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Seismic Performance of RC Frame Buildings Resting on Sloping Ground

Kiran.T[1], N Jayaramappa[2],
Associate professor, and ***Ishrat Fatima[3]****, M.E student, Earthquake Engineering, Civil Engineering Department, UVCE, Bangalore University, JnanaBharathi Campus, Bangalore 560056*

Abstract: *The structures are generally constructed on level ground; however, due to scarcity of level grounds the construction activities have been started on sloping grounds. There are two types of configuration of building on sloping ground, the one is step back and the other is step back setback. In this study, G+ 12 storeys RCC building and the ground slope for* 20^0*,*30^0 *&* 40^0 *have been considered for the analysis. A comparison has been made with the building resting on level ground (setback). The modeling and analysis of the building has been done by using structure analysis tool ETAB, to study the effect of varying height of the column in bottom storey at different position during the earthquake. The results have been compared with the results of the building with and without level ground. The seismic analysis was done by linear static analysis and the response spectrum analyses have been carried out as per IS: 1893 (part 1): 2002. The results were obtained in the form of top storey displacement, drift, base shear and time period. It is observed that short column is affected more during the earthquake. The analyses showed that for construction of the building on sloppy ground the stepback setback building configuration is suitable.*

Keywords: *Sloping ground, Linear static analysis, Stepback, Stepback setback and Response spectrum analysis.*

I. Introduction

Generally the structures are constructed on level ground. In some areas the ground itself is a slope. In that condition it is very difficult to excavation, leveling and it is very expensive .Due to the scarcity of level ground engineers started construction on sloppy ground itself. Some of the hilly areas are more prone to the earthquake. In that areas generally construction works carried out by locally available materials such as bamboo, timber, brick, RCC and also they gave more important to the light weight materials for the construction of houses. As the population density increases at hilly region requirement of structure also increases. The popularity and demand of multistory building on hilly slope is also increases.

Earthquakes are one of the most dangerous natural hazards. Earthquake occurs due to sudden movement of the tectonic plates as a results it release large amount of energy in a few seconds. The impact of this function is most harmful because it affects large vicinity, and which occurs sudden and unpredictable. It causes large scale loss of life and property and damages important services such as, sewerage systems, communication, power, transport and water supply etc. They not only destroy towns, cities and villages, but the result leads to weaken the financially viable and social structure of the country. To defeat from the problem we need to find out the seismic performance and lateral stability of the building structure.

In sloping ground the height of the column is different at the bottom storey. It is asymmetric in plane and elevation. The short columns are most effects and damage occurs during the earthquake. Care should be taken for making this building earthquake resistance. The various methods are used for the analysis such as static and dynamic. Due to the asymmetry dynamic analysis must be used for seismic analysis of the building. These methods are time history and response spectrum method. In the response spectrum method the data such as zone factor, type of soil etc. are applied from I.S.-1893. In time history method the actual record of accelelogram is applied on the building and analysis of the building is carried out in software. Time history method gives more realistic result compared to the response spectrum method because in time history the actual acceleration data of earthquakes are applied and response of building is studied.

1.1 Objectives

- To determine the ground slope varying from 0^0 to 40^0.
- To capture the response for the three types of modeling .
  - Step back
  - Set back (Level Ground)
  - Step back set back
- To obtain capacity curve.

1.2 Methodology

1.3 The methodology followed out to achieve the above mentioned objectives is as follows:

1. Setting up of properties required for analysis of hill buildings, like material properties, geometric properties, loading cases, etc.

2. Modelling of selected building configuration on sloping ground located in seismic zones IV using ETAB software.

3. Static and dynamic analysis of sloping ground structure as per IS 1893 (part 1)2002.

II. Modeling And Analysis

In the present study, three building configurations are considered, which include step back buildings, stepback setback buildings and set back buildings situated on sloping ground. Number of storey considered for each type of configurations is 12 storeys. Plan layout of each configuration includes 4 bays across the slope direction and 6 bays are considered along slope direction, which is kept same for all configurations of building frame. Slopes of ground considered are 20 degree, 30 degree and 40 degree with the horizontal. The columns are taken to be square to avoid the issues like orientation. The depth of footing below ground level is taken as 1.5 m where, the hard stratum is available.

2.1 Geometric Properties And Material Properties are Given Below.

Floor height: 3.5 m
Spacing in X direction: 7.0 m
Spacing in Y direction: 4.5 m
Beam Sizes: 230 X 450 mm
Column sizes : 550 X 550 mm
Slab Thickness : 125 mm
Live load : 3 kN\m2
For Terrace : 1.5 kN\m2
Floor finish : 1 kN\m2
Concrete Grade : M25
Modulus of Elasticity : 25000000 kN\m2
Poison's ratio : 0.2
Compressive strength : 25000 kN\m2
Steel : Fe415, Strength of steel : 415000 kN\m2

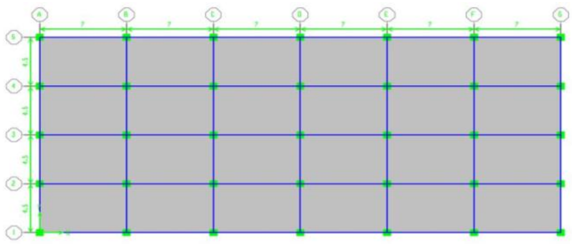

Fig 4.0: Typical plan layout of 6 X 4 bays

As per IS 1893 (part 1): 2002 following methods have been recommended to determine the design lateral loads which are:

1. Equivalent Static Method
2. Response Spectrum Method

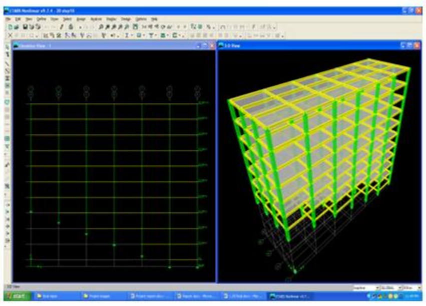

Fig 1.0: Typical 2D and 3D Step back building model on 20° slope

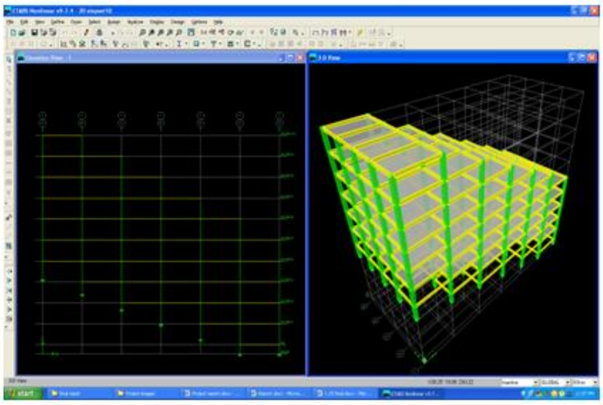

Fig 2.0: Typical 2D and 3D Step back set back building model on 20° slope

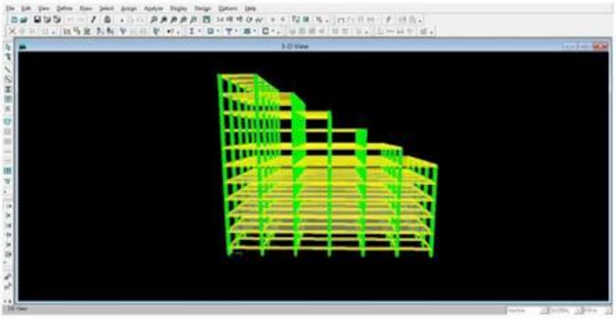

Fig 3.0: Typical 2D and 3D Set back building model on level ground

III. Results And Discussion

➢ **Equivalent Static Method**

(Top Storey Displacement, Base Shear and Storey Drift)

Table-1: Analysis results of displacement, base shear, drift values obtained by Equivalent static method

Model configuration	Slope angle in degree	Top storey Displacement (mm)		Top storey Drift (m)		Base shear (kN)		Time period
		EQX	EQY	EQX	EQY	EQX	EQY	
STEP BACK	20	41.7	37.1	0.000464	0.00037	1241.17	1237.8	2.7599
	30	29.4	27.5	0.000553	0.00037	1356.3	1125.05	2.2500
	40	22.6	22.7	0.000778	0.000405	1968	1285.03	2.0650
STEP BACK SET BACK	20	41.4	42.6	0.000645	0.000425	1256.3	1255.08	2.0788
	30	30	28.5	0.000781	0.000455	1379.53	1248.94	1.4687
	40	24.4	17.3	0.001132	0.000517	1941.04	1507.48	1.2257
SET BACK	LEVEL GROUND	69.603	57.81	0.000596	0.000471	1100.39	1100.39	2.756

Displacement-

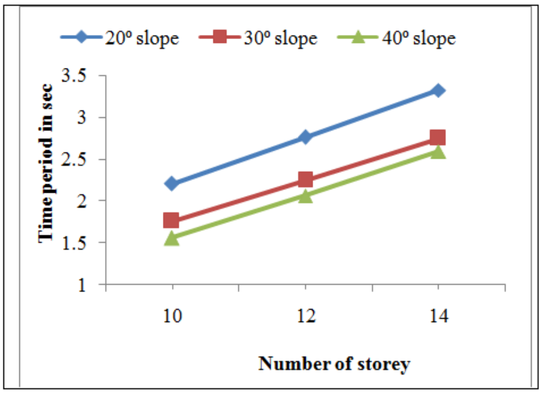

Fig 4.1: Variation of Time period For STP with respect to Slope angle

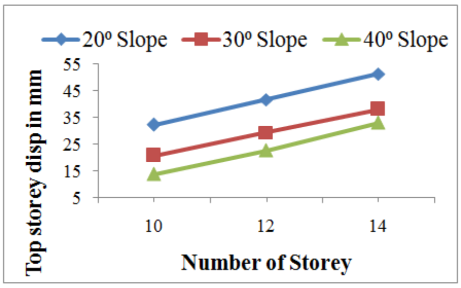

Fig 4.2: Variation of top storey displacement with respect to hill slope for STP buildings along longitudinal direction (Equivalent Static analysis)

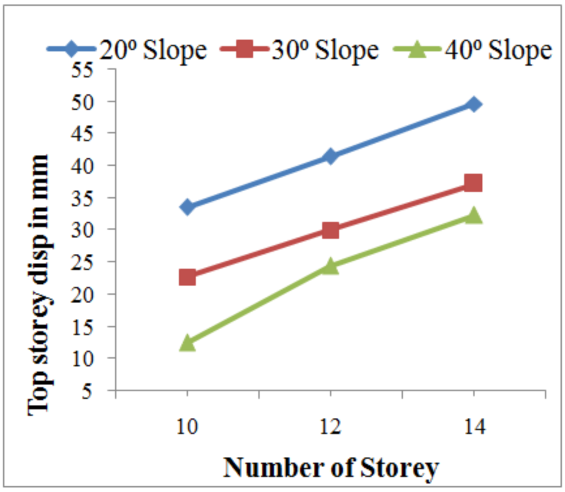

Fig 4.3: Variation of top storey displacement with respect to hill slope for STPSET buildings along longitudinal direction (Equivalent Static analysis).

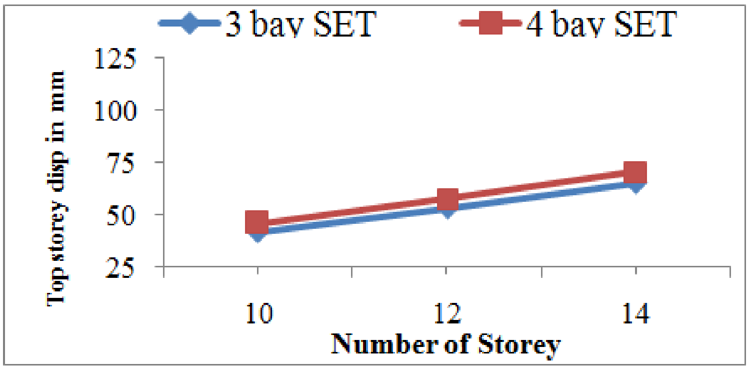

Fig 4.4: Variation of top storey displacement on levelground

Drift-

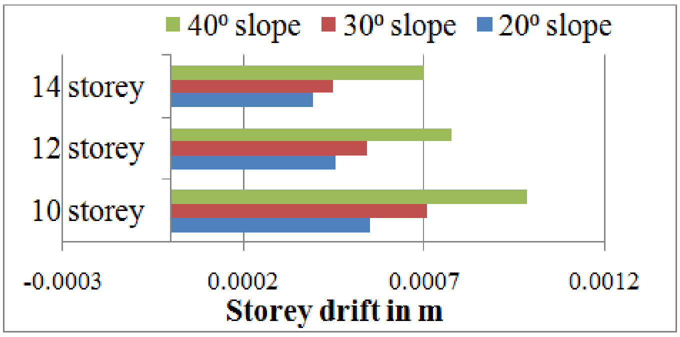

Fig 5.1: Variation of storey drift with respect to hill slope for STP building along longitudinal direction (Equivalent Static Analysis)

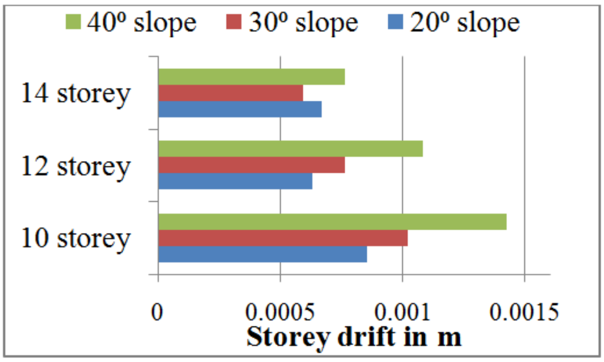

Fig 5.2: Variation of storey drift with respect to hill slope for STPSET building along longitudinal direction (Equivalent Static Analysis)

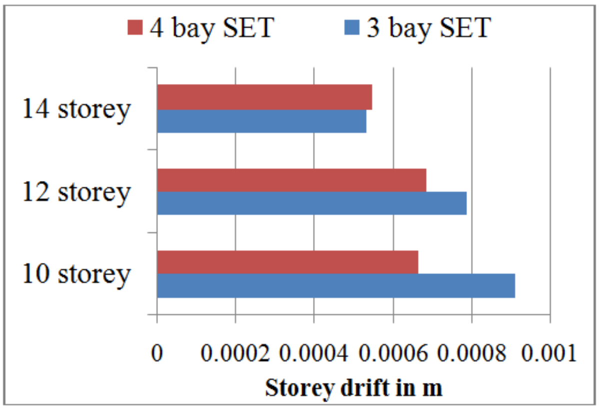

Fig 5.3: Variation of base shear with respect to number of bays across slope for SETback buildings along longitudinal direction (Equivalent Static analysis)

➢ **Response Spectrum Method Step Back**

Top Storey Displacement, Base Shear and Storey Drift

Table -2: Analysis results of displacement, base shear, drift values obtained by Response spectrum method

Model configuration	Slope angle in degree	Top storey Displacement (mm)		Top storey Drift (m)		Base shear (kN)		Time period
		EQX	EQY	EQX	EQY	EQX	EQY	
STEP BACK	20	39.1	33.7	0.0006	.000626	1399.47	1345.07	2.7599
	30	24.8	24.3	0.000671	.000595	1775.21	1167.21	2.2500
	40	18.6	20.4	0.000778	.000618	2303.89	1340.85	2.0650
STEP BACK SET BACK	20	36.7	39.3	0.000927	.000457	1302.56	1363.11	2.0788
	30	23.7	23.4	0.001055	.000507	1653.97	1302.75	1.4687
	40	18.1	10.1	0.001132	.000355	2075.01	1517.91	1.2257
SET BACK	Level Ground	44.496	51.694	0.000492	0.000413	961.65	936.68	2.756

Displacement-

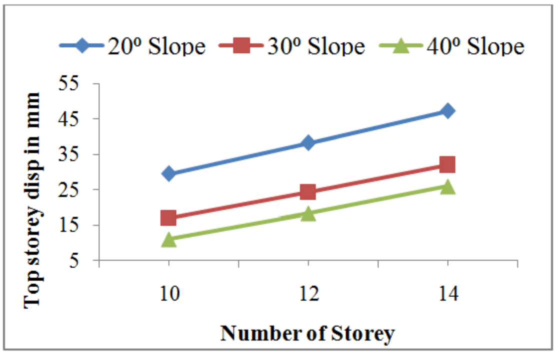

Fig 5.1: Variation of top storey displacement with respect to hill slope for STP buildings along longitudinal direction (Response Spectrum Analysis)

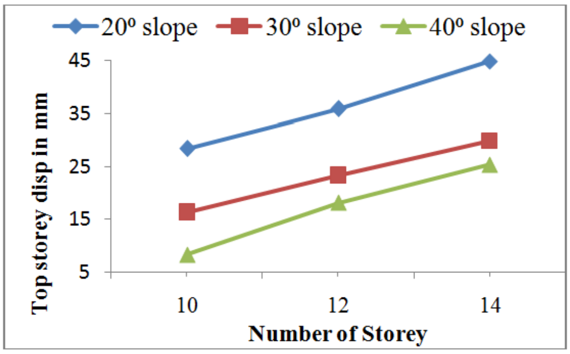

Fig 5.2: Variation of top storey displacement with respect to hill slope for STPSET buildings along longitudinal direction (Response Spectrum Analysis).

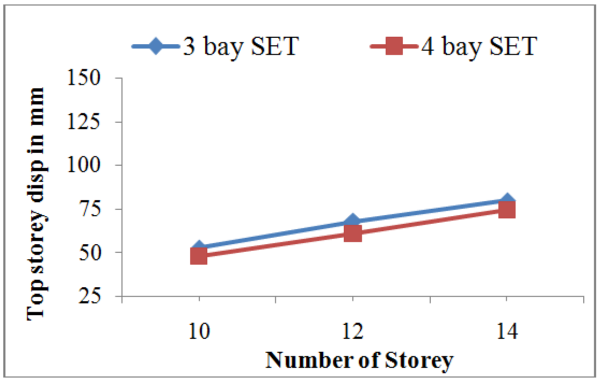

Fig 5.3: Variation of top storey displacement on levelground

Base Shear –

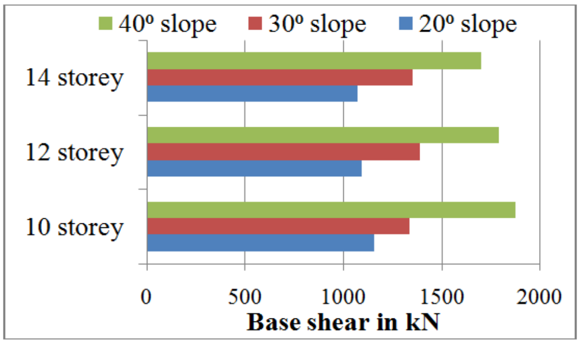

Fig 5.4: Variation of base shear with respect to hill slope for STP buildings along longitudinal direction (Response Spectrum analysis)

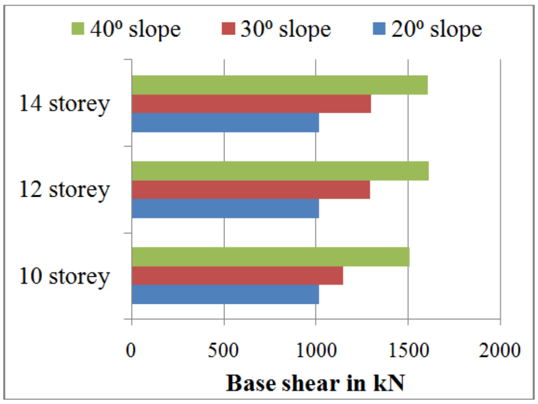

Fig 5.5: Variation of base shear with respect to hill slope for STPSET buildings along longitudinal direction (Response Spectrum analysis)

Drift –

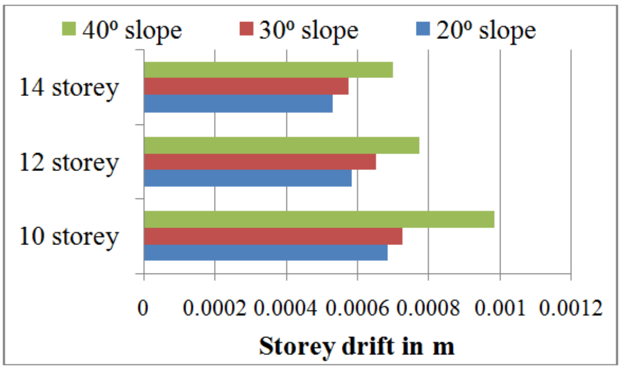

Fig 5.6: Variation of storey drift with respect to hill slope for STP building along longitudinal direction (Response Spectrum Analysis)

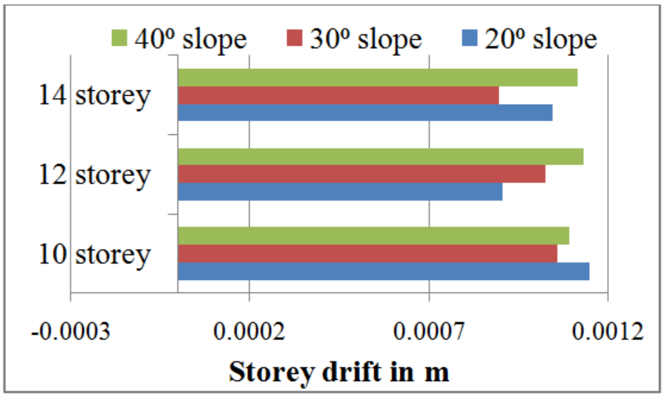

Fig 5.7: Variation of storey drift with respect to hill slope for STPSET building along longitudinal direction (Response Spectrum Analysis)

IV. Conclusions

Based on the study carried out and the results obtained, the following conclusions can be drawn.

1. Time period and top storey displacement increases with increase in number of story level. Base shear, storey drift decreases with increase in number of story level.
2. Step back buildings produces higher value of time period, top storey displacement and base shear than Step back Set back building frames.
3. Step back set back buildings produces 45-60% higher value of storey drift than Step back buildings.
4. As the number of bays increases across slope direction, time period decreases, however, top storey displacement, base shear, storey drift increases due higher stiffness.
5. As the Slope angle increases, time period, top storey displacement decreases, which indicates that the stiffness is increasing of the buildings with increase in hill slope.
6. As the Slope angle increases, Base shear, Storey drifts increases.
7. In case of buildings resting on sloping ground, short column on uphill side attracts maximum shear force in the range of 39-319%, compared to adjacent long columns, which are the worst affected due to seismic excitation. Special attention should be given while designing these columns.
8. Step back set back buildings may be favoured on sloping ground, provided special attention is given to reduce storey drift.
9. Buildings resting on higher angle are the critical buildings, as they produce 58-63% higher value of base shear and 31-43% higher value of storey drift than the buildings resting on lower slope angles.

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