Lateral Stability of Irregular RC Building With Shear Wall Located on Slope

Muluk Shreyas Shankar[1] Mulay B.N.[2], Patil S.K.[3], Pujari A.B.[4]

[1]Post Graduate Student, at K J College of Engineering and Management Research, Pune, Maharashtra, India.
[2]Assistant Professor of Civil Engineering Department, at K J College of Engineering and Management Research, Pune, Maharashtra, India.
[3]Associate Professor and HOD of Civil Engineering Department, at K J College of Engineering and Management Research, Pune, Maharashtra, India.
[4]Associate Professor of Civil Engineering Department, at K J College of Engineering and Management Research, Pune, Maharashtra, India.

---***---

Abstract - *Structure subjected to seismic/earthquake forces are always vulnerable to damage and if it occurs on a sloped building as on hills which is at some inclination to the ground the chances of damage increases much more due to increased lateral forces on short columns on uphill side and thus leads to the formation of plastic hinges. Structures on slopes differ from those on plains because they are irregular horizontally as well as vertically. In north and northeastern parts of India have large scale of hilly terrain which falls in the category of seismic zone IV and V.*

In present work a parametric investigation has been carried out, in which hill buildings slopes are geometrically varied in angle and effect of shear wall studied. The ground slope variation is in range of 15^0,25^0,35^0 and 45^0 respectively. Total eight analytical models of S+8 storeyed buildings have been subjected to seismic forces along and across hill slope direction and Response Spectrum analysis have been done using structural engineering software ETABS 18.0.The seismic parameters based on IS 1893 (part 1):2016 obtained from analyses have been discussed in terms of fundamental time periods, diaphragm displacements, storey drifts and storey shear in buildings, modal behavior and diaphragm acceleration compared within the considered configurations of hill buildings.

Key Words: Response spectrum, diaphragm acceleration, Displacement, Drift, Shear Wall, ETAB-2017.

1. INTRODUCTION

Earthquake is the most disastrous and unpredictable phenomenon of nature. When a structure is subjected to seismic forces it does not cause loss to human lives directly but due to the damage cause to the structures that leads to the collapse of the building and hence to the occupants and the property. Mass destruction of the low and high rise buildings in the recent earthquakes leads to the need of investigation especially in a developing country like India.

The adobe burnt brick, stone masonry & dressed stone masonry buildings are generally made over level ground in hilly regions. Since level land in hilly regions is very limited, there is a pressing demand to construct buildings on hill slope. Hence construction of multi-storey RC Framed buildings on hill slope is the only feasible choice to accommodate increasing demand of residential & commercial activities.

Now a days, rapid construction is taking place in hilly areas due to scarcity of plain ground. As a result the hilly areas have marked effect on the buildings in terms of style, material and method of construction leading to popularity of multi-storeyed structures in hilly regions. Due to sloping profile, the various levels of such structures step back towards the hill slope and may also have setback also at the same time.

1.1 Need of Structure General

India consists of great arc of mountains which consists of Himalayas in its northern part which was formed by on-going tectonic collision of plates. In this region the housing densities in good quantity. Hence there is need of study of seismic safety and the design of the structures on slopes. The response of a sloped building depends on frequency content of the earthquake as it affects its performance when it is subjected to ground motion. Such buildings have mass and stiffness varying along the vertical and horizontal plains, resulting the center of mass and center of rigidity do not coincide on various floors. This requires torsional analysis; in addition to lateral forces under the action of earthquakes

2. Objective of Study

The purpose of this project is to study three dimensional analysis of two different configurations of buildings which is built on sloping ground has been undertaken and the effect of plain aspect ratio has been parametrically studied by altering slopes using 15, 25 and 35 degree angles. Results have been discussed in terms of static and dynamic properties of buildings such as shear forces, bending moments induced in the columns at foundation level, fundamental time periods, diaphragm displacements, storey drifts and storey shear in buildings and compared within the considered configurations of hill buildings.

Three dimensional space frame analysis of S+8 storied is carried out for eight analytical models with variation of slope angles and provision of shear walls. Dynamic response of these buildings using ETABS 18.0 software, in terms of base shear & top floor displacement is presented & compared within the considered configuration as well as with other configurations.

3. DETAILS OF STRUCTURE CONSIDERED

Table- I: Data of the Structures

Total storey and height of building	(S+8) , 26.5 m
Height of each storey	3.1m
Depth of foundation	1.9m
Size of beams (G+3)	230 mm x 450 mm
Size of beams (G+5, G+12)	300 mm x 500 mm
Thickness of slab	125 mm
Thickness of external walls	230 mm
Thickness of internal walls	115mm
Seismic zone	V
Soil condition	Medium
Response reduction factor	5
Importance factor	1.2
Floor finishes	1.0 kN/m^2
Live load at all floors	3 kN/m^2
Grade of Concrete	M30
Grade of Steel	Fe500
Density of Concrete	25 kN/m^3

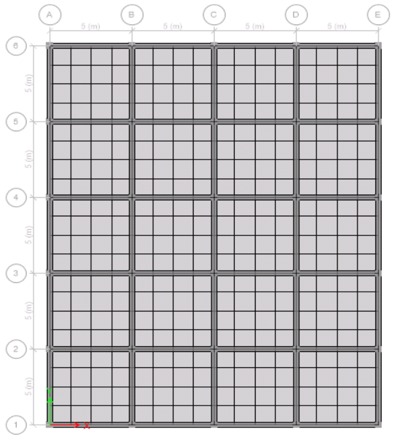


Fig. I: 5 x 4 bay building typical plan for all BC models

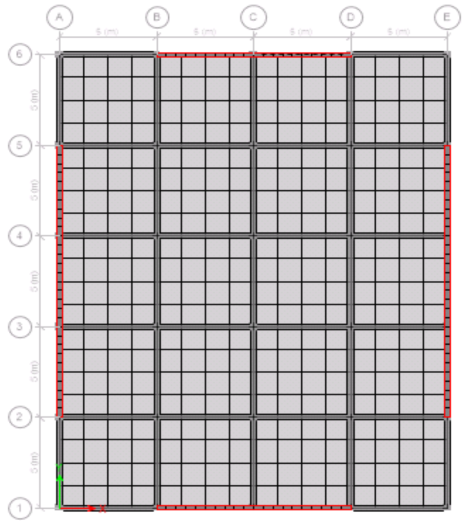


Fig. II 5 x 4 bay building typical plan for all SW models

4. RESULTS AND DISCUSSION

The results are obtained based on Displacement, and Base Shear, and mode vs period Table 2 and Table 3 show Storey displacement in X and Y direction respectively and Graph 1 and Graph 2 are respective graphs. The base shear results show in Table 4 and Table 5 and its graphical representation in Graph 3 and Graph 4. Table 6 shows mode vs period and its graphical representation in graph 5.

Table-II: Displacement at floor levels for all model in X direction

Story	15 BC	25 BC	35 BC	45 BC	15 SW	25 SW	35 SW	45 SW
Base	0	0	0	0	0	0	0	0
Story1	0	0.18	0.25	0.077	0.0000109	0.042	0.012	0.0002535
Story2	3.755	2.214	1.719	0.593	0.588	0.242	0.072	0.045
Story3	8.018	8.053	3.087	1.286	0.952	0.533	0.074	0.076
Story4	15.458	14.809	4.792	1.809	1.753	1.131	0.339	0.053
Story5	22.682	20.898	7.092	2.292	2.682	1.932	0.682	0.212

Story6	29.414	27.451	10.773	3.468	3.688	2.848	1.241	0.375
Story7	35.351	33.284	16.539	7.502	4.731	3.836	1.923	0.723
Story8	40.163	38.414	21.765	11.313	5.785	4.863	2.671	1.137
Story9	43.507	42.59	26.331	16.604	6.815	5.9	3.458	1.606
Terrace	45.558	46.042	30.012	20.669	7.803	6.934	4.254	2.086
Additional Story 1		48.831	33.012	23.736		8.005	5.048	2.567
Additional Story 2		50.832	35.39	25.649		9.279	5.868	3.08
Additional Story 3			36.972	26.096			6.831	3.883

Table-III: Displacement at floor levels for all model in X direction

Story	15 BC	25 BC	35 BC	45 BC	15 SW	25 SW	35 SW	45 SW
Base	0	0	0	0	0	0	0	0
Story1	0	0.278	0.36	0.147	0.002	0.044	0.027	0.01
Story2	8.99	2.331	2.601	1.128	0.359	0.152	0.101	0.096
Story3	16.695	6.701	5.171	2.325	0.568	0.336	0.195	0.195
Story4	24.358	12.32	8.196	2.972	0.946	0.574	0.347	0.235
Story5	31.469	18.453	11.973	3.273	1.375	0.853	0.534	0.354
Story6	38.017	26.568	16.624	3.602	1.828	1.205	0.754	0.491
Story7	43.714	33.997	21.894	4.499	2.288	1.579	1.052	0.648
Story8	48.213	40.65	26.601	4.375	2.746	1.962	1.369	0.812
Story9	51.167	46.271	30.566	4.402	3.185	2.341	1.693	1.034
Terrace	51.292	50.725	33.981	4.407	3.318	2.749	2.015	1.255
Additional Story 1		53.93	37.889	3.568		3.119	2.168	1.305
Additional Story 2		55.83	40.666	2.726		3.599	2.245	1.266
Additional Story 3			42.19	1.884			2.333	1.204

Table-IV: Base shear and roof displacement for all model in X direction

MODEL	BASE SHEAR	DISPLACEMENT
NAME	KN	mm
15 BC	2292.1751	45.558
25 BC	2032.7571	50.832
35 BC	1892.5504	36.972
45 BC	2192.407	26.096
15 SW	2830.0571	7.803
25 SW	2576.4929	9.279
35 SW	2299.9068	6.831
45 SW	1961.4114	3.883

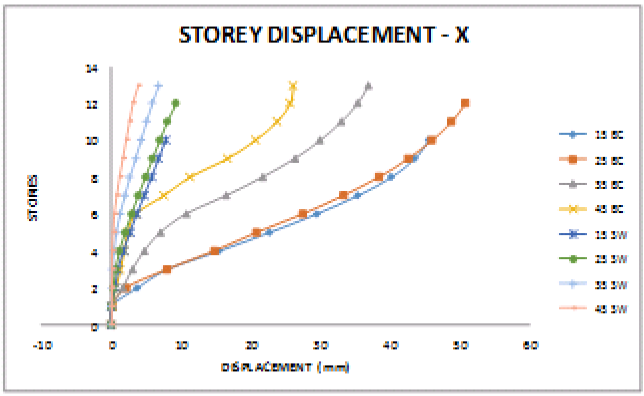
Table-V: Base shear and roof displacement for all model in X direction

MODEL	BASE SHEAR	DISPLACEMENT
NAME	KN	mm
15 BC	2485.9988	51.292
25 BC	2251.5719	55.83
35 BC	2115.8441	42.19
45 BC	793.8813	1.884
15 SW	3069.3634	3.318
25 SW	2853.8377	3.599

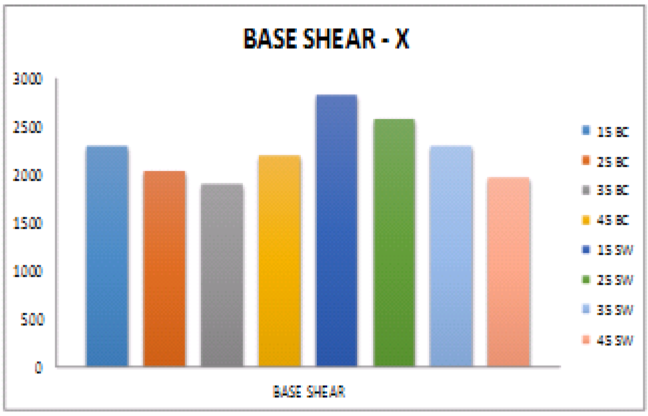
35 SW	2571.2628	2.333
45 SW	2192.8298	1.204

Table VI: Mode shapes variation for all models

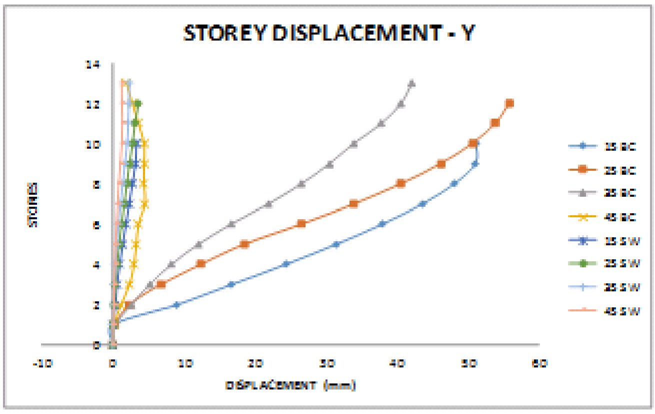
Modes	15 BC	25 BC	35 BC	45 BC	15 SW	25 SW	35 SW	45 SW
	Period (sec)							
1	1.208	1.303	1.143	0.866	0.421	0.468	0.416	0.313
2	1.14	1.223	1.118	0.835	0.27	0.277	0.267	0.227
3	0.992	1.097	0.978	0.738	0.208	0.227	0.186	0.137
4	0.389	0.44	0.403	0.348	0.102	0.149	0.139	0.132
5	0.377	0.407	0.399	0.323	0.078	0.134	0.128	0.128
6	0.328	0.375	0.348	0.278	0.07	0.102	0.091	0.126
7	0.223	0.273	0.274	0.253	0.069	0.079	0.075	0.123
8	0.222	0.255	0.266	0.246	0.057	0.06	0.074	0.116
9	0.194	0.235	0.223	0.195	0.053	0.053	0.073	0.095
10	0.16	0.195	0.212	0.194	0.049	0.051	0.072	0.075
11	0.156	0.187	0.2	0.179	0.049	0.042	0.068	0.073
12	0.137	0.168	0.179	0.164	0.049	0.037	0.06	0.052



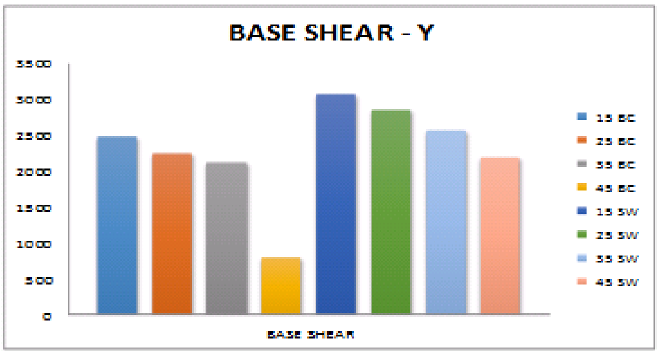
Graph-I: Storey Displacement in X Direction



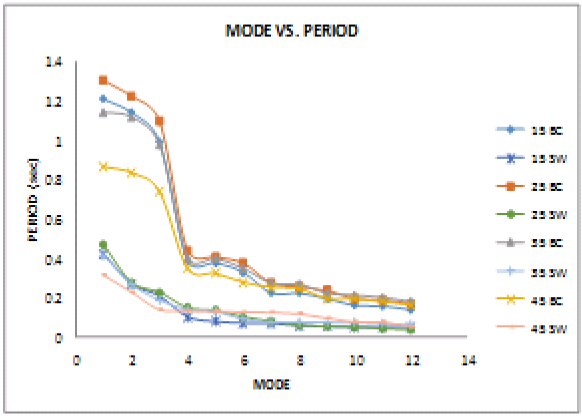
Graph-III: Base shear and roof displacement for all model in X direction



Graph-II: Storey Displacement in Y Direction



Graph-IV: Base shear and roof displacement for all model in V direction



Graph-V: Mode vs. period variation for all models

5. CONCLUSIONS

A. Storey Displacement

1. Performance of all beam column models having higher displacement values in X and Y direction.

2. Model 25BC and 25SW shows maximum storey displacement which clears effect of angle torsion in vertical element in X and Y direction.

3. Model 15BC shows less displacement in X and Y direction as compared to 25BC model it may due to less angle distributed lateral load uniformly and very less column subjected short column effect.

4. All Shear wall models (SW) performed well in X and Y direction and shows very less storey displacement even in Y direction where slope is along Y direction. It is due to increased stiffness due addition of shear wall and reduced height of shear wall.

B. Base Shear and displacement

1. Base shear of model 35BC,45BC and 35SW,45SW observed as lowest and model 15SW and 15BC observed as highest values in X . From this it is clear that as slope angle of ground increases with respect to horizontal the height of vertical element columns/shear wall reduces and reduced height increases stiffness which attracts the more lateral force. increase of stiffness i.e replacement of column by shear wall.

2. Reduction of displacement observed maximum in case of model 45SW when compared to all other models which counts to be only 9% and 3% respectively in X and Y direction. In Y direction model 45BC shows maximum reduction in displacement as compared to X direction it is due to ground slope is in y direction.

C. Mode Vs Fundamental Time period

1. Time period is reducing with rising ground slope angles. 2. Model 15BC,25BC and 35BC shows higher time period (i.e > 1sec) in their first mode as compared to all other models. This indicates flexibility or deformability of structure whereas less time period denotes stiffer structure. 3. first three modes of all BC models having reduction in time period from 3% to 14% which shows stiffer to flexible model and all SW models shows reduction in time period from 22% to 55%.As per IS 1893:2016 the modal time period should be apart at least by 10%. This clears shear wall models performed well.

REFERENCES

[1]B.G. Birajdar and S. S. Nalawade,"Seismic analysis of buildings resting on sloping ground".In Thirteenth World Conference on Earthquake Engineering (13WCEE), 2004, Vancouver, Canada.

[2]S.M.Nagargoje and K.S.Sable,"Seismic performance of multistoreyed building onsloping ground", Elixir International Journal, 7 December 2012.

[3]Y.Singh,"Seismic Behavior of Buildings Located on Slopes" - An Analytical Study and Some Observations From Sikkim Earthquake of September 18, 2011.15th World Conference on Earthquake Engineering Journal 2012.

[4] Arango and Uribe, "Common practice in growing cities located in mountainous regions to undertake the construction of buildings". iternational Symposium on New Technologies for Urban Safety of Mega Cities in Asia (USMCA 2013) Report No: IIIT/TR/2013/-1.

[5] D.H. Lang and E. Erduran,"Buildings in hilly areas have to be configured differently due to scarcity of flat ground". An analytical study and some observations from Sikkim earthquake of September 18, 2011. 15 WCEE, Lisbon, Portugal.

[6] Joseph and Phadtare, "Effect of earthquake on step back-setback structure with bracing on different slope of ground".Thesis(1996), Earthquake engineering, University of Roorkee, Roorkee.

[7] Ravikumar C M, Babu Narayan K S, "Effect of Irregular Configurations on Seismic Vulnerabilityof RC.Buildings". ArchitectureResearch2012,2(3):20-26DOI: 10.5923/j.arch.20120203.01.

[8]Rayyan-Ul-Hasan Siddiqui and , H. S. Vidyadhara, "Seismic Analysis of Earthquake Resistant Multi Bay Multi Storeyed 3D – RC Frame" International Journal of Engineering Research & Technology (IJERT) ISSN: 2278- 0181 Vol. 2 Issue 10, October – 2013.

[9] Dr. S. A. Halkude, "Seismic Analysis of Buildings Resting on Sloping Ground With Varying Number of Bays and Hill Slopes" International Journal of Engineering Research and Technology ISSN:2278- 0181,Vol.2 Issue 12, December-2013.

[10]Prashant D, Dr. Jagadish Kori G, " Seismic Response of one way slope RC frame building with soft storey" International Journal of Emerging Trendsin Engineering and Development Issue 3, Vol.5 (September 2013).

[11]Mohammed Umar Farooque Patel, "A Performance study and seismic evaluation of RC frame buildings on sloping ground" IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN: 2278-1684, p-ISSN: 2320-334X-, PP 51-58, 2014.

AUTHORS PROFILE

Muluk Shreyas Shankar is a PG student of Structural Engineering at Civil Engineering Department, KJ College of Engineering and Management Research,Pune,Maharashtra.

Mulay B.N. is working as Assistant Professor in Civil Engineering Department,KJ Collegeof Engineering and Management Research, Pune, Maharashtra.

Dr Santosh K Patil is HOD of Civil Engineering Department, KJ College of Engineering and Management Research, Pune,Maharashtra.

Dr Atul B. Pujari is working as Associate Professor in Civil Engineering Department, at KJ College of Engineering and Management Research, Pune, Maharashtra.