%.

**4. Conclusions and Recommendations**

From above study following conclusion are made:

- On analyzing base shear, it can be concluded that addition of shear wall increase the base shear of building.
- On analyzing time period of buildings, time period for building with shear wall decrease than building without shear wall.
- On analyzing Storey drift of buildings, it is concluded that provision of shear wall reduces the storey drift in buildings.
- On analyzing storey stiffness of buildings, it is concluded that Storey stiffness of building increase greatly with provision of shear wall on building.
- On analyzing top storey displacement of buildings, it is concluded that top storey displacement of building with shear wall is less than building without shear wall.
- On analyzing overturning moments of buildings, it is concluded that overturning moments for building with shear wall is less than building without shear wall.
- Hence, building with shear wall is favored in sloping ground of uneven slope without changing its existing ground profile.
- In this study the buildings are analysed with linear static and linear dynamic analysis only, it is recommended to analysed buildings with non- linear dynamic analysis. Also it is recommended to consider natural hazards like landslides, flood etc.

**REFERENCES**

**1.** A. S. Swathi, G.V. Rama Rao, R. A. B. D. (2015). Seismic performance of buildings resting on sloping ground. *Advances in Structural Engineering: Dynamics, Volume Two*, 803–813..

**2.** Birajdar, B. G., & Nalawade, S. S. (2016). Seismic Analysis of Buildings Resting on Sloping Ground. 1–31.

**3.** Dangol, A., & Motra, G. B. (2021). Seismic Response of Buildings Resting on Hill Slope. *Proceedings of 10th IOE Graduate Conference*, *10*, 115–122.

**4.** Kumar, S., Garg, V., & Sharma, A. (2014). Effect of Sloping Ground on Structural Performance of Rcc Building Under Seismic Load. *International Journal of Science, Engineering and Technology*, *2*(6), 1310–1321.

**5.** Prasad, R. V. (2014). Seismic analysis of building with shear wall on sloping ground. *International Journal of Civil and Structural Engineering Research*, *2*(2), 53–60.

**6.** BIS, I. (2016). Criteria for Earthquake Resistant Design of Structures Part 1 General provisions and Buildings. *Bureau of Indian Standards, Fifth revision*.