Analysis of RC Building Resting on Sloping Ground

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Abstract: ***Increase in the population leads to shortage of the plain land for the construction. A frame building on hill slopes is the only possible choice to accommodate increasing demand of residential and commercial building. Usually Seismic activities are higher in hilly areas of north India. Building has to construct on sloped region due to shortage of flat land. Hence earthquake activity requires great observation in analysis & design due to its destruction power.Analysis of buildings in hill region is somewhat different than the buildings on levelled ground. Due to site conditions, buildings on hill-slopes have an unequal column height which results in shorter column attracts more forces and undergoes damage, subjected to earthquakes. In the present study, the response spectrum method is carried out on two basic type of structure that rests on sloping ground. Building frame with stepback and stepback-setback are considered and are analysed with varying parameters such as slope and height. All the Eighteen models were analysed using ETABS v17 and results were discussed in terms of storey displacement, storey shear, time period and storey drift and best configuration is suggested based on the results and that can be adopted.***

Keywords: Step back, Step back-Setback, Sloping ground, Seismic analysis

1. Introduction

Increase in the population leads to shortage of the plain land for the construction. Due to scarcity of the plain land on hills, houses built on steep slopes and Analysis of buildings in hill region is somewhat different than the buildings on levelled ground.Economic development of hill areas in last century has led to reconsideration of building style and method of construction. Due to rapid growth in population & limited flattened ground, there is popular insistence for construction of more than one floor building on sloping ground in and around hilly areas.The column behaviour is highly unpredictable by theoretical analysis unless the model is developed & analysed by using FEA based software. Buildings with such condition which results in center of mass & center of rigidity don't coincide on various floors. Hence reinforced concrete structures in hilly regions are of great importance and one of the biggest challenges to a structural engineer is to design a seismic resistant building on sloping ground. Due to different type of rock and soil strata, the hilly region is much dangerous and difficulty for execution of work.

2. Literature Survey

Zaid Mohammad, Abdul Baqiconsidered the common two design of building namely Building with stepback and building with stepback-setback, they are analysed by altering plan dimensions.Initially, they prepared the model by using FEA software by varying plan dimensions and height of the building. The stepback and stepback-setback are usually a different model and entirely different analysis when compared to each other. They also considered seismic parameter by using static and dynamic (response spectrum) method using ETABS v9.0. Topstorey displacements, storey drift, fundamental time period, column shear at ground level are considered parameters in both the directions. Based on above parameters, results are discussed and compared. Storey shear in both the configurations results in similar, hence the structural member should be design accordingly shear force and moments conforming to IS codes. Based on results they concluded that stepback buildings are not much suitable in hilly areas when compared with stepback-setback.

S M Nagargoje and K S Sable made an analysis of building by considering both flat and sloping ground, they are stepback and stepback-setback for sloping ground & Setback for flat ground. All these configurations are modelled by varying height of building (i,e 15–50m). They considered seismic parameter by using only Dynamic method (Response Spectrum method) using ETABS. Topstorey displacement and base shear are the parameters considered to describe the results and compared between flat and sloping ground. The results were topstoey displacement in stepback-setback is less when compared with stepback building resting on sloping ground. Maximum base shear induced in stepback-setback building and least in stepback building on levelled ground. Based on the above results, they concluded that stepback-setback configuration may be preferred on sloping ground.

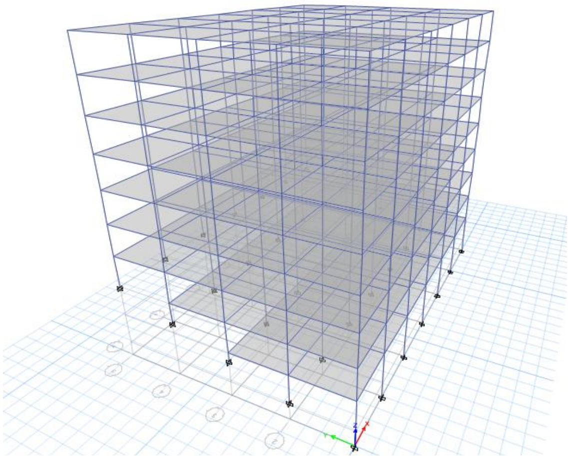
Sindhurashmi B.M and Bhavani Shankar led the stepback and stepback-setback configuration for analysis. They vary the models with the increasing number of bays (i,e two models of 5 bays and two models of 7 bays). All the models were analysed only for earthquake loads considering both static and dynamic method. The Results were expressed in terms of maximum storey displacement, storey shear, storeydrift and fundamental time period for both X and Y directions.Based on seismic parameters the following are stepback-setback configuration shows reduced values in all topstorey displacement, storey shear and storey drift when compared with stepback configuration. On consideration of time period, both the configuration shows almost same values. From the above results, they concluded that the stepback-setback is most appropriate for hilly regions.

3. Objectives of the work

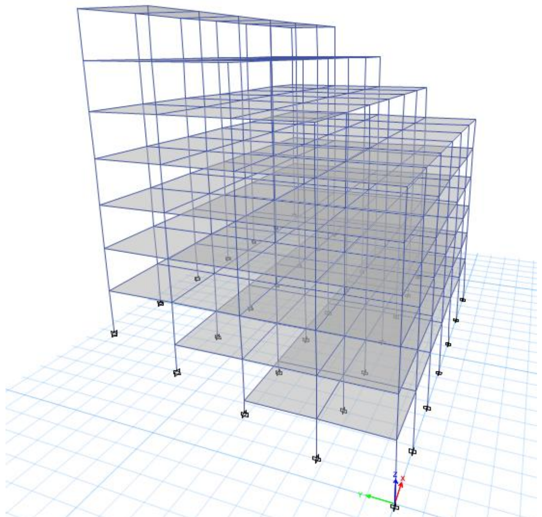
1) To study the effectiveness of configuration of building frames such as step back and step back-set back frames.
2) To study the variation of maximum storey displacement by varying slope angle and story height for considered configurations.
3) To study the variation of storey shear by varying slope angle and story height for considered configurations.
4) To study the variation of time period by varying slope angle and story height for considered configurations.
5) To study the variation of storey drift by varying slope angle and story height for considered configurations.

4. Problem Formulation

4.1 Type of Frame



(a)



(b)

Figure 1: (a) Step back type of building frame structure (b) Step Setback (Step back-Setback) type of building frame structure

4.2 Number of Storeys

The Model used to examine the frames by considering three differential heights of storeys. Most of the building in this region is considered up to 10 storeys. Three Storey configurations are considered such as 9-storey, 10-storey and 11-storey. In both the models (i.e SB and SBS) the typical storey height is 3m.

4.3 Slope of the hills

The Models were analysed by considering three different slopes such as 15^0, 20^0 and 25^0.

Both Static and dynamic analysis has been carried out to calculate the parameters such as base shear, top-storey displacement, time period &storey shear based on Indian codal provision and the response is evaluated in ETABS.

4.4 Details of Analytical work

Table 1: Earthquake Limitations

From IS 1893(Part 1) :2016	
Name	**Description**
Seismic Zone	V
Zone factor (Z)	0.36 from Table 3
Importance Factor	1.5 (Important Building) from Table 6
Response Reduction factor	5 (SMRF) from Table 7
Soil Type	Medium Soil from Table 2

Table 2: Primary data considered for all building arrangements

Title	Description
Occupancy	Residential Building
Category of Structure	SMRF
Floor Height	3m
Lines in X direction	7
Lines in Y direction	5
Space in X direction	5m
Space in Y direction	5m
Beam Size	300X500mm
Column Size	400X400mm
Slab Thickness	125mm
Concrete Grade	M25
Grade of Steel	Fe500

5. Results and Discussions

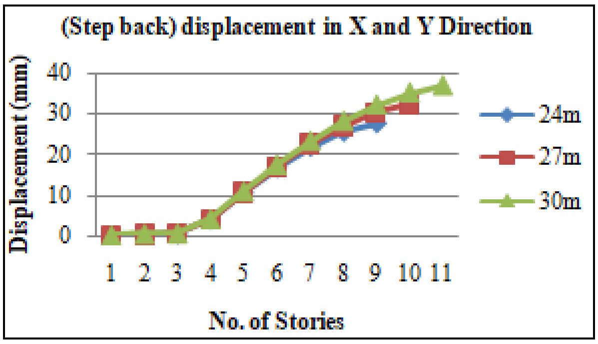
Software analysis of all the 18 models is done and result obtained in parametric values of Maximum Storey Displacement, Storey Drift, Storey Shear, Time Period and Base Shear.

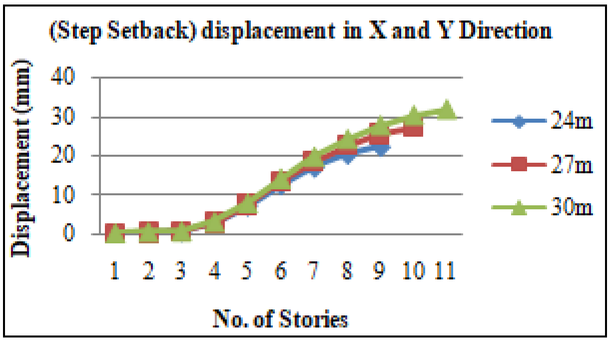
ETABS results for Top Storey Displacement, Storey Drift and Storey Shear reported in the both the directions (i.e. X and Y), Time Period are obtained from the results as described below.

Response spectrum analysis carried out for all the models of two configurations by using standard Indian code (i.e IS1893-2016).All the 18 models were analysed for seismic load in both X and Y directions. The results were stated based on comparison between both the configurations.

The maximum values from the results were considered. As the slope increases, the storeydisplacement, drift, time period and shear value increased. Hence the maximum slope angle is result is included in this paper. (i.e 25^0 slope).

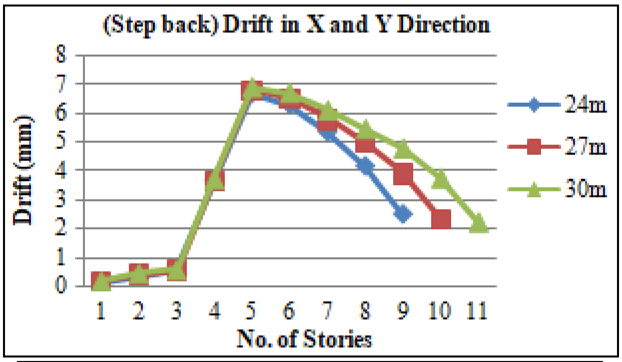
5.1 Storey Displacement

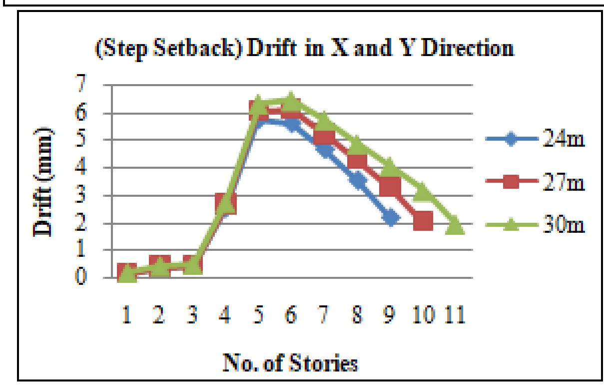




On comparisons of charts in both X and Y directions, it's noted that Stepback configuration shows higher displacement than Step Setback configuration. Hence on consideration of displacements, Step Setback is better option than other.

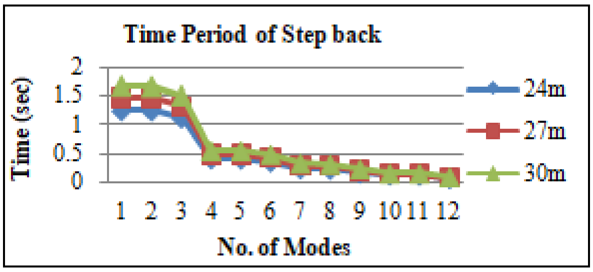
5.2 Storey Drift

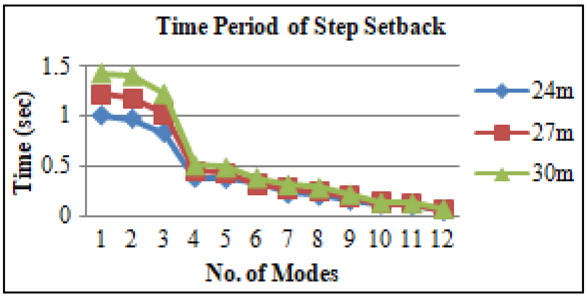




Since evaluation of chart, it's noted that Stepback configuration shows higher storey drift in all the storeys when compared to Stepback-setback configuration.

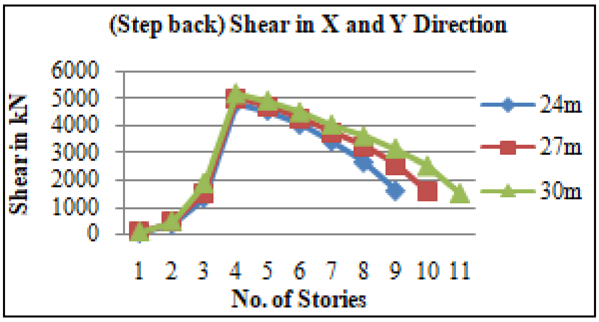
5.3 Time Period

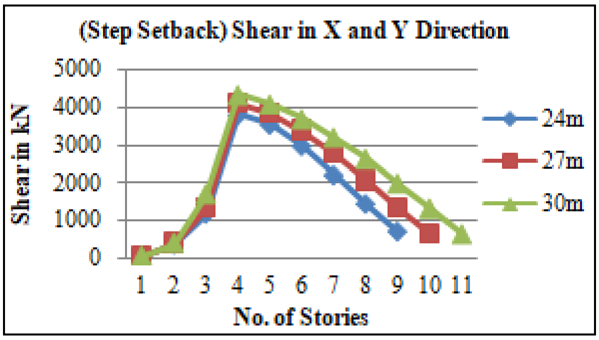




From the above comparison, it can be distinguished that time period in stepback shows slightly higher compared to stepback-setback configuration.

5.4 Storey Shear





On comparisons of charts in both X and Y directions, it's noted that stepback shows greater shear values when compared with stepback-setback configuration in all storeys, but in 1^{st}& 2^{nd}storeys the shear values remains same in both the configurations.

6. Conclusion

By considering all three angles (i.e 15^0, 20^0, 25^0) and varying height of the model under study (i.e 24m, 27m, 30m), the conclusions are as follows:

1) The SB building frames give greater values of Storey displacement as compared to SBS frames.
2) The SB building shows higher values of time period when compared with SBS building.
3) In both SB and SBS frames, it is observed that the columns which are short are most affected. Special attention is required while designing these short columns.
4) On observation in all the models, around 30-35% decrease in storey shear in case of SBS when compared to SB frames.
5) Around 7-10% reduction of storey drift in SBS configuration when compared with other configuration.
6) The Performance of SB frames during seismic excitation could prove more vulnerable than other configurations of building frames, Hence SBS frames are more desirable than SB frames.
7) As the increase in the height of the building the maximum displacement and time period in both configuration increases, whereas in slope the maximum displacement is getting decreased.
8) Hence it can be stated that the SBS building frame perform better than SB building frame when subjected to seismic force.
9) Stepback-setback building frame may be favoured on sloping ground.
10) Based on Observation of results obtained, Step back-Setback configuration shows lesser values of displacements and drifts therefore sloping angle can be permitted to 30 Degree.

References

[1] Zaid Mohammad, Abdul Baqi, Arif "Seismic Response of RC Framed Buildings Resting on Hill Slopes" Elsevier http://doi.org/10.1016/j.proeng.2016.12.221.
[2] S M Nagargoje and K S Sable "Seismic performance of multi-storeyed building on sloping ground" Elixir International Journal 53 (2012) 11908-11982.
[3] Joshua Dainel and Sivakamasundari"Seismic Behaviour of Stiffness Building on Hill Slope" International journal of Aerospace and Lightweight Structures http://doi.org/10.3850/S201042861410004.
[4] Sindhurashmi B.M and Bhavani Shankar "Seismic Response of RC Framed Structures resting on Sloping Terrain" IRJET Volume: 05, Issue: 05, July-2018, e-ISSN: 2395-0056, p-ISSN: 2395-0072.
[5] Paresh G. Mistry and Hemal J. Shah "Seismic analysis on sloping ground Considering Bi-Directional Earthquake" IJSDR Volume: 01, Issue: 04, ISSN: 2455-2631.
[6] Bahram M Shahrooz and Jack P Moehle"Seismic Response and Design of Setback Buildings" ASCE.
[7] Narayan Kalsulkar and SathishRathod"Seismic Analysis of RCC Building Resting on Sloping ground with varying number of Bays and Hill Slopes" IJCET E-ISSN 2277-4106, P-ISSN 2347-5161.
[8] Ashwani Kumar, Pushplata"Building Regulations for hill towns" Elsevier http://dx.doi.org/10.1016/j.hbrcj.2014.06.006

Author Profile

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