EXPERIMENTAL INVESTIGATION OF RC FRAMED BUILDING ON SLOPING GROUND SUBJECTED TO EARTHQUAKE 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 V. This study compares various reinforced concrete models framed in highest earthquake zone and analyze their response against dynamic loading to identify and combat 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 against various seismic and non-seismic parameters. Various parameters are compared against various constraints and results obtained from various cases illustrates that that the most optimum case is*

Keywords- Hilly terrain, multistory building, hill slope angle, seismic response, sloping ground, response spectrum, optimum case, setback case, step-back setback case.

1. 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 proclivity towards sloping terrain would may rise the load on these place 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 structure.

1.1 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.

2. 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 all the mutually perpendicular directions.
2. To analyze and compare the story drift among all the models frame for analysis of the structure.
3. To compare the maximum of axial force at the base story
4. To compare and analyze the shear force and bending moment.
5. To compare and analyze the torsional moment generated in lateral or longitudinal directions.
6. To explore the optimum case among various structural arrangements to resist the seismic hazard and structural irregularities.

3. METHODOLOGY AND STRUCTURAL MODELLING

15 Storied multistoried building is configured comprising of 8 number of equally spaced bays in both the direction but with varying dimensions with a constant floor height of 3.66m for a total of 9 cases including building rested on flat ground as well as sloping ground as illustrated in tables mentioned below along with figures of structural arrangements. All the cases are analyzed and studied as per Indian Standard Code IS 1893 (Part 1): 2005 against various seismic parameters and constraints for earthquake zone V by response spectrum analysis method by "STAAD Pro V8i" software to explore the possibilities to resist the deformation and withstand against seismic and structural menaces.

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

Table-1: Building Data

Parameter	Assumed data
Length of building	32m
Width of building	24m
Height of building	54.9m
Floor to floor height	3.66m
Beam sizes	300mm X 450mm
Column sizes **i) Up to 8th floor** **ii) 8th floor to 15th floor**	 350mm X 500mm 350mm X 600mm
Slab thickness	125mm
Depth of foundation	3.66m
Material properties	Concrete(M25)
Support	Fixed

Table-2: Seismic Data

Parameter	Assumed data
Soil type	Medium Soil
Seismic zone	V
Response reduction factor (SMRF)	5
Importance factor	1 (For all general building)
Damping ratio	5%
Fundamental natural period of vibration (Ta)	0.09*h/(d)0.5 Ta_x= 0.8735 seconds Ta_z=1..0086 seconds

Table-3: Different cases with respect to building configurations

S.No.	Model Configuration Cases	Abbre-viation
1	Modelling and analysis of 15 storied regular building rested on flat ground	A
2	Modelling and analysis of 15 storied sloping building having step back configuration rested on 10° slope.	B
3	Modelling and analysis of 15 storied sloping building having step back configuration rested on 20° slope.	C
4	Modelling and analysis of 15 storied sloping building having step back configuration rested on 30° slope.	D
5	Modelling and analysis of 15 storied sloping building having step back configuration rested on 40° slope.	E
6	Modelling and analysis of 15 storied sloping building having setback & step back configuration rested on 10° slope.	F
7	Modelling and analysis of 15 storied sloping building having setback & step back configuration rested on 20° slope.	G
8	Modelling and analysis of 15 storied sloping building having setback & step back configuration rested on 30° slope.	H
9	Modelling and analysis of 15 storied sloping building having setback & step back configuration rested on 40° slope.	I

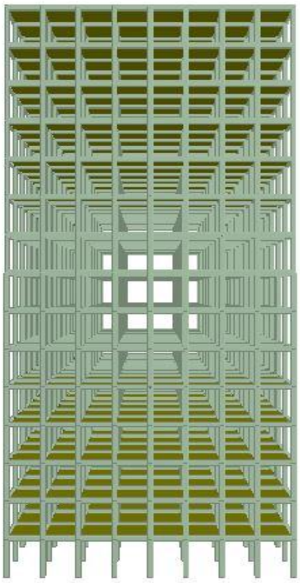


Fig. 1: *Case A*

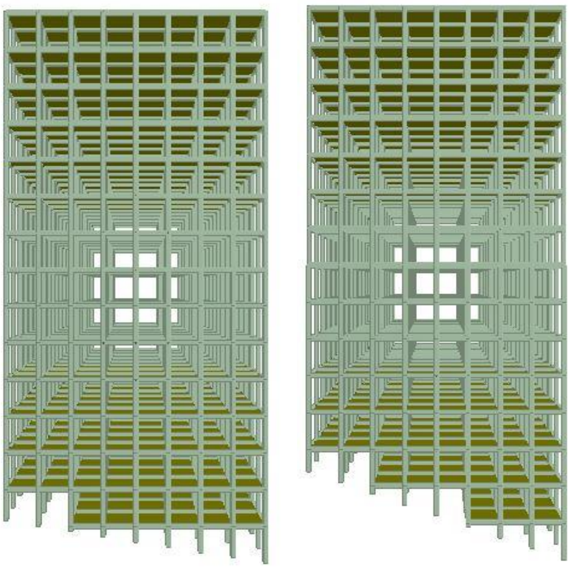


Fig. 2: *Case B & Case C*

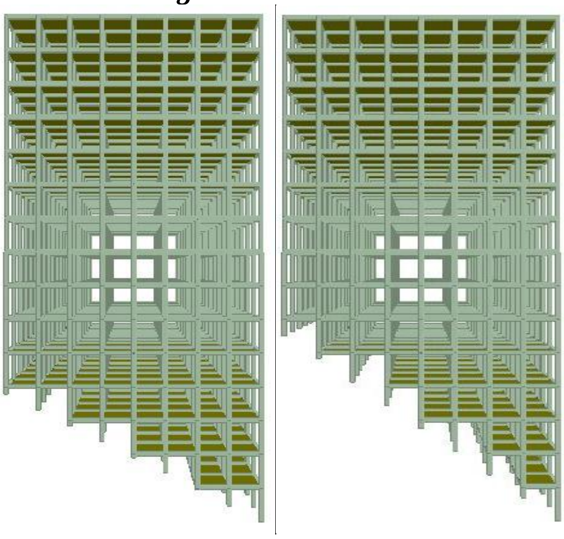


Fig. 3: *Case D & Case E*

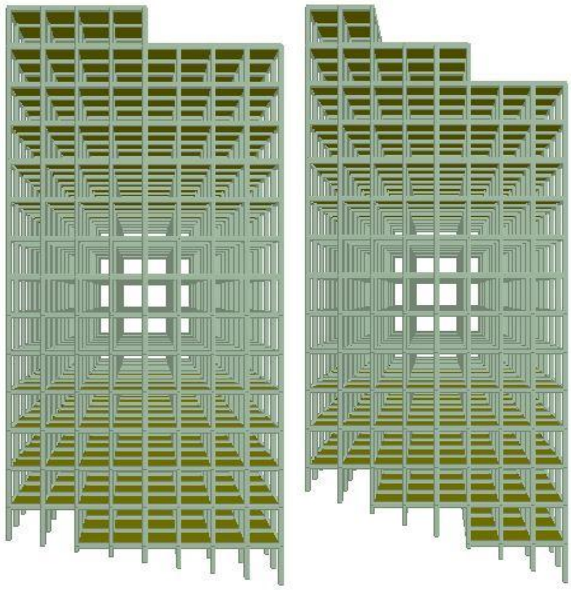


Fig. 4: *Case F & Case G*

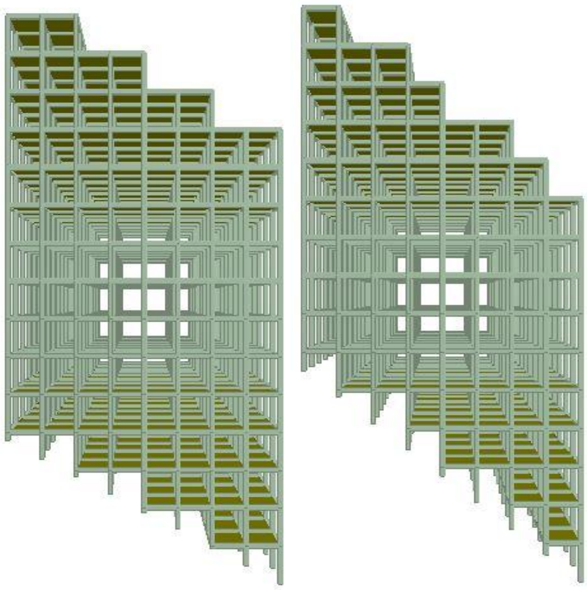


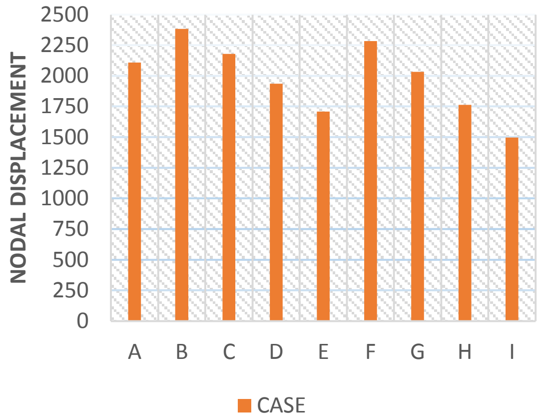
Fig. 5: *Case H & Case I*

4. RESULTS AND DISCUSSION

In this research study various cases are analyzed as per IS 1893:2002(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 encompassing normal structure, stepback configuration and stepback & setback configuration. The parameters taken for comparative examinations are maximum nodal displacement, maximum axial force, maximum shear force, maximum bending moment, maximum torsional moment, and story drift in both tabular and graphical form.

Table 4: Maximum Nodal displacement for various cases

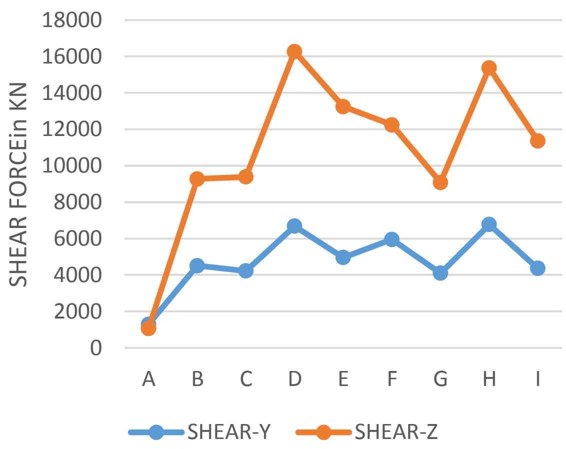
CASE	NODE	DISPLACEMENT
A	136	2108.381
B	136	2383.954
C	1288	2179.219
D	1288	1936.464
E	1288	1708.831
F	1279	2284.032
G	136	2034.934
H	136	1763.299
I	136	1498.009



Graph 1: *Graphical representation of Nodal Displacement for all cases*

Table 5: Maximum Shear Force in Y & Z direction for various cases

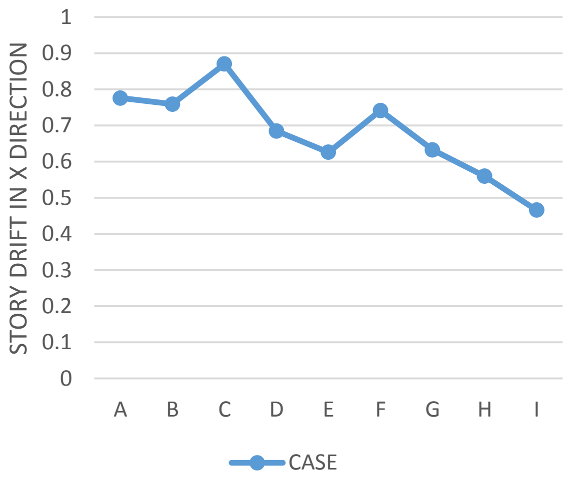
CASE	SHEAR Y	SHEAR Z
A	1298.648	1071.393
B	4516.147	9278.059
C	4221.975	9385.124
D	6678.224	16264.766
E	4963.825	13242.391
F	5955.342	12243.537
G	4096.297	9080.987
H	6769.776	15367.652
I	4362.973	11352.542



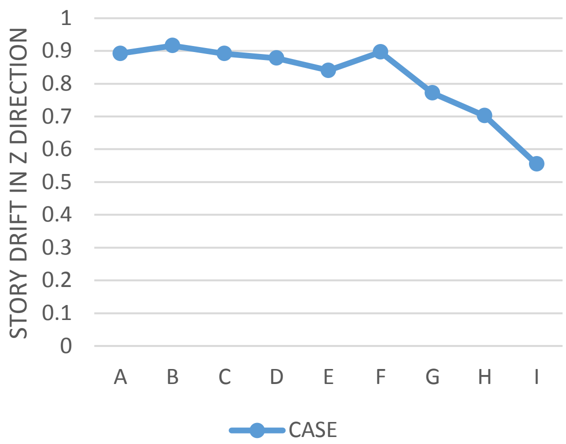
Graph 2: *Graphical representation of Shear Force in Y & Z direction*

Table 6: Maximum Story Drift in X & Z direction for various cases

CASE	FLOOR	HEIGHT	MAXIMUM STORY DRIFT	
			X DIRECTION	Z DIRECTION
A	G+8	32.94	0.7759	
	G+8	32.94		0.8919
B	G+8	32.94	0.7589	
	G+2	10.98		0.9162
C	G+1	7.32	0.87	
	G+8	32.94		0.8915
D	G+8	32.94	0.6844	
	G+8	32.94		0.8779
E	G+8	32.94	0.6260	
	G+8	32.94		0.8401
F	G+8	32.94	0.7411	
	G+2	10.98		0.8965
G	G+8	32.94	0.6326	
	G+4	18.3		0.7717
H	G+8	32.94	0.5596	
	G+5	21.96		0.702
I	G+12	47.58	0.4659	
	G+6	21.96		0.5546



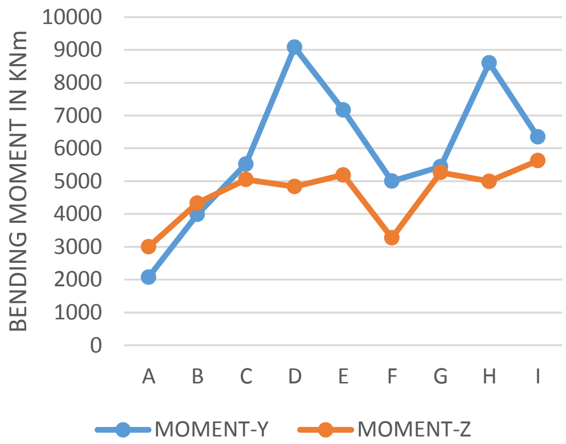
Graph 3: *Graphical representation of Story Drift in X direction for all cases*



Graph 4: *Graphical representation of Story Drift in Z direction for all cases*

Table 7: Maximum Moment in Y & Z direction for various cases

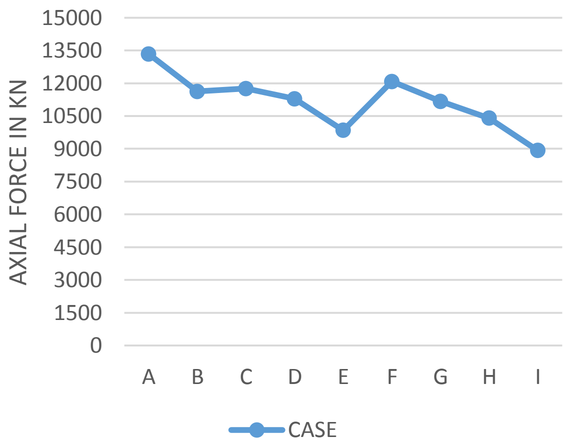
CASE	MOMENT Y	MOMENT Z
A	2075.066	2998.823
B	3985.588	4330.206
C	5525.652	5047.739
D	9083.899	4835.838
E	7168.174	5190.821
F	5000.948	3273.717
G	5442.254	5262.22
H	8603.193	4996.412
I	6348.461	5625.764



Graph 5: *Graphical representation of Moment in Y & Z direction*

Table 8: Maximum Axial forces for various cases

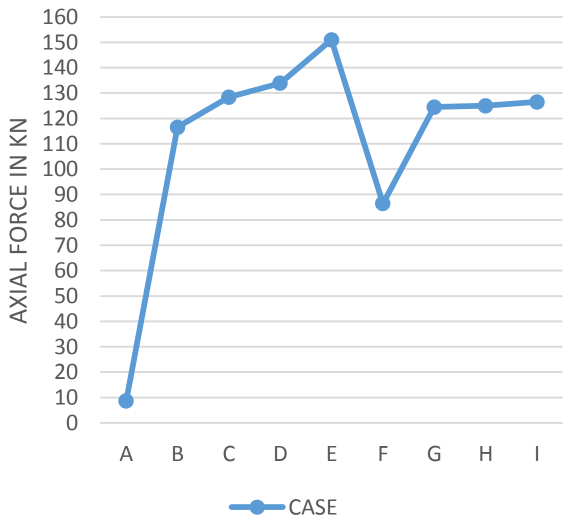
CASE	AXIAL FORCE
A	13338.367
B	11626.208
C	11754.453
D	11288.041
E	9847.439
F	12080.475
G	11170.259
H	10399.609
I	8923.104



Graph 6: *Graphical representation of Axial Force for all cases*

Table 9: Maximum Torsional moment for various cases

CASE	TORSIONAL MOMENT
A	8.623
B	116.503
C	128.383
D	133.842
E	150.985
F	86.456
G	124.467
H	124.97
I	126.499



Graph 7: *Graphical representation of Torsional moment for all cases*

5. CONCLUSIONS

Till date various researches has 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 cases it has been concluded that the nodal displacement is found minimum for case I with a value of 1498.009mm.
2. After analyzing shear force the best case found out of all cases is case A, C & G. Out of that A is simple building rested on plain ground without any irregularity so the optimum cases are C & G.
3. On comparing story drift for all the cases at each story it was concluded that the cases H and I are most efficient in both directions longitudinal as well as transverse respectively.
4. Subsequently analyzing bending moment the most optimum case out of all cases is case A & B. Out of that A is simple building rested on plain ground without any irregularity so the most efficient is case B.
5. After comparing various cases the results obtained for axial forces are case I is found the most efficient one at the base story results.
6. On comparing various cases it has been found that the torsional moment is least for case A, B & F.
7. 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 the case I& B is found most efficient.

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