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Study on Seismic Response of Reinforced Concrete Frames on Sloping Ground

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***Abstract*-Recent earthquakes, 18 Sep 2011, Sikkim earthquake, M6.9 and 1 May 2013 Doda earthquake, M5.8 produced two major effects, namely on buildings and on hill slopes. The maximum intensity of ground shaking experienced during these earthquakes was only about VI or less on the MSK scale. Considering the low intensity of ground shaking in the affected areas, the damage attributed was disproportionately higher. It is mainly due to high amplification in local site areas. In this regard, a research is carried out to understand the performance of buildings on hill slopes.In this paper, the study of the behavior of a G+3 building on varying slope anglesi.e., 20°, 30°, 45° and 60° is studied and compared with the same on the flatground. Building is designed as per IS 456 and later subjected to earthquake loads. It was observed that as the slope angle is increasing, building is becoming stiffer. Two types of analyses were conducted viz., lateral load analysis and incremental dynamic analysis. It was observed from the initial results that the columns on the higher side of the slope i.e., short columns were subjected to more shear force then longer columns on the lower side. Finite element method is used to study the static behavior where as Applied Element Method (AEM) is used to perform incremental dynamic analysis.**

Key words : hill-slopes, incremental dynamic analysis

1.0 INTRODUCTION

Earth quakes are the natural phenomenon's which are caused by the release of large strain energy by the moving faults below the surface of the earth, which ultimately causes the shaking of the earth top surface in all possible directions with different amplitudes and intensities of lateral forces. Earthquake can be classified depending on the intensity of quake, duration and directions as minor, moderate and severe and is measured on the Richter magnitude scale. Anything above magnitude 7 is considered as severe type of quakes.

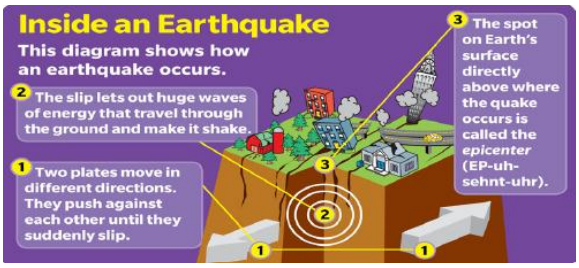

Fig 1. Earthquake occurrences

Due to the industrial revolution, in the recent decade the growths in the cities have been on rise in incremental folds. Due to which the scarcity of plain topography land is a common problem in many cities, for this reason developers are often constructing multistory buildings to accommodate The analysis procedure teaches us how to identify the seismic forces and its demand. Depending upon the type of structure and its cost, the method of analyzing the structure varies from linear to non linear. The static non – procedure indicates which part of the building fails first and the elements begin to yield and deform in elastically as the load and displacement increases. Thus the resulting curve shows the capacity of the building and demand for the specific intensity of seismic forces, this resulting graph will generate a point on the curve where the capacity and demand will meet and we get a performance point. This point can be actually considered as the actual displacement of the structure in response to the specified lateral ground forces.

2.0 METHODOLOGY

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

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

b) Modeling of selected building configuration on sloping ground located in seismic zones (v) using ETAB software.

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

The building used in this study are multistoried with 3 m bays along longitudinal direction and 3 m bays along transverse direction and it is located in seismic zone V. Table 1 shows the specification of multistoried RC building and the complete details of the structure including modelling concepts. The three dimensional RC frame of multistoried building having columns of different height with respect to the slope angle variation were considered in this study. Figure 1 shows the plan of the building representing the X and Y direction used for analysis. Figure 2 shows the three dimensional line sketch of the building frame on slope in the X, Y and Z direction.

Table 1 : Specification on Buildings

Title	Specification
Floor Height	3m
Spacing in X direction	3m
Spacing in Y direction	3m
Live load	3kN/m2
Floor finish	1kN/m2
Grade of concrete	M25,M30
Wind Speed	47 m/s
Seismic Zone	V
Grade of steel	HYSD bars for reinforcement Fe500

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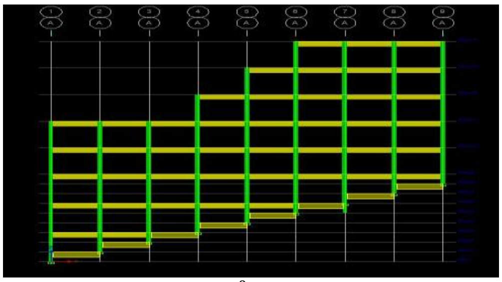

Figure 2:Elevation of 20^0 stepback set back Model

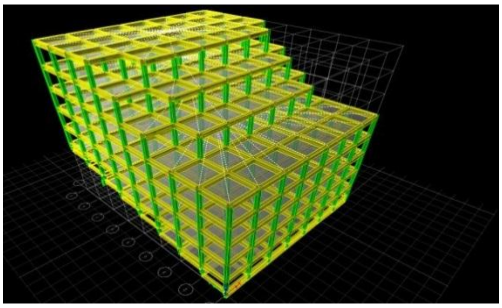

Figure 3:3D view of 20^0 steps back set back model.

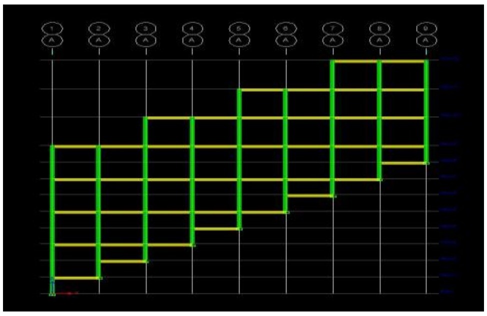

Figure 4: Elevation of 30^0 stepback set back Model

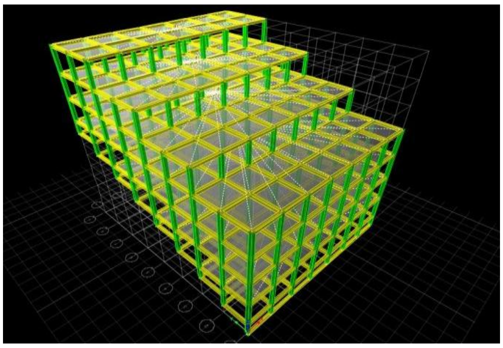

Figure 5: 3D view of 30^0 stepback set back Model

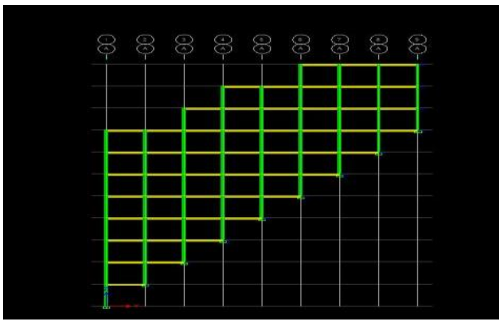

Figure 5: Elevation of 30^0 stepback set back Model

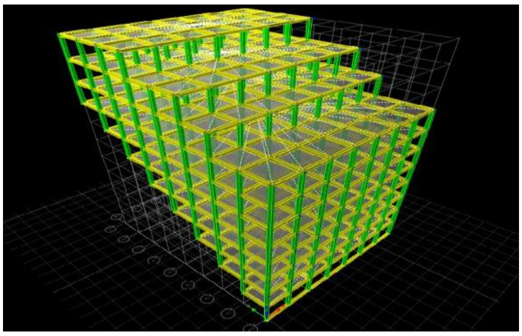

Figure 6: 3 D view of 45^0 stepback set back Model

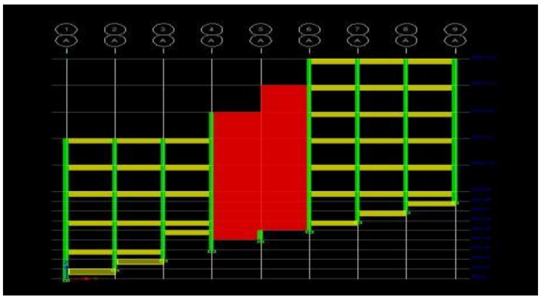

Figure 7:side view of 20^0step backModel with shear wall at the center

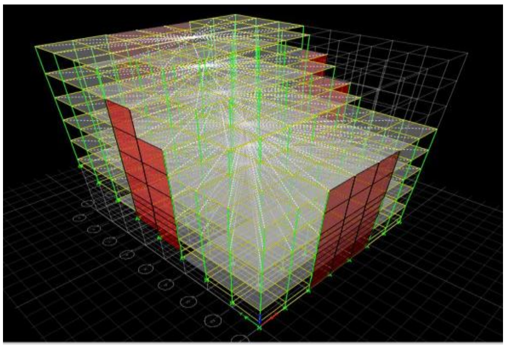

Figure 8:side view of 20^0 step backModel wall at the center

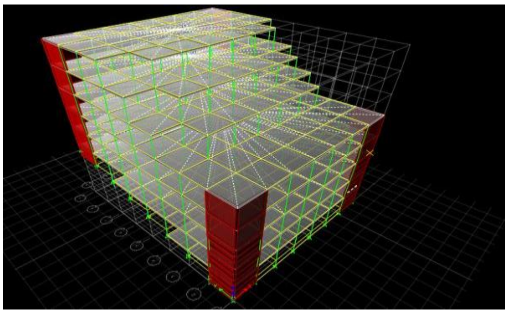

Figure 9 :side view of 20^0step back Model with shear wall at the center

3. EARTHQUAKE ANALYSIS

Analysis results of top story displacement of setback building on ground level and step back setback building on 20^0,30^0 and 45^0 slope due static earthquake load. EQX indicates displacement due to earthquake load along X axis and EQY indicates displacement due to earthquake load along X axis and Y axis.

Table 2: showing displacement Vs Slope angle

Load	Ground level	20^0	30^0	45^0
EQX	49.497	30.374	24.342	16.4
EQY	40.174	26.614	22.666	15.4

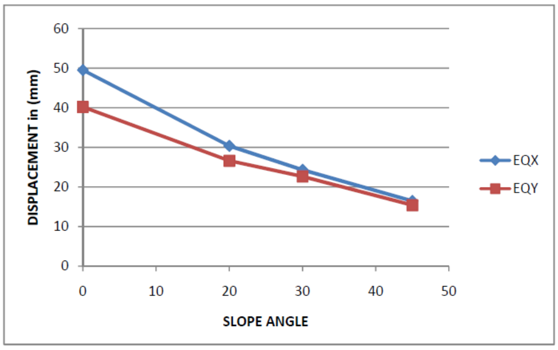

Figure 10 :Graph showing displacement Variation with slope angle

3.1.1 Story Drift

Analysis results of top storey drift of setback building on ground level and step back setback building on 20º, 30^0 and 45^0 slope due static earthquake load. EQX indicates drift due to earthquake load along X axis and EQY indicates drift due earthquake load along axis

Table 3 :showing drift Vs Slope angle

Load	Ground level	20^0	30^0	45^0
EQX	0.00083	0.0009	0.0013	0.0011
EQY	0.00095	0.000988	0.001535	0.001233

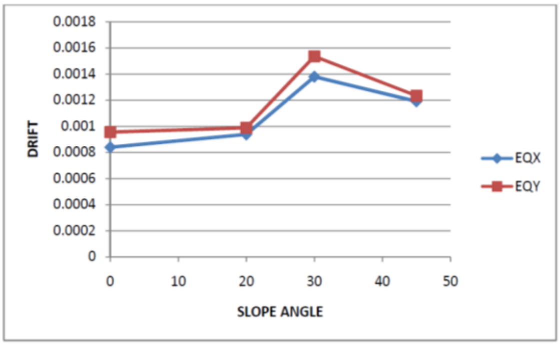

Figure 11 :Graph showing drift Variation with slope angle

3.12 Base Shear

Analysis results of base shear of setback building on ground level and step back building on 20^0,30^0 and 45^0 slope due static earthquake load. EQX indicates base shear due to earthquake load along X axis and EQY indicates base shear due to earthquake load along Y axis

Table 4 :showing base shear Vs Slope angle

Load		Ground level	20^0	30^0	45^0
EQX		1664	1874	2544	238
EQY		1784	2743	3013	212

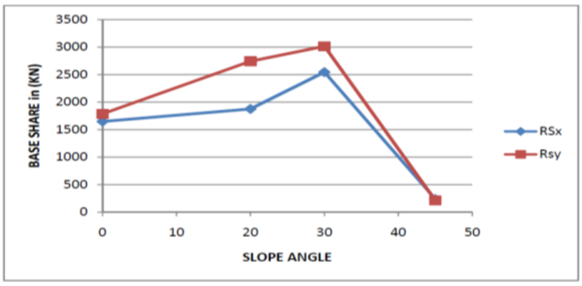

Figure 12 :Graph showing drift Variation with slope angle

4. WIND ANALYSIS

Analysis results of top storey displacement of setback building on ground level and steptback setback building on 20^0,30^0 and 45^0 slope. Wx indicates displacement obtained by wind analysis method along X axis and Wy indicates displacement obtained by wind analysis method along Y axis.

Table 5: showing displacement Vs Slope angle

Load	Ground level	20^0	30^0	45^0
WX	6.347	1.808	1.164	0.899
WY	13.981	4.057	3.873	2.723

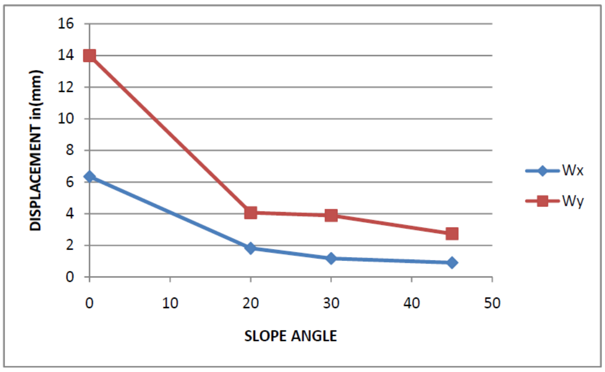

Figure 13 :Graph showing dispacement Variation with slope angle

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4.1.1 Story Drift

Analysis results of top storey drift of setback building on ground level and step back setback building on 20^0,30^0 and 45^0 slope.Wx indicates drift obtained by wind analysis method along X axis and Wy indicates drift obtained by wind analysis method along Y axis

Table 6: showing drift Vs Slope angle

Load	Ground level	20^0	30^0	45^0
WX	0.000104	2.80*10-5	3.70*10-5	4.40*10-5
WY	0.000391	9.40*10-5	0.00236	0.000185

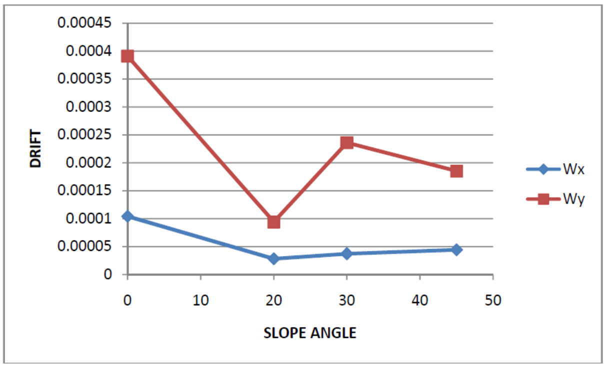

Figure 14 :Graph showing drift Variation with slope angle

4.1.2 Base shear

Analysis results of base shear of setback building on ground level and step back setback building on 20^0,30^0 and 45^0 slope. Wx indicates base shear obtained by wind analysis method along X axis and Wy indicates base shear obtained by wind analysis method along Y axis.

Table 7 : showing base shear Vs Slope angle

Load	Ground level	20^0	30^0	45^0
WX	307	282	200	18
WY	700	623	700	40

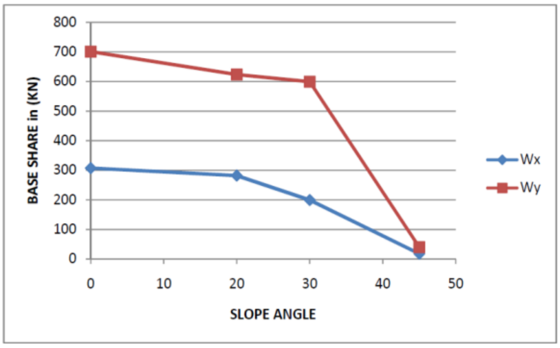

Figure 15 :Graph showing base shear with slope angle

5.0 EFFECT OF SHEAR WALL

Analysis results of top storey displacement of stepback setback building on 20^0 slope with and steptback setback building on 20^0 slope with shear wall present in corner and CENTRE of building. EQX indicates displacement obtained by static earthquake load along X axis and EQY indicates displacement obtained by static earthquake load along Y axis.

Table 8 : showing shear wall position Vs dispacement

Load	Shear wall at corner	Shear wall at Centre
EQX	282	18
EQY	623	40

Analysis results of top storey displacement of stepback setback building on 20^0 slope with stept back setback building on 20^0 slope with shear wall present in corner and centre of building. Vertical axis indicates displacement obtained by static earthquake load and horizontal axis indicates the structure.

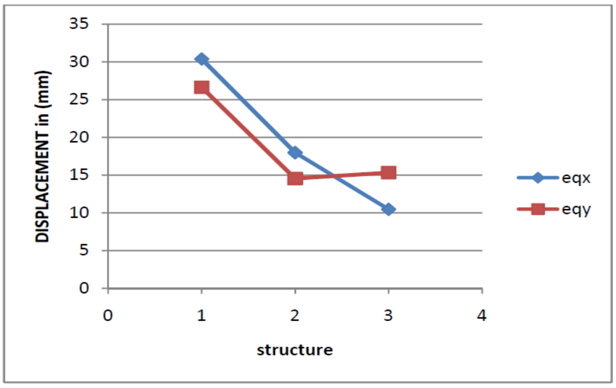

Figure 16 :Graph showing dispacement Variation with slope angle

5.12 Storey drift

Analysis results of top storey drift of step back Setback building on 20^0 slope and steptback setback building on 20^0 slope with shear wall present in corner and CENTRE of building. Vertical axis indicates drift obtained by static earthquake load and horizontal axis indicates the structure.

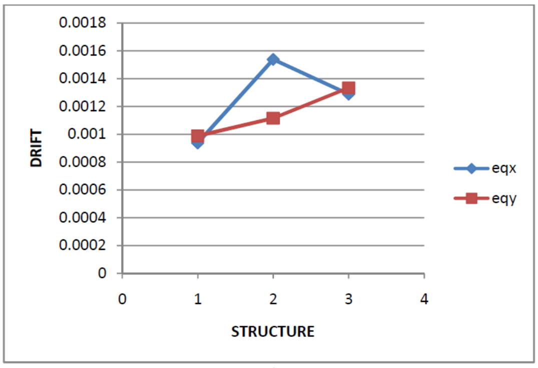

Figure 17 :Graph showing drift Variation with slope angle

5.13 Base shear

Table 9: showing shear wall position Vs base shear

Load	Shear wall at corner	Shear wall at Centre
EQX	2035	5913
EQY	3010	5913

Analysis results of base shear of stepback setback building on 20^0 slope and steptback setback building on 20^0 slope with shear wall present in corner and CENTRE of building. Vertical axis indicates base shear obtained by static earthquake load and horizontal axis indicates the structure

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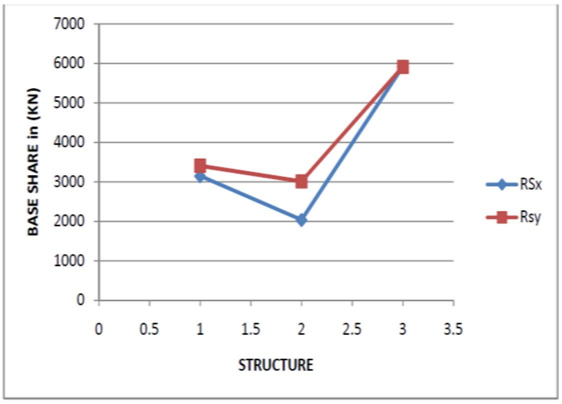

Figure 18 :Graph showing base shear Variation with slope angle

6. CONCLUSION

1. In equivalent static method, response spectrum method and wind analysis, as the slope angle increases the top storey displacement.
2. The step back setback building configuration having less displacement compared to the other two configurations.
3. Presence of the shear wall at the corner of the building, displacement value is less than then displacement shear wall present in centre.
4. Presence of the shear wall at the centre building, drift value is reduces and base shear value increases as compared to without shear wall building.
5. The buildings which are resting on sloping ground are subjected to short column effect, attract more base shear &forces and are worst affected during seismic excitation.

6. Base shear is maximum at 20^0 in step back setback buildings. For construction of the building on sloping ground the step back setback building configuration is suitable, along with shear wall placed at the corner of the building.

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