International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056
Volume: 02 Issue: 04 | July-2015 www.irjet.net p-ISSN: 2395-0072

LATERAL STABILITY OF MULTISTOREY BUILDING ON SLOPING GROUND

Nagarjuna
Research scholar, civil engineering, SDMCET, Dharwad, Karnataka, India

Shivakumar B. Patil
Assistant professor, civil engineering, SDMCET, Dharwad, Karnataka, India

---***---

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+ 10 storeys RCC building and the ground slope varying from 10^0 to 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 and the effect of shear wall at different position during the earthquake. The results have been compared with the results of the building with and without shear wall. 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 slopy ground the stepback setback building configuration is suitable, along with shear wall placed at the corner of the building.*

Key Words: Sloping ground, Linear static analysis, Stepback, Stepback setback and Response spectrum analysis.

1. 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 to 40^o.
- To capture the response for the three types of modelling
  - I. Step back
  - II. Set back
  - III. Step back set back
- To obtain capacity curve.
- To study the performance evaluation of building under the presence of shear wall.

1.2 METHODOLOGY

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

2. MODELING AND ANALYSIS

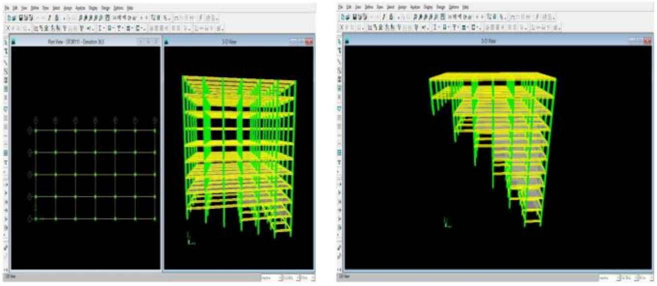
In the present study, three building configurations are considered, which include step back buildings, stepback setback buildings and set back buildings situated on sloping ground. Number of storey considered for each type of configurations is 10 storeys. Plan layout of each configuration includes 4 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 10 degree, 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\m^2
For Terrace	: 1.5 kN\m^2
Floor finish	: 1 kN\m^2
Concrete Grade	: M_{20}
Modulus of Elasticity	: 22360000 kN\m^2
Poison's ratio	: 0.17
Compressive strength	: 20000 kN\m^2
Steel	: Fe415
Strength of steel	: 415000 kN\m^2
Thickness of Shear wall	:150mm

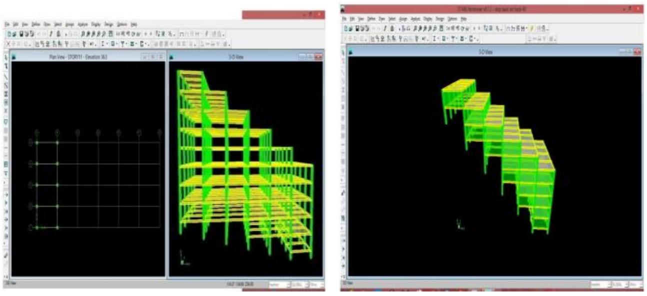
As per IS 1893 (part 1): 2002 following methods have been recommended to determine the design lateral loads which are:

1. Equivalent Static Method
2. Response Spectrum Method



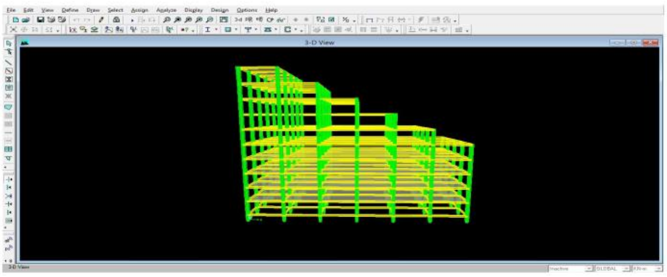
10 degree slope 40 degree slope

Fig-1: Typical Step back building model on 10 to 40⁰ slope



10 degree slope 40 degree slope

Fig-2: Typical Stepback setback building model on 10 to 40⁰ slope



ON LEVEL GROUND

Fig- 3: Typical Setback building model on level ground

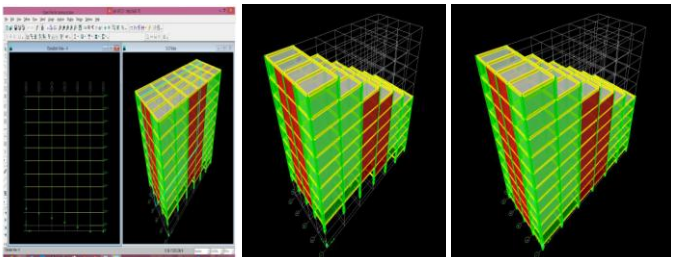


Fig-4: Shear wall present at the center of the building

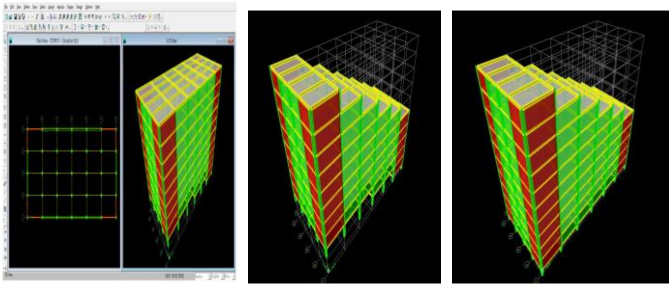


Fig-5: Shear wall present at the corner of the building

3.RESULTS AND DISCUSSION

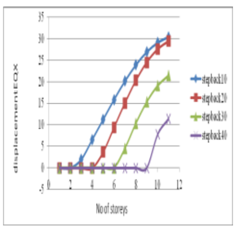
EQUIVALENT STATIC METHOD

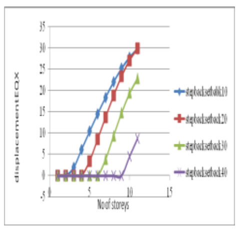
Top Storey Displacement, Base Shear and Storey Drift

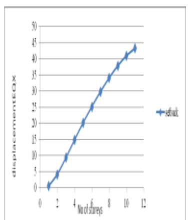
Table-1: Analysis results of displacement, base shear, drift values obtained by Equivalent static method

Model configuration	Slope angle in degree	Top storey Displacement(mm)		Top storey Drift(mm)		Base shear(kN)		Time period (s)	
		EQX	EQY	EQX	EQY	EQX	EQY	EQX	EQY
STEP BACK	10	30.42	23.154	0.384	0.294	787.67	676.86	2.5646	2.4673
	20	29.403	19.860	0.536	0.346	1104.71	997.14	2.3209	2.5712
	30	22.481	11.892	0.68	0.354	1368.77	979.51	1.6065	2.2450
	40	11.426	3.956	1.046	0.708	2311.76	970.76	0.7691	1.8314
STEP BACK SET BACK	10	29.814	33.697	0.564	0.387	753.46	753.80	1.9275	1.9267
	20	29.317	31.974	0.805	0.519	1056.23	1003.78	1.6838	1.7717
	30	21.625	21.125	1.008	0.612	1214.11	1096.87	1.1663	1.2910
	40	8.65	4.924	1.194	0.867	1479.41	964.86	0.5031	1.0242
SET BACK	Level ground	43.189	51.896	0.666	0.471	901.65	886.68	2.7238	2.7698

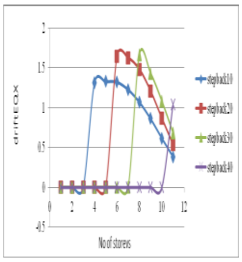
DISPLACEMENT

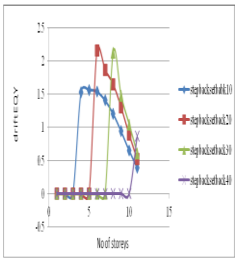


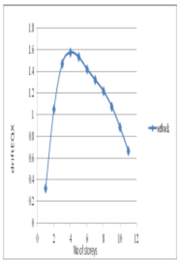




DRIFT







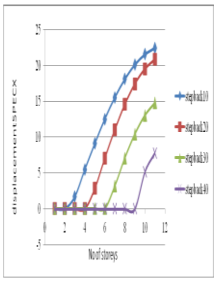
RESPONSE SPECTRUM METHODSTEP BACK

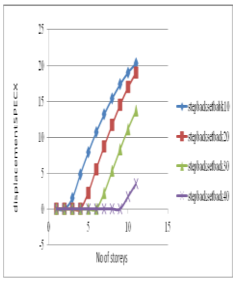
Top Storey Displacement, Base Shear and Storey Drift

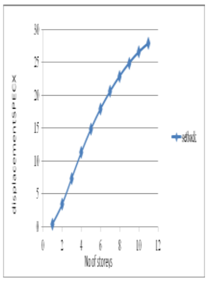
Table -2: Analysis results of displacement, base shear, drift values obtained by Response spectrum method

Model configuration	Slope angle in degree	Top storey Displacement(mm)		Top storey Drift(mm)		Base shear(kN)	
		SPECX	SPECY	SPECX	SPECY	SPECX	SPECY
STEP BACK	10	22.451	16.025	0.337	0.224	847.67	726.86
	20	20.852	14.947	0.500	0.306	1164.71	1047.14
	30	14.746	10.604	0.592	0.375	1428.77	1029.51
	40	7.789	5.059	0.764	0.911	2371.76	1020.76
STEP BACK SET BACK	10	20.331	22.955	0.514	0.264	813.46	803.8
	20	19.055	22.205	0.798	0.440	1116.23	1053.78
	30	13.695	12.135	0.878	0.389	1274.11	1146.87
	40	3.543	1.662	0.525	0.297	1539.41	1014.86
SET BACK	Level ground	27.907	31.637	0.575	0.321	961.65	936.68

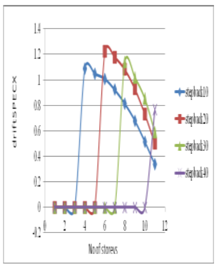
DISPLACEMENT

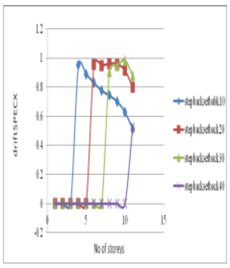


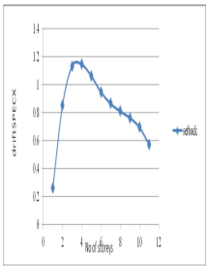




DRIFT







PRESENCE OF SHEAR WALL AT CENTER

Displacement, Base Shear and Storey Drift and Time period

Table-3 : Analysis results in the presence of shear wall at centre of buildings obtained by Equivalent static method

Model configuration	Slope angle in degree	Top storey Displacement (mm)		Top storey Drift(mm)		Base shear(kN)		Time period(s)	
		EQX	EQY	EQX	EQY	EQX	EQY	EQX	EQY
STEP BACK	10	13.344	14.290	0.341	0.469	2678.51	2319.39	1.1097	1.2815
	20	10.79	8.911	0.315	0.307	3029.92	2253.50	0.8872	1.1928
	30	8.447	4.477	0.224	0.157	2974.28	2046.14	0.7828	1.1275
	40	5.45	2.700	0.262	0.125	2786.98	1772.20	0.6087	1.0505
STEP BACK SET BACK	10	14.32	14.479	0.966	0.469	2130.68	1967.44	0.7285	0.7890
	20	13.43	11.508	1.277	0.379	2755.18	2454.24	0.6753	0.7581
	30	12.343	5.817	1.150	0.169	2221.14	2223.16	0.6128	0.6358
	40	7.236	1.929	1.094	0.082	1544.51	1545.18	0.4534	0.6320
SET BACK	Level ground	20.484	24.552	1.496	0.753	3382.72	2352.25	0.7618	1.0955

PRESENCE OF SHEAR WALL AT CORNER

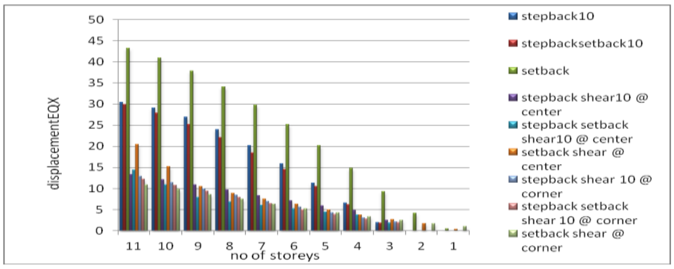
Displacement, Base Shear and Storey Drift and Time period

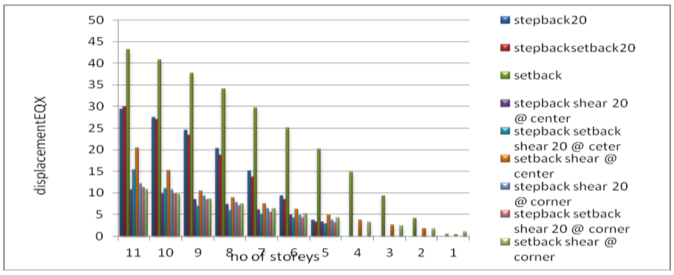
Table -4: Analysis results in the presence of shear wall at corner of buildings obtained by Equivalent static method

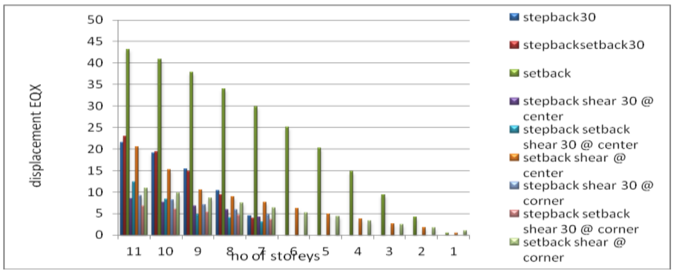
Model configuration	Slope angle in degree	Top storey Displacement (mm)		Top storey Drift(mm)		Base shear(kN)		Time period(s)	
		EQX	EQY	EQX	EQY	EQX	EQY	EQX	EQY
STEP BACK	10	12.826	14.454	0.402	0.487	2251.45	1740.67	0.9617	1.2437
	20	12.185	10.802	0.403	0.405	2859.19	2048.60	0.9418	1.3145
	30	9.191	5.428	0.300	0.233	3008.73	1920.18	0.7684	1.2040
	40	5.935	2.579	0.157	0.121	2794.33	1675.53	0.5809	1.1140
STEP BACK SET BACK	10	12.179	16.808	0.401	0.592	2204.61	1706.24	0.7063	0.9126
	20	11.291	13.832	0.387	0.542	2275.08	2133.22	0.6728	0.8753
	30	6.758	7.127	0.198	0.318	2228.49	2036.97	0.5475	0.7308
	40	3.193	2.093	0.055	0.082	1551.86	1467.48	03706	0.7064
SET BACK	Level ground	10.878	20.409	0.322	0.650	3382.72	2946.06	0.6349	0.9598

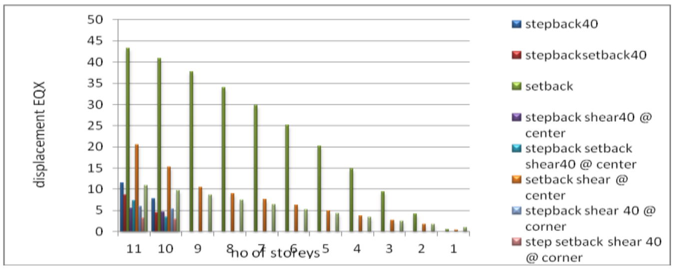
COMPARISON OF BUILDING MODEL WITHOUT SHEAR WALL, @ CENTRE, AND @ CORNER

DISPLACEMENT

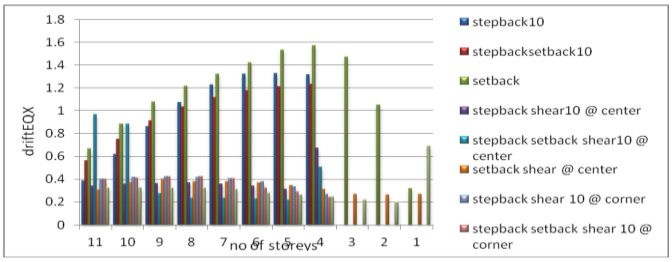


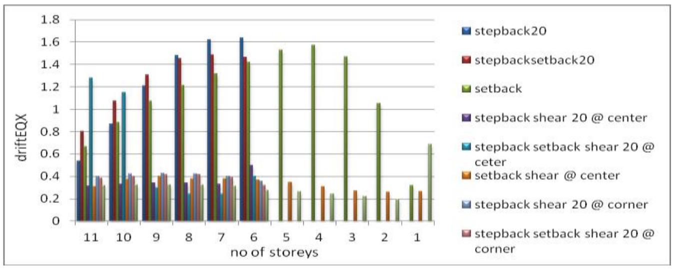


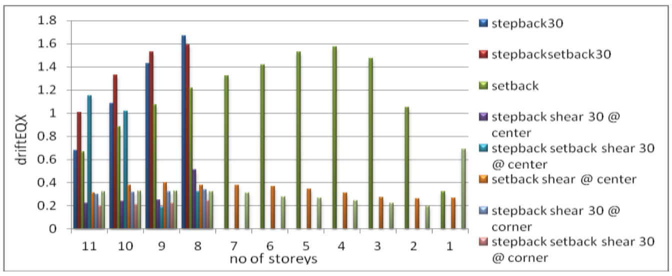


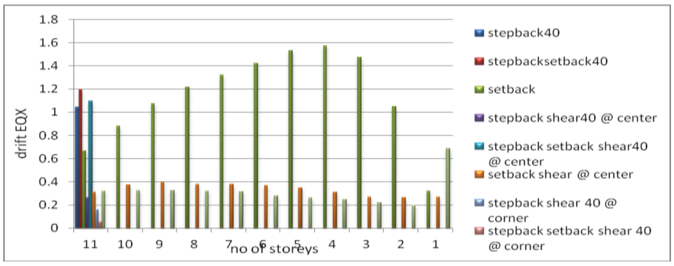


DRIFT





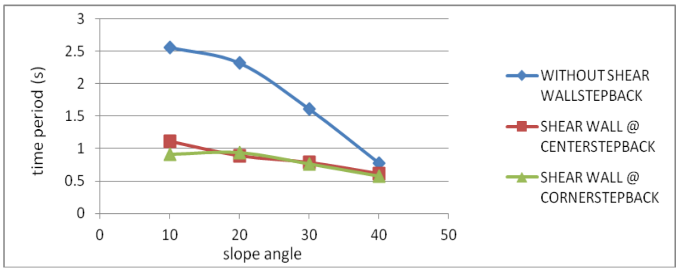




TIME PERIOD

Table-5: Time period of buildings obtained by Equivalent static method

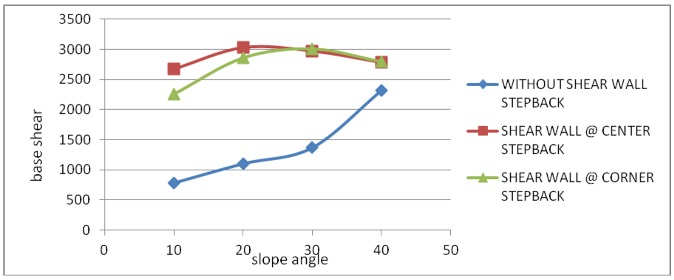
building configuration	angles in degree	without shear wall		Shear wall @ centre		Shear wall @ corner	
		EQX	EQY	EQX	EQY	EQX	EQY
STEP BACK	10	2.5646	2.5712	1.1097	1.2815	0.9167	1.2439
	20	2.3209	2.5712	0.8872	1.1928	0.9418	1.3145
	30	1.6065	2.2450	0.7828	1.1275	0.7684	1.2040
	40	0.7691	1.8314	0.6087	1.0505	0.5809	1.1140
STEP BACK SET BACK	10	1.9275	1.9267	0.7285	0.7890	0.7063	0.9126
	20	1.6838	1.7717	0.6753	0.7581	0.6728	0.8753
	30	1.1663	1.2910	0.6128	0.6358	0.5475	0.7308
	40	0.5031	1.0242	0.4534	0.6320	0.3706	0.7064
SET BACK	On level ground	2.7238	2.7698	0.7618	1.0955	0.6349	0.9598



BASE SHEAR

Table-6: Base of buildings obtained by Equivalent static method

building configuration	angles in degree	without shear wall		Shear wall @ centre		Shear wall @ corner	
		EQX	EQY	EQX	EQY	EQX	EQY
STEP BACK	10	787.67	676.86	2678.51	2319.39	2251.45	1740.67
	20	1104.71	997.14	3029.92	2253.50	2859.19	2048.60
	30	1368.77	979.51	2974.28	2046.14	3008.73	1920.18
	40	2311.76	970.76	2786.98	1772.20	2794.33	1675.53
STEP BACK SET BACK	10	753.46	753.80	2130.68	1967.44	2204.61	1706.24
	20	1056.23	1003.78	2755.18	2454.24	2275.08	2133.22
	30	1214.11	1096.87	2221.14	2223.16	2228.49	2036.97
	40	1479.41	964.86	1544.51	1545.18	1551.86	1467.48
SET BACK	On level ground	901.65	886.68	3382.72	2352.25	4233.03	2496.06



3. CONCLUSIONS

1. In equivalent static method and response spectrum method, as the slope angle increases the top storey displacement and time period reduces.

2. The stepback setback building configuration having less displacement compared to the other two configurations.

3. In response spectrum method base shear value for stepback building 7%, 5%, 4.19%, 2.53%, and for stepback setback building 7.37%, 5.37%, 4.7%, 3.89% more compared to the linear static method.

4. Presence of the shear wall at the corner of the building, displacement & time period value is reduces. For stepback building shear wall percent at corner having displacement 3.85%, 11.48%, 8.094%, 8.171% less compared to the shear wall present at the centre of the building. For stepback setback building shear wall percent at corner having displacement 14.95%, 15.92%, 45.23%, 55.83% for 10^0,20^0, 30^0, 40^0, respectively less compared to the shear wall present at the centre of the building.

5. 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. For stepback building presence of shear wall at the centre of the building is 15%, 21.83%, 25.33%,32% which is lesser than shear wall at the corner building and for stepback setback building presence of shear wall at the centre of the building is 58%, 69.69%, 82.78%, 94.98% which is more than shear wall at the corner building for 10^o 20^o, 30^o, 40^o respectively.

6. Base shear is maximum at 20^o in both stepback and stepback setback buildings.

For construction of the building on sloping ground the stepback setback building configuration is suitable, along with shear wall placed at the corner of the building.

ACKNOWLEDGEMENT

The successful completion of any task would be incomplete without mentioning the people who made it possible. So it is with the gratitude that I acknowledge the help, which crowned my efforts with success.

I am extremely thankful and indebted to my *guide* Asst. Proff.Shivkumar B.Patil for his able guidance, valuable time spent, relentless effort and constant encouragement in the entire tenure of the Project work. It will not be an over statement that the entire journey of the research work is enlightened with his vision and mission.

I express my deep sense of gratitude to K. Anil Hegde , Vimal anil structural and survey consultants Mangalore, who has been a guiding beacon of light, who with his constant motivation and support, has rendered meticulous guidance throughout the research work.

I wish to thank our *coordinator*, Dr. D.K Kulkarni for being a source of technical support, patience and understanding and also for giving an opportunity to carry out our project.

I remain indebted and highly grateful to Dr. S. G Joshi *Head, Department of Civil Engineering* for his keen interest and support in carrying out the project.

I take the opportunity to thank Dr. S. Vanakudre *Principal, S.D.M.C.E.T*, for providing great leading environment and excellent laboratory facilities for successful completion of project.

My special thanks to our department staffs and friends for their cheerful support during execution of Project.

Last but not the least I extend my thanks to my entire family members and friends who helped me directly or indirectly in completion of this task.

REFERENCES

.

1] Dr. S. A. Halkude et al "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

[2] Hemal J shah, Dr.S and S.S Gandhy (2014) "Seismic Time History Analysis Of Building On Sloping Ground Considering Near/Far field Earthquake" (2014)

[3]. Pandey A.D , Prabhat Kumar , Sharad Sharma3 "Seismic soil structure interaction of buildings on hill slopes" Volume 2, No 2, 2011

[4] K.S.L Nikhila, Dr. B Pandunangrao "Static Linear and Nonlinear analysis of R.C Building on Sloping Ground with Varying Hill Slope" American Journal of Engineering Research (AJER) e-ISSN:2320-0847 p-ISSN :2320-0936 Volume-03. Issue-11 (2014).

[5]. N. Jitendra Babu, K.Y.G.D Balaji "Pushover analysis of unsymmetrical framed structures on sloping ground" International Journal of Civil, Structural, Environmental and Infrastructure Engineering Research and Development (IJCSEIERD) ISSN 2249-6866 Vol. 2 Issue 4 Dec- 2012 45-54

[6] Patel, Mohammed Umar Farooque, A. V. Kulkarni, and Nayeemulla Inamdar. "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.

[7]. S.M.Nagargoje and K.S.Sable," Seismic performance of multi-storeyed building on sloping ground", Elixir International Journal, 53 (2012) 11980-11982, 7 December 2012

[8] B.G. Birajdar and S.S. Nalawade5, Seismic analysis of buildings resting on sloping ground, 13th world conference on earthquake engineering, Vancouver, B.C., Canada, August 1-6, 2004, paper No. 1472.

[9] Shivanand.B, H.S Vidyadhara "Design of 3D RC Frame on Sloping Ground" International Journal of Research in Engineering & Technology eISSN-2319-1163 pISSN :2312-7308 Volume 3 Issue:08 Aug 2014.

[10] Ravikumar C M, Babu Narayan K S "Effect of Irregular Configurations on Seismic Vulnerability of RC Buildings" Architecture Research 2012,2(3):20-26DOI: 10.5923/j.arch.20120203.01.

[11]Y. Singh and Phani Gade "Seismic Behaviour 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.

[12] Kalyanrao, Gude Ramakrishna "Pushover Analysis of Sloping Ground Rc- Buildings" International Journals of

Engineering Research & Technology(IJRT) ISSN :2278-0181 Volume-3 Issue 6, June-2014.

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

[14] S: 1893 (I)-2002. "Criteria for Earthquake Resistant Design of Structures" BIS, New Delhi.

[15] Structural Analysis program ETABS V 9.7.4, "User's manual, computers and structures, Inc.

[16] S .K.Duggal "Earthquake resistant design of structures" Oxford university press 2007, ISBN-13:978-0-19-568817-7.

[17] IS: 1893 (part I)-2002. "Criteria for Earthquake Resistant Design of Structures" BIS, New Delhi.

[18] IS: 875 (Part) 1, (Part) 2, (Part) 3,

BIOGRAPHIES

Nagarjuna, Research Scholar, SDMCET,Dharwad, M.Tech. in Computer Aided Design of Structures.

Shivakumar B. Patil ,
M-tech Structures, Assistant Professor SDM College of Engineering and Technology

