Analysis of building on Sloping Ground subjected to Seismic Forces

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Abstract— In the current scenario appealing architecture along with high rise buildings is not limited to plain terrain but also extended to the hilly terrain keeping in mind the problems aroused and their effects. This paper presents the comparative analysis of various configurations of 15 storied building with to be found on varying slope with different plan and different structural arrangements situated on seismic zone III. This study compares various reinforced concrete models framed and analyzed their response against dynamic loading to identify and struggle the worst possible scenario. The study is carried out for a combination of four different slopes and different building configuration by response spectrum analysis method and various parameters are compared against various constraints and results obtained from various building cases illustrates that the most optimum case is building C1 and C2 for both step back and step back set back configurations.

Keywords— Multistorey building, hill slope angle, seismic response, sloping ground, response spectrum, optimum case, setback case, step-back setback case.

I. INTRODUCTION

Seismic history of India shows that the zones of higher seismic activity and higher magnitudes are mostly presents in hilly terrains of northern and north-eastern regions. As well these places are more likely attracts peoples from plains for different purposes varying from adventure, tourism, religious and also for resolving problem of habitat due to decrease in habitable land in the urban areas. These all purposes may lead to resolve the problem of migration of peoples from hilly regions due to lack of resources which may provide aids to comply their basic needs.

But tendency towards sloping terrain may raise the load on these places and to accomplish this load we need to accommodate more buildings but due to the topography of hilly terrain we could not effortlessly use space everywhere. So we have to move towards multistoried high-rise building to resolve this problem. Also structural stability of the structure will be next problem in the arena to combat various constraints either it may be the typical topographical conditions or it may be the seismic proximity of the area which will be variable from place to place.

These glitches may be sorted by adopting proper and suitable building configuration as per need keeping in mind the economy of the project and the construction practices which will be the ultimate concluding factor that may leads to stability or proximity to the building.

II. CONFIGURATION OF BUILDING IN HILLY TERRAIN

Configuration of the structure infers that the structural and architectural arrangement building might possesses in the sloping regions. Depending upon the arrangement of bays fundamentally there are two prominent types of configurations consisting of:

i) Step back type of configuration: The building arrangement in which horizontal plane remains same but on the lower part it will maintain slope as per terrain or topography of the area.

ii) Setback and step back type of configuration: In this building configuration the structure is arranged in stepping pattern in which the horizontal plane is not remains same along with lower part of the structure.

III. OBJECTIVES OF THE PRESENT STUDY

Research review from various papers provides that the construction on hilly terrain is not a daily task but needs the firm structural arrangement especially for variable slope. So the building is analyzed for four different slopes 10˚, 20˚, 30˚ and 40˚ along with a regular building rested on flat terrain against various parameters. The key objectives set for the analysis are:

1. To analyze and determine the maximum displacement in longitudinal and transverse directions.

2. To find and compare base shear in both X and Z direction.
3. To compare the maximum of axial forces in column at base.
4. To compare and analyze the shear force and bending moment.
5. To explore the optimum case among various structural arrangements to resist the seismic hazard and structural irregularities.

IV. METHODOLOGY AND MODELING

A 15 Storied multistoried building is configured comprising of 5numbers of equally spaced bays in both the direction of 4 m with a constant floor height of 3.66m and ground floor of 4.58m. Total of 5 cases in step back and 5 cases for step back set back cases including building rested on flat ground as well as sloping ground as illustrated in in tables mentioned below along with figures of structural arrangements. All the cases are analyzed and studied as per Indian Standard Code IS 1893 (Part1): 2016 against various seismic parameters and constraints for earthquake Zone III by response spectrum analysis method by "STAAD Pro V8i" software to explore the possibilities to resist the deformation and withstand against seismic and structural hazards.

Table 1: Building Data

Parameter	Assumed data
Length of building	20m
Width of building	20m
Height of building	59.48m
Floor to floor height	3.66m
Beam sizes	350mm X 550mm
Column sizes	550mm X 600mm
Slab thickness	165mm
Shear Wall	200mm
Depth of foundation	3.66m
Material properties	Concrete(M25)
Support	Fixed

Table 2: Earthquake Parameters

Parameter	Assumed data
Soil type	Medium Soil
Seismic zone	III (Z = 0.16)
Response reduction factor (Ordinary shear wall with SMRF)	4
Importance factor	1.2(For Residential and commercial building)
Damping ratio	5%
Fundamental natural period of vibration (Ta)	$0.09 \cdot h/(d)^{0.5}$ $Ta_x = 1.197 \text{seconds}$ $Ta_Z = 1.197 \text{seconds}$

Following are the cases taken for analysis against various parameters possess following building and seismic data used for analysis of the step back configuration are tabulated below:

Table 3: Different cases with respect to building configurations for Step Back Cases

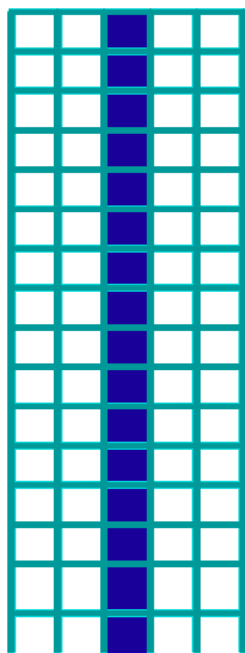| S. No.	Model Configuration Cases	Abbreviation	Degree
1	15 storied regular building rested on flat ground.	A0	0 degree
2	15 storied sloping building having step back configuration rested on 10° slope.	A1	10 degree
3	15 storied sloping building having step back configuration rested on 20° slope.	B1	20 degree
4	15 storied sloping building having step back configuration rested on 30° slope.	C1	30 degree
5	15 storied sloping building having step back configuration rested on 40° slope.	D1	40 degree

Following are the cases taken for analysis against various parameters possess following building and seismic data used for analysis of the step back configuration are tabulated below:

Table 4: Different cases with respect to building configurations for Step Back Set Back Cases

S. No.	Model Configuration Cases	Abbreviation	Degree
1	15 storied regular building rested on flat ground.	A0	0 degree
2	15 storied sloping building having step back set back configuration rested on 10° slope.	A2	10 degree
3	15 storied sloping building having step back set back configuration rested	B2	20 degree

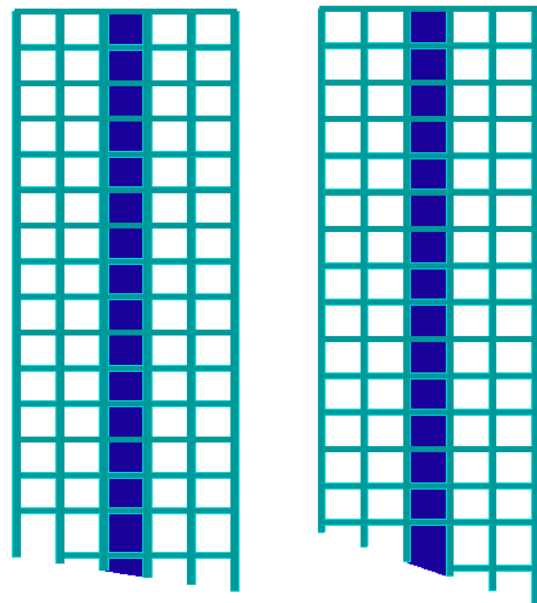|			
	on 20° slope.		
4	15 storied sloping building having step back set back configuration rested on 30° slope.	C2	30 degree
5	15 storied sloping building having step back set back configuration rested on 40° slope.	D2	40 degree

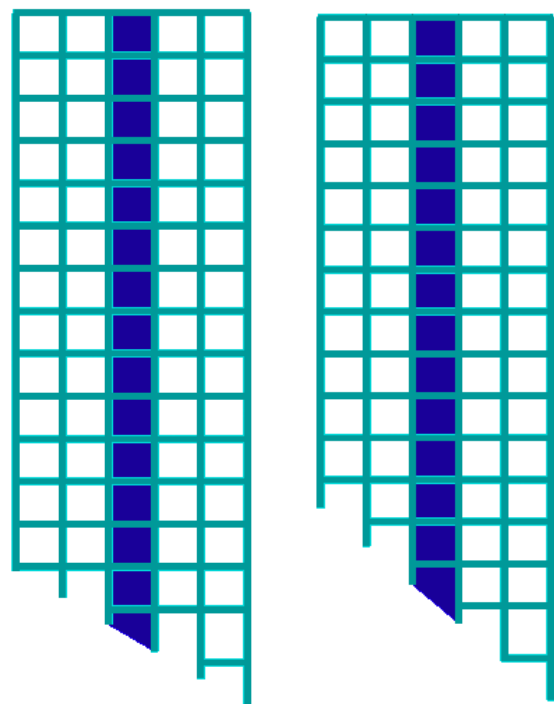*Fig. 2: Building A1 and B1*

Fig. 1: Building A0

Fig. 3: Building C1 and D1
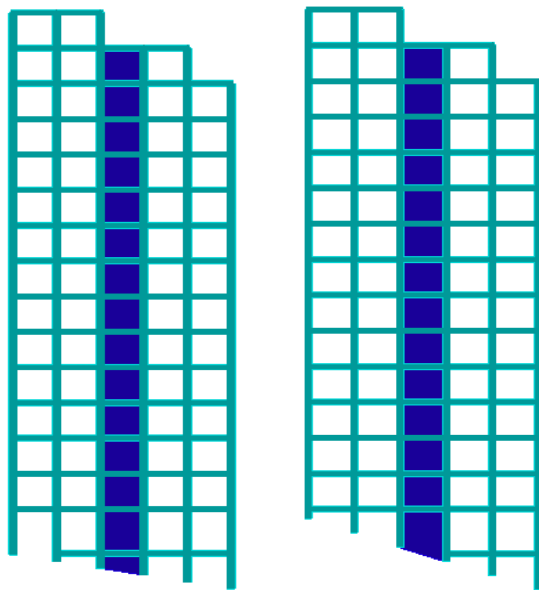
Fig. 4: Building A2 and B2
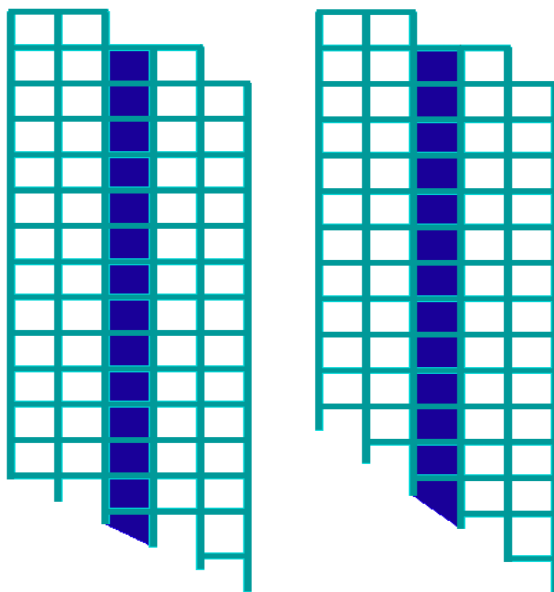
*Fig. 5: Building C2 and D2*

Table 5: Loading Details

Parameter	Assumed data
Floor Finish Load	2.2 KN/ sq. m.
Wall load (Exterior)	17.12 KN/m
Wall load (Interior)	9.52 KN/m
Wall load (Parapet)	2.38 KN/m
Water Proofing	0.5 KN/sq. m.
Imposed Load (Floors)	4 KN/sq. m.
Imposed Load (Roof)	1.5 KN/sq. m.

V.   RESULTS AND DISCUSSION

In this research study various cases are analyzed as per IS 1893:2016 (part-1) by response spectrum method for seismic zone V against all constraints as mentioned in the objectives. Dynamic analysis was performed against various seismic parameters for multiple load combination for all the models consist of structure on normal ground, step back configuration and step back & setback configuration. The parameters taken for comparative examinations for individual cases are maximum nodal displacement, maximum axial force, maximum shear force, maximum bending moment, maximum torsional moment, and base shear by tabular and graphical form.

Table 6: Maximum Nodal displacement for various building cases

| Building	Displacement (mm)	Building	Displacement (mm)
A0	182.637	A0	182.637
A1	153.778	A2	134.821
B1	142.528	B2	130.763
C1	137.539	C2	118.595
D1	162.410	D2	140.241
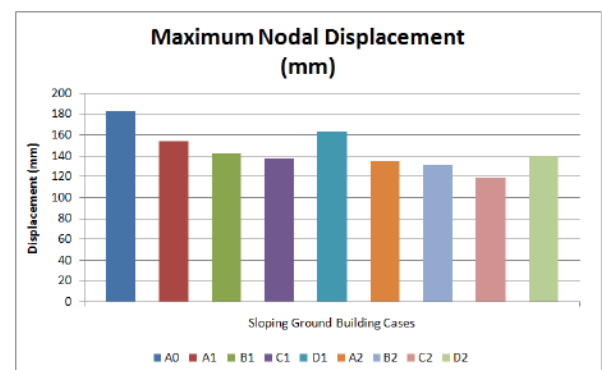
Graph 1: Graphical representation of Maximum Nodal Displacement for all building cases

Table 7: Maximum Base Shear in X & Z direction for A0 to D1 building cases

Building	Base Shear X (KN)	Base Shear Z (KN)
A0	3334.25	3334.43
A1	3784.90	3784.79
B1	4535.20	4348.43
C1	3461.08	3519.05
D1	5227.73	4928.65

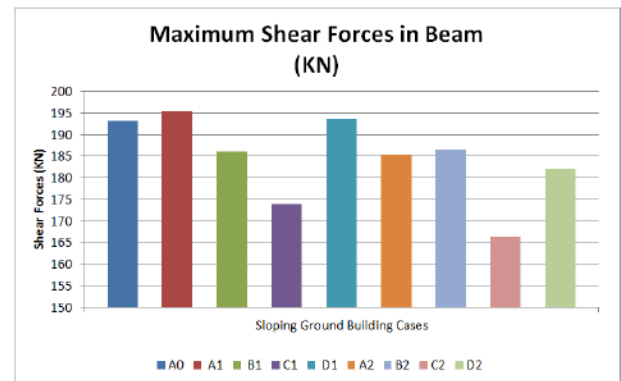*Table 8: Maximum Base Shear in X & Z direction for A0 to D2 building cases*

Building	Base Shear X (KN)	Base Shear Z (KN)
A0	3334.25	3334.43
A2	3625.40	3625.20
B2	4545.66	4322.67
C2	3454.85	3474.36
D2	5259.98	5213.47
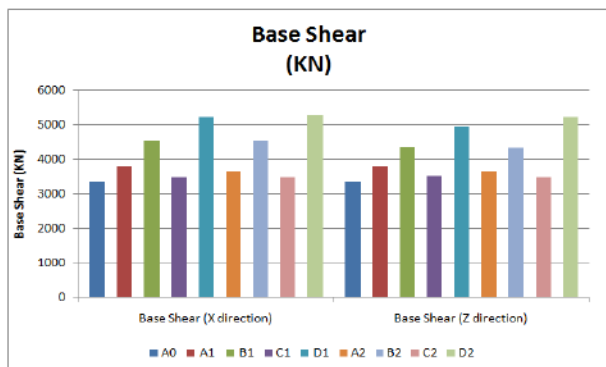
Graph 2: Graphical representation of Base Shear in X & Z direction for all building cases

Table 9: Maximum Axial forces for various building cases

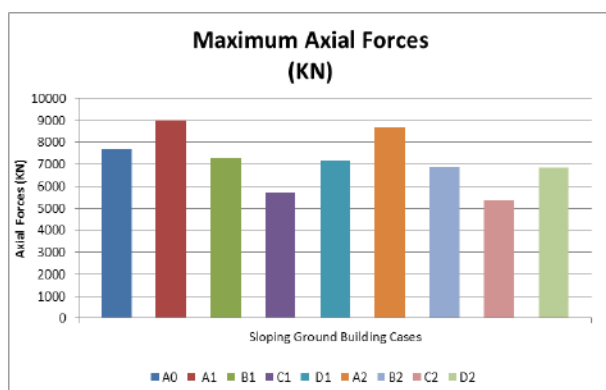| Building	Axial Forces (KN)	Building	Axial Forces (KN)
A0	7709.861	A0	7709.861
A1	9017.059	A2	8670.360
B1	7275.176	B2	6859.171
C1	5732.039	C2	5379.167
D1	7167.571	D2	6843.198

Graph 3: Graphical representation of Axial Force for all building cases

Table 10: Maximum Shear Force in Beam for various building cases

Building	Shear Forces (KN)	Building	Shear Forces (KN)
A0	193.225	A0	193.225
A1	195.407	A2	185.299
B1	186.121	B2	186.381
C1	173.915	C2	166.246
D1	193.526	D2	181.950

Graph 4: Graphical representation of Shear Forces in Beam for all building cases
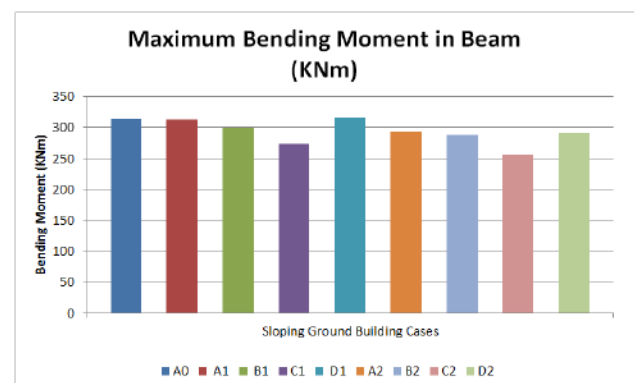
Table 11: Maximum Moment in Beam for various building cases

Building	Bending Moment (KNm)	Building	Bending Moment (KNm)
A0	314.255	A0	314.225
A1	313.177	A2	292.659
B1	299.627	B2	287.991
C1	274.144	C2	256.061
D1	314.976	D2	291.165

Graph 5: Graphical representation of Moment in Beam for all building cases

VI.   CONCLUSIONS

Till date various researches have been done on multistoried building rested on hilly or sloping terrain but there had not been any study that enhances the vision of extent in terms of height analyzing parameters with such diversity. After analyzing various parameters from above results following conclusions are drawn from this research work:-

1. After comparing various sloping cases with A0, it has been concluded that the nodal displacement is found minimum for building C1 and C2 with efficiency of 75.30 % for C1 and 64.93 % for C2 respectively.

2. On analyzing base shear values the best case which has found out by comparing all buildings rested on sloping ground is building C1 3.80 % less efficient and C2 3.61 % less efficient which is nearly equal.

3. On comparing axial force values for all the cases it has concluded that the building C1 and C2 generate lesser axial forces with efficiency of 74.34 % and 69.77 % as compared to A0.

4. Subsequently analyzing shear force values in beam parallel to X and Z direction of A0 with other cases, again building C1 and C2 shows the least values with efficiency of 90% and 86% among all the sloping ground cases and for this parameter, building C1 and C2 is most efficient.

5. Again for bending moment parameters for beams, building C1 and C2 shows least values with efficiency of 87.23% and 81.48 % and shows itself as most efficient case.

6. It has been concluded from this study, out of all the cases with different configuration of step back & step back along with setback in the plain and sloping terrain with variable slope, building C1 and C2 is found most efficient as per lowest parametric values.

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