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# EFFECT OF EARTHQUAKE ON MULTISTORIED BUILDING RESTING ON SLOPING GROUND

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**Abstract** — Due to topography of India, structures are going to be constructed on hills as a result of increase in population and rapid urbanization. But structures on hills or resting on slopes are more susceptible for earthquake due to the irregularity in the vertical configuration. This irregularity is produced due to variation in column height. Because of this irregularity, building fails due to short column effect, which causes torsion forces in the structure. In this paper, the study of step back building and step back and set back building has performed by considering the effect of slope on building with respect to the storey drift, base shear and fundamental time period. For this study an analysis on building models of three different storey heights as 6 storey, 8 storey and 10 storey has been performed. This analysis uses the response spectrum method in analytical software STAAD v8i. For this work some parameters related with earthquake such as Zone factor, Importance factor, Response Reduction Factor are consider according to IS 1893 – 2002. This study gives the result for two configurations, Step Back building and Step back and Set back Building, with reference to storey drift, base shear and fundamental time period. Among these two configurations for three different storey height, Step back and Set back building is more preferable during earthquake as Step back building is found more susceptible during earthquake.

**Key Words:** hill slope, vertical irregularity, short column, response spectrum method.

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## INTRODUCTION

Earthquakes are the natural hazards under which the damage is the collapse of buildings and other than manmade structures. Earthquake causes enormous damage to the structure. Engineers have made many efforts to understand and improve the earthquake resistant capacity of the structures. In India more than 50% area in the country is considered prone to damaging earthquakes. The north- eastern region of the country as well as the entire Himalayan belt is susceptible to great earthquakes of magnitude more than 8.0. Due to the globalization and increased population, the structures are going to be constructed in hilly regions. Buildings resting on sloping ground or in hilly regions are different than on the plain ground. These structures have different column height at different location or in other words these structures have vertical irregularity and hence these are more vulnerable during earthquake due to short column effect as shown in figure 1. Objectives of this study related with the configuration of buildings on slope are as below

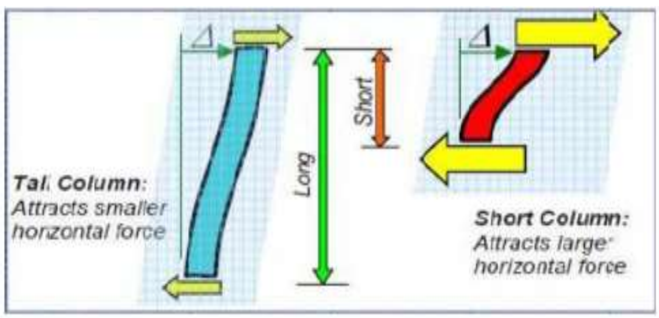


**Fig 1: Short Column Effect**

This study narrate the analysis of building on slopes having two different configurations to know the effect of lateral load due to seismic activity, and the performance of this configuration contributes for following points:

1. The variation in storey drift of various building configurations.
2. The dynamic response of building configuration with respect to fundamental time period and base shear.
3. Effective configuration to be used in hilly region among step back building and step back and set back building.

For making these objectives, following steps were carried out from literature study up to result and conclusion on this study:

1. Study the literature related with this work.
2. Parameters related with building models including plan of building has been decided.
3. Slope for these buildings were fixed as $10^0$ on which Step back building and Step back and set back building of three different storey height as 6 storey, 8 storey and 10 storey has modeled.
4. Response Spectrum Analysis in STAAD v8i has been performed.
5. Results are found in terms of storey drift, base shear and fundamental time period.

**MODELING AND ANALYSIS**

Models of two configurations, Step back building and Step back and Set back Building of three different storey as 6 Storey, 8 Storey and 10 Storey are modeled and analyzed for earthquake parameters using structural software STAAD v8i using response spectrum method. For this analysis the categorization of models are as given in table 1 and figure 2 & 3:

**Table – 1: Model Details**

| Group | Model No. | Storey | Slope | Configuration |
|---|---|---|---|---|
| Group I | Model 1 | 6 Storey | $10^0$ | Step Back Structure |
| | Model 2 | 8 Storey | | |
| | Model 3 | 10 Storey | | |
| Group II | Model 4 | 6 Storey | $10^0$ | Step back and Set back Structure |
| | Model 5 | 8 Storey | | |
| | Model 6 | 10 Storey | | |

These models are of same plan of dimension 30 X 30 m. These models are resting on ground of same slope as $10^0$. For this building column size are assigned as 700 X 700 mm whereas beam size of 230 X 700 mm with 150 mm slab thickness.

The parameters required for response spectrum analysis are as below:

| | |
|---|---|
| **Storey Height:** | **3 m** |
| **Depth of Foundation:** | 1.75 m |
| **Wall Thickness:** | |
| **a) External :** | 230 mm |
| **b) Partition:** | 115 mm |
| **Grade of Concrete:** | M 25 |
| **Slab thickness:** | 0.15 m |
| **Superimposed Load:** | 4 $KN/m^2$ |
| **Zone factor:** | 0.24 |
| **Importance Factor:** | 1.5 |
| **Response Reduction Factor (SMRF):** | 5 |
| **Damping Ratio:** | 0.05 |

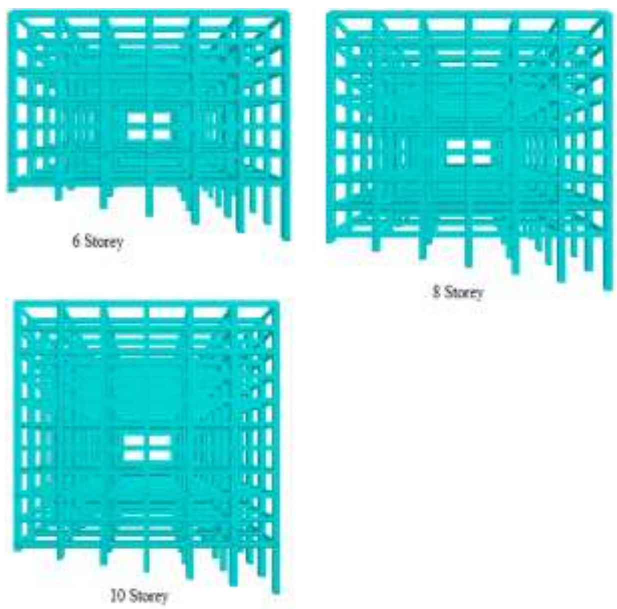


**Fig 2: Group I Model for Step back building**

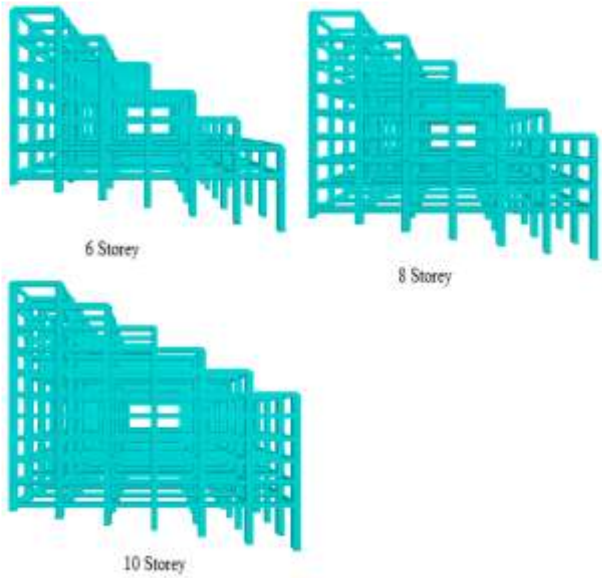


**Fig 3: Group II Model for Step back and Set back building**

**RESULTS AND DISCUSSION**

The results obtained from above analysis is represented in the form of tabulation and graph for three different storey height in two building configuration. Results include parameters such as Storey Drift, Base Shear and Fundamental Time Period from the Response Spectrum Analysis in STAAD v8i.

1. Storey Drift:

a) For 10 Storey

**Table - 2: Storey Drift for 10 Storey**

| Storey Height | 10 Storey | |
|---|---|---|
| | Storey Drift of Step back building(cm) | Storey Drift of Step back and Set back building (cm) |
| 0 | 0.4511 | 0.4325 |
| 3 | 0.9592 | 0.8914 |
| 6 | 1.1028 | 0.9783 |
| 9 | 1.0532 | 0.878 |
| 12 | 0.9548 | 0.7778 |
| 15 | 0.8502 | 0.6911 |

| | | |
|---|---|---|
| **18** | 0.749 | 0.6003 |
| **21** | 0.6436 | 0.5728 |
| **24** | 0.529 | 0.5222 |
| **27** | 0.3898 | 0.5018 |
| **30** | 0.2485 | 0.4563 |

Graphical representation:

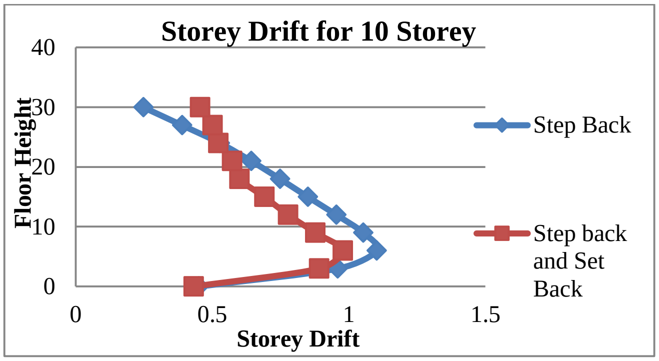


**Fig 4: Storey Drift for 10 Storey**

b) For 8 Storey

**Table - 3: Storey Drift for 8 Storey**

| Storey Height | 8 Storey | |
|---|---|---|
| | Storey Drift of Step back building(cm) | Storey Drift of Step back and Set back building (cm) |
| **0** | 0.5457 | 0.4257 |
| **3** | 1.1478 | 0.8682 |
| **6** | 1.297 | 0.9548 |
| **9** | 1.2086 | 0.8657 |
| **12** | 1.0616 | 0.7852 |
| **15** | 0.9037 | 0.7251 |
| **18** | 0.7331 | 0.672 |
| **21** | 0.5383 | 0.5969 |
| **24** | 0.3343 | 0.499 |

Graphical representation:

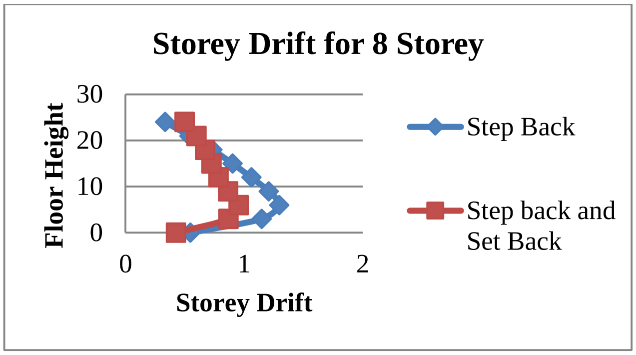


**Fig 5: Storey Drift for 8 Storey**

c) For 6 Storey

**Table - 4: Storey Drift for 6 Storey**

| Storey Height | 6 Storey | |
|---|---|---|
| | Storey Drift of Step back building(cm) | Storey Drift of Step back and Set back building (cm) |
| 0 | 0.5111 | 0.3198 |
| 3 | 1.0653 | 0.6479 |
| 6 | 1.1846 | 0.7717 |
| 9 | 1.0647 | 0.7665 |
| 12 | 0.8608 | 0.6932 |
| 15 | 0.6151 | 0.587 |
| 18 | 0.3681 | 0.4565 |

Graphical representation:

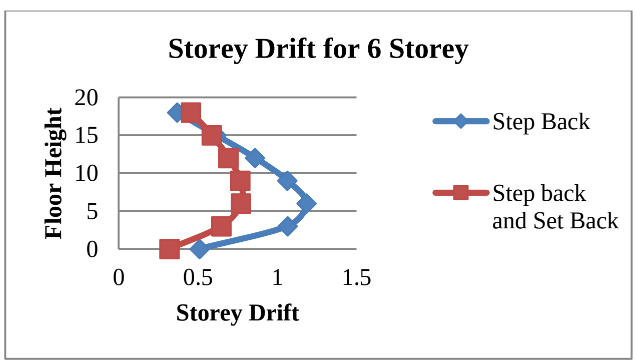


**Fig 6: Storey Drift for 6 Storey**

This result shows the difference in storey drift for two configurations in multistoried buildings. It shows that storey drift in Step back and Set back building Configuration is less than that of Step back building Configuration. About 75% decrease in storey drift in case of Step back and Set back building Configuration.

2. Base Shear:

**Table - 5: Base Shear for 10, 8 and 6 Storey**

| Storey Height | Step Back Building | Set Back and Step Back Building |
|---|---|---|
| 10 Storey | 9935.11 KN | 7764.46 KN |
| 8 Storey | 9903.03 KN | 7270.65 KN |
| 6Storey | 7875.86 KN | 5126.7 KN |

Graphical representation of Base Shear:

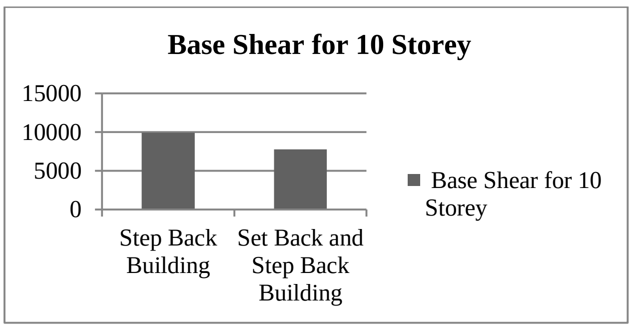


**Chart 1: Base Shear for 10Storey**

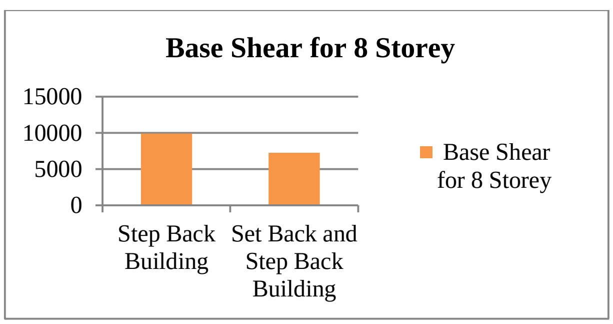


**Chart 2: Base Shear for 8 Storey**

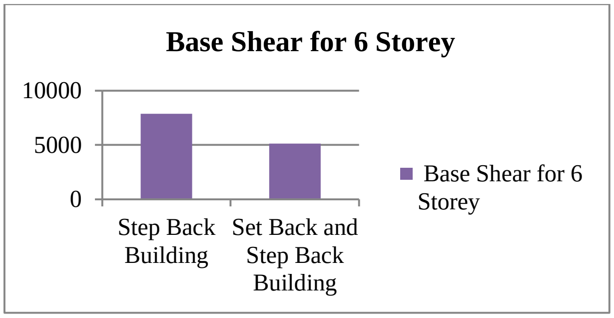


**Chart 3: Base Shear for 6 Storey**

This result shows the change in base shear when instead of Step back configuration, Step back and Set back configuration is used. It shows in average 72% reduction in base shear in Step back and Set back Configuration compare to Step back Configuration.

3. Fundamental Time Period:

**Table - 6: Fundamental Time Period**

| Storey Height | Step Back Building | Set Back and Step Back Building |
|---|---|---|
| 10 Storey | 1.50525 Sec | 1.23753 Sec |
| 8 Storey | 1.23829 Sec | 0.97755 Sec |
| 6Storey | 0.97651 Sec | 0.72179 Sec |

Graphical representation of Fundamental Time Period:

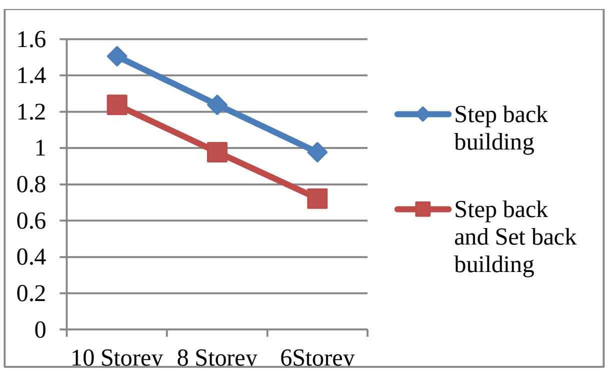


**Fig 7: Fundamental Time Period**

Similarly, fundamental time period in decreased for Step back and Set back building Configuration compare to Step back Configuration and this reduction is in average 78%.

**CONCLUSIONS**

From all the results seen above which are plotted from the response spectrum analysis of step back building and step back and set back building it can be concluded that,

1. For Storey drift Step back building analysis gives more drift compare to Step back and set back building.

2. Similarly, fundamental time period for Step back and Set back building is less.

3. Step back and Set back building is more preferable in hilly region or on sloping round as the storey drift, base shear and fundamental time period are less compare to step back building. Step back building attracts more earthquake force as it is vulnerable during earthquake.

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