STUDY ON EARTHQUAKE RESISITANT BUILDINGS ON GROUND SURFACE BY USING ETABS

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Abstract - *In many parts of India it is common practice to construct buildings on hill slopes, if there is a natural hill sloping terrain. The buildings on a sloping terrain undergo severe torsion under earthquake excitations due to considerable variation in the height of ground floor columns. Buildings constructed on hill slopes are highly unsymmetrical in nature. In the present study, three groups of building (i.e. configurations) are considered, out of which two are resting on sloping ground and third one is on plain ground. The first one is set back buildings and next two are step back and step back-set back buildings. The slope of ground is 10 degree with horizontal, which is neither too steep nor too flat. The height and length of building in a particular pattern are in multiple of blocks (in vertical and horizontal direction), the size of block is being maintained at 5m x 5 m x 4m. The depth of footing below ground level is taken as 2 m where, the hard stratum is available.*

Key Words: *ETABS, set back buckling, step back buckling, ground surface, storey drift.*

1. INTRODUCTION

India had witnessed several major disasters due to earthquakes over the past century. In fact more than 50 percent of the country is considered prone to severe earthquakes. The north - east region of the country as well as the entire Himalayan belt is susceptible to great earthquakes of magnitude more than 8.0 the main cause of earthquakes in these regions is due to the movement of the Indian plate towards the Eurasian plate at the rate of about 50 mm per year. Besides the Himalayan region and the Indo-Gangetic plains, even the peninsular India is prone to severe earthquakes as clearly .illustrated by the Konya (1967), the Latur (1993), and the Jabalpur (1997) earthquakes, Sumatra earthquake (2004) Kashmir earthquake (2005).and Nepal earthquake (2015) The Bhuj earthquake is considered to be the largest intra-plate earthquake ever recorded. The 2001 Bhuj earthquake had great implications for earthquake hazard, not only in India, but also in other parts of the world.

1.1 Significance of study

Hill buildings are different from those in plains; they are very irregular and unsymmetrical in horizontal and vertical planes, and torsionally coupled. Hence, they are susceptible to severe damage when affected by earthquake ground motion. Past earthquakes [e.g. Kangra (1905), Bihar- Nepal (1934 & 1980), Assam (1950), Tokachi-Oki-Japan (1968), Uttarkashi-India (1991)], have proved that buildings located near the edge of stretch of hills or sloping ground suffered severe damages. Such buildings have mass and stiffness varying along the vertical and horizontal planes, 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. Little information is available in the literature about the analysis of buildings on sloping ground. The investigation presented in this paper aimed at predicting the seismic response of RC buildings with different configuration on sloping and plain ground.

1.2 Objectives of the study

- To understand the effect of Earthquake loads in multistoried building.
- To study the effect of sloping ground and nonlinearity of floor level.
- To study the effect of short columns.
- To provide the comparison of various dynamic response properties.
- To prove the building configuration which is more suitable on ground sloping.

2. METHODOLOGY

In the present study, three groups of building (i.e. configurations) are considered, out of which two are resting on sloping ground and third one is on plain ground.

- **Setback buildings.**
- **Step back buildings.**
- **Setback &Step back buildings.**

The slope of ground is 10 degree with horizontal, which is neither too steep nor too flat. The height and length of building in a particular pattern are in multiple of blocks (in vertical and horizontal direction), the size of block is being maintained at 5m x 5 m x 4m. The depth of footing below ground level is taken as 2 m where, the hard stratum is available.

The results such as Lateral loads, Base shear, Storey displacement, Storey drift and Torsion of the building are studied for buildings with different ground slopes and compared.

2.1 Building Configuration

The height and length of building in a particular pattern are in multiple of blocks (in vertical and horizontal direction), the size of block is being maintained at 5 m x 5 m x 4 m. The depth of footing below ground level is taken as 2 m where, the hard stratum is available.

1. Set back buildings resting on plain ground having SET 8, SET 9 and SET 10, as shown in figure 4.1, 4.2, and 4.3 respectively. The building with equal number of bays has same floor area in all three configurations.
2. The buildings shown in figure 4.4, 4.5, and 4.6, having step back configuration are labeled as STEP8, STEP9 and STEP10 for 8 to 10 storey respectively.
3. Step back -Set back configuration of buildings is shown in figure 4.7,4.8,and 4.9 , are labeled as STEPSET 8, STEPSET 9 and STEPSET 10 for 8 to 10 storey.

2.2 Geometrical properties

Geometrical properties of members for different configuration of building are given in table 1.

Building Configuration	Size of Column	Size of Beam
Set Back building	300 X600 mm	230 X 500 mm
Step Back Buildings	300X 600 mm	230 X 500 mm
Step Back and Set Back building	300X 600 mm	230 X 500 mm

2.3 Loads considered in the analysis

The following loads were considered for the analysis is given in table 2.

Live load	4.0 KN/m^2 at typical floor 1.5 KN/m^2 at terrace
Floor finish	1.0 KN/m^2
Terrace finish	1.0 KN/m^2
Earthquake load	As per IS-1893 (Part 1) - 2002
Depth of foundation below ground	2 m
Type of soil	Type II, Medium as per IS: 1893
Storey height	4m at Typical floor
Walls	230 thick brick masonry

3. ELEVATIONS AND 3D VIEW OF BUILDING

Elevations and 3D view of building for different storeys are given in below.

3.1 SET BACK BUILDINGS WITH 0^0 SLOPE (STOREY'S 8, 9, 10)

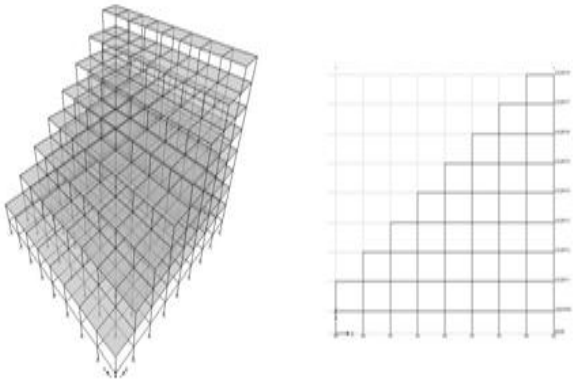

Fig 1: 3-D View and Elevation of Setback building for Storey 8(0^o Slope)

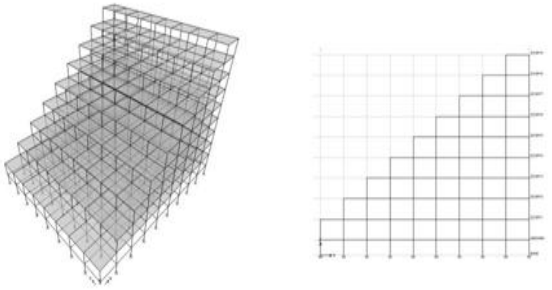

Fig 2: 3-D View and Elevation of Setback building for Storey 9(0^{o}Slope)

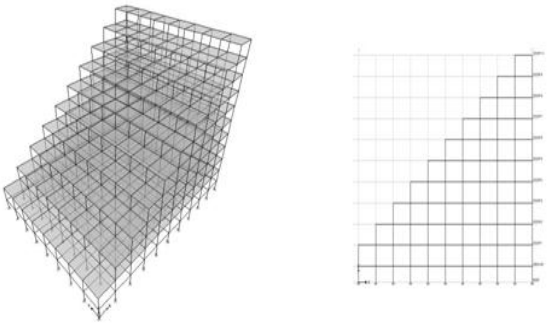

Fig 3: 3-D View and Elevation of Setback building for Storey 10 (0^{0} slope)

3.2 STEP BACK BUILDINGS WITH 10^{0} SLOPE (STOREY 8, 9, 10)

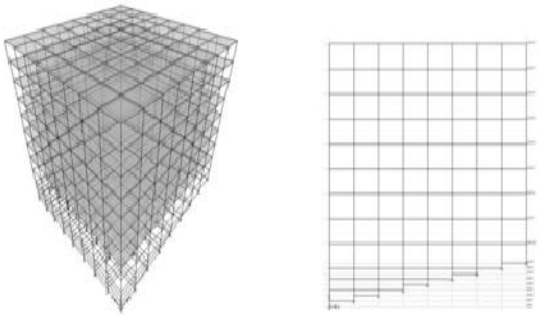

Fig 4: 3-D View and Elevation of a Step back building for Storey 8 (10^{o} Slope)

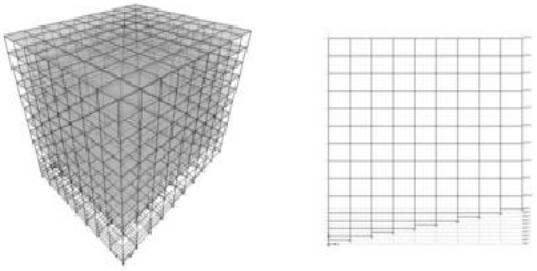

Fig 5: 3-D View and elevation of a step back building for storey 9 (10^{o} Slope)

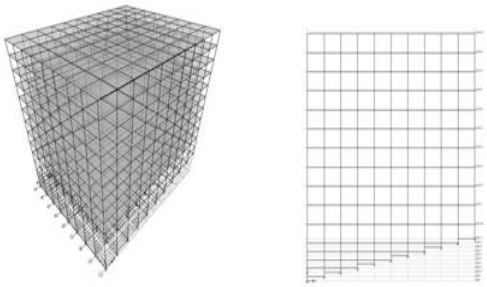

Fig 6: 3-D View and Elevation of a Step back building for Storey 10 (10^{o} Slope)

3.3 SET BACK & STEP BACK BUILDING WITH 10^{0}SLOPE (STOREY 8, 9, 10)

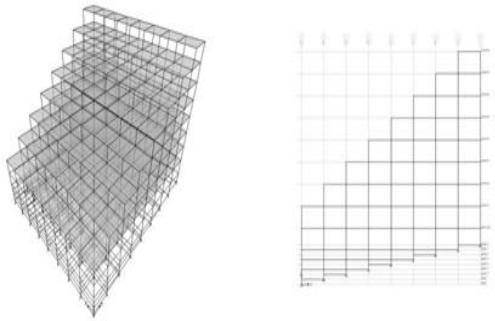

Fig 7: 3-D View and Elevation of a Set & Step back building for storey (10^{o}Slope)

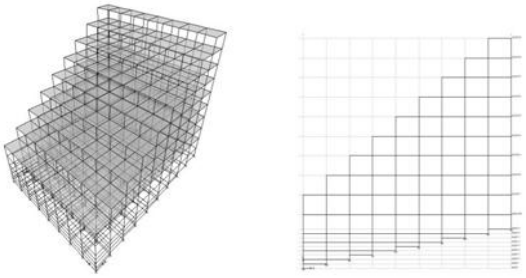

Fig 8: 3-D View and Elevation of Set & Step back building for Storey 9 (10°Slope)

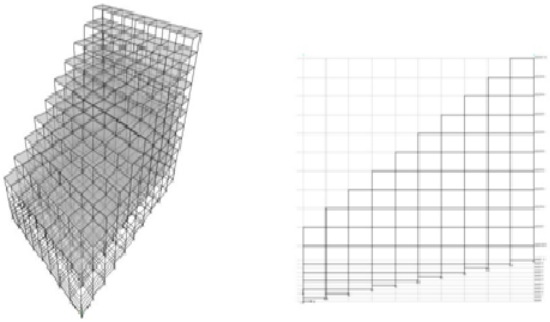

Fig 9: 3-D View and Elevation of Set & Step back building for Storey 10 (10°Slope)

4. RESULTS AND DISCUSSIONS

4.1 LATERAL LAOD DISTRIBUTION

The lateral load distribution with storey height for different buildings of storey 8 lying on 0^0 to 10^0 ground slope using both linear static method and response spectrum method are shown in table below.

SET BACK BUILDING

Table -3: Lateral load distributions for setback building of storey 8.

Storey level	Storey No	Lateral loads by linear static method(KN)	Lateral load by Response spectrum method(KN)
Eighth	8	78.900	33.86
Seventh	7	129.851	89.62
Sixth	6	212.226	159.17
Fifth	5	430.803	232.64
Fourth	4	602.834	302.94
Third	3	683.090	363.59
Second	2	763.830	410.00
First	1	934.782	440.15
Ground	ground	1183.220	440.15

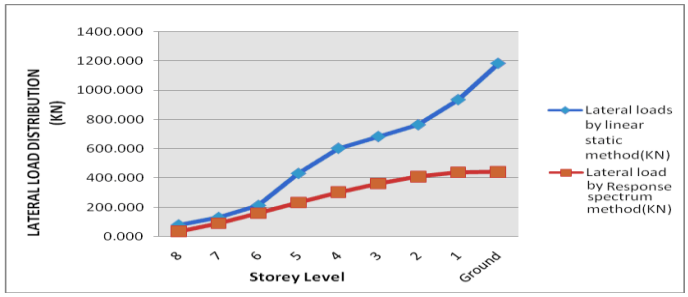

Fig 10: Lateral load distributions for set back building of storey 8

STEP BACK BUILDING

Table-4: Lateral load distributions for step back building of storey 8

Storey level	Storey No	Lateral loads by linear static method(KN)	Lateral load by Response spectrum method(KN)
Eighth	8	663.597	88.50
Seventh	7	799.540	173.53
Sixth	6	833.277	257.77
Fifth	5	957.964	327.70
Fourth	4	1214.354	385.98
Third	3	1692.449	437.36
Second	2	2392.249	473.65
First	1	3213.752	494.87
Ground	Ground	4156.960	496.44

Fig 11: Lateral load distributions for setback building of storey 8

SET & STEP BACK (STOREY 8)

Table-5: Lateral load distributions for set and step back building of storey 8

Storey level	Storey No	Lateral loads by linear static method(KN)	Lateral load by Response spectrum method(KN)
Eighth	8	300.606	110.47
Seventh	7	657.464	294.65
Sixth	6	977.160	530.38
Fifth	5	1289.334	789.29
Fourth	4	1678.927	1042.68
Third	3	2495.935	1273.49
Second	2	3355.172	1458.57
First	1	4136.030	1591.00
Ground	Ground	4683.311	1611.05

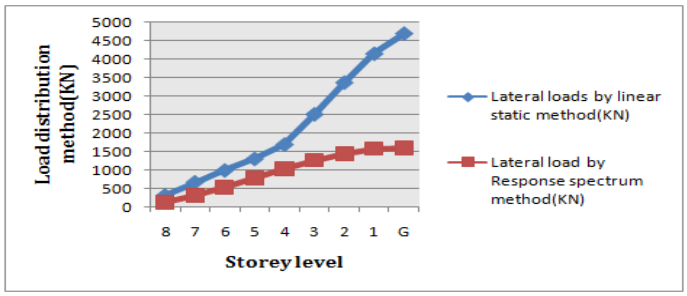

Fig 12: Lateral load distributions for setback building of storey 8.

4.2 STOREY DISPLACEMENT

Displacement for individual frames along the direction considered is tabulated at each storey level.

Table -6: Storey displacement for 8 storey building

S.No	Storey level	Storey Displacement (mm)		
		Set Back	Step Back	Set and Step Back
1	8	0.1135	0.1535	0.1359
2	7	0.1084	0.1481	0.1297
3	6	0.0991	0.1388	0.1193
4	5	0.0875	0.1261	0.1062
5	4	0.0742	0.1105	0.0913
6	3	0.0596	0.0922	0.075
7	2	0.044	0.0715	0.0575
8	1	0.0274	0.0486	0.0389
9	GROUND	0.0085	0.0215	0.0175

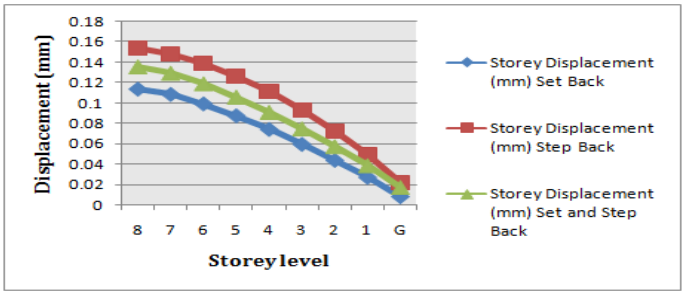

Fig 13: Storey displacement for 8 storey building

Table-7: Storey displacement for 9 storey building

S.No	Storey level	Storey Displacement (mm)		
		Set Back	Step Back	Set and Step back
1	9	0.1278	0.1486	0.1296
2	8	0.1231	0.1449	0.1257
3	7	0.1143	0.138	0.1177
4	6	0.1031	0.1282	0.1073
5	5	0.0903	0.1158	0.0951
6	4	0.076	0.101	0.0815
7	3	0.0608	0.0841	0.0668
8	2	0.0447	0.0653	0.0512
9	1	0.0277	0.0445	0.0348
10	Ground	0.0086	0.0041	0.0158

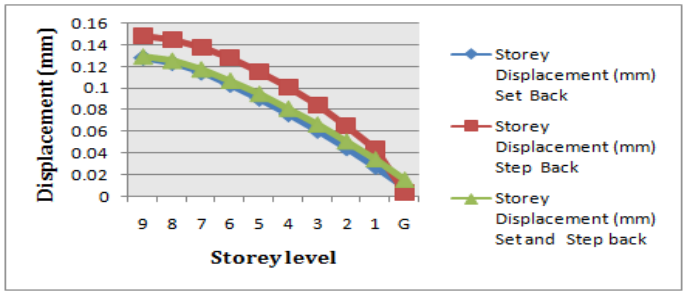

Fig 14: Storey displacement for 9 storey building

Table-8: Storey displacement for 10 storey building

S.No	Storey level	Storey Displacement (mm)		
		Set back	Step Back	Set & Step Back
1	10	0.1399	0.1633	0.1418
2	9	0.1357	0.1633	0.1384
3	8	0.1275	0.1599	0.131
4	7	0.1169	0.1599	0.1211
5	6	0.1045	0.1535	0.1095
6	5	0.0909	0.1444	0.0965
7	4	0.0763	0.1444	0.0824
8	3	0.0608	0.1329	0.0674
9	2	0.0446	0.1329	0.0517
10	1	0.0085	0.1192	0.0162
11	GROUND	0.0086	0.1035	0.0035

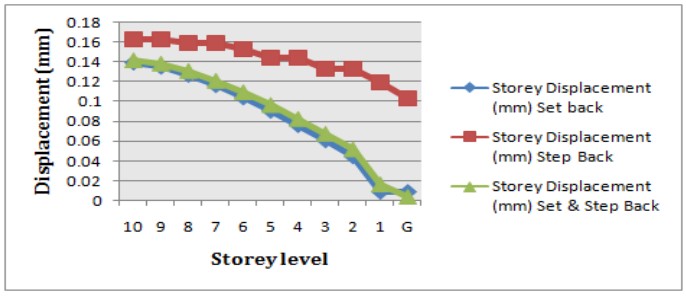

Fig 15: Storey displacement for 10 storey building

4.3 STOREY DRIFT

Storey drift for individual frames along the direction considered is tabulated at each storey Level.

Table-9: Storey drift values for 8 storey building.

S.No	Storey level	Storey Drift(mm)		
		Set back	Step Back	Set and Step back
1	8	0.00298	0.001975	0.00344
2	7	0.00362	0.003052	0.004062
3	6	0.00387	0.003818	0.004333
4	5	0.00402	0.004456	0.004488
5	4	0.00415	0.004999	0.004611
6	3	0.00422	0.005466	0.004707
7	2	0.00427	0.005893	0.004775
8	1	0.00476	0.006995	0.005505
9	GROUND	0.00283	0.007089	0.005694

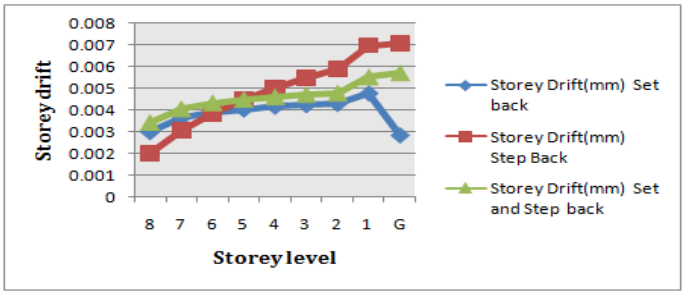

Fig 16: Storey drift values for 8 storey building

Table-10: Storey drift values for 9 storey building

S.No	Storey level	Storey Drift(mm)		
		set back	step back	set & step back
0	9	0.00307	0.001428	0.00291
2	8	0.00367	0.002412	0.003469
3	7	0.00391	0.00312	0.003736
4	6	0.00403	0.003685	0.00388
5	5	0.00418	0.004181	0.003997
6	4	0.00427	0.004619	0.004101
7	3	0.00431	0.005008	0.004174
8	2	0.00435	0.005374	0.004228
9	1	0.00482	0.006377	0.004877
10	GROUND	0.00285	0.006612	0.005137

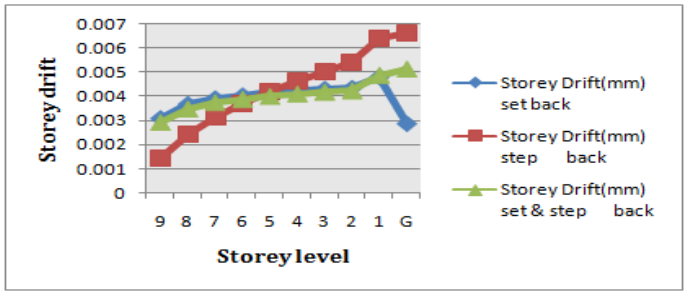

Fig 17: Storey drift values for 9 storey building

Table-11: Storey drift values for 10 storey building

S.No	Storey level	Storey Drift(mm)		
		set back	step back	set & step back
1	10	0.00316	0.001363	0.003011
2	9	0.00371	0.002301	0.003522
3	8	0.00391	0.002979	0.00376
4	7	0.00401	0.003524	0.003892
5	6	0.00414	0.003995	0.003982
6	5	0.00424	0.004417	0.004066
7	4	0.00429	0.004794	0.004143
8	3	0.00432	0.005138	0.004195
9	2	0.00435	0.005462	0.004236
10	1	0.0048	0.006452	0.004885
11	Ground	0.00284	0.00684	0.005254

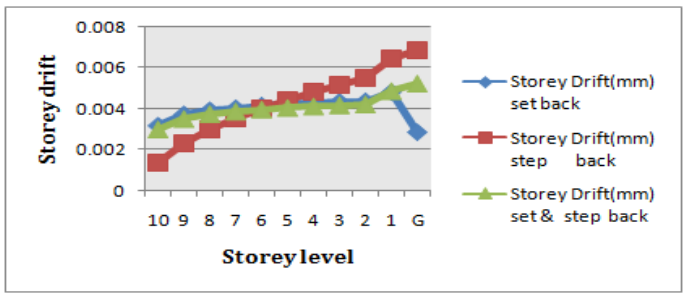

Fig 18: Storey drift values for 10 storey building

4.4 STOREY SHEAR

Table-12: Storey shear values for 8 storey building

S.No	Storey	Shear(VX),(KN)		
		set back	step back	set & step back
1	8	305.22	1158.05	357.54
2	7	683.6	1800.88	760.06
3	6	1028.54	2266.43	1140.72
4	5	1360.88	2660.15	1517.5
5	4	1702.66	2995.78	1900.4
6	3	2033.44	3285.19	2277.79
7	2	2362.56	3539.04	2645.99
8	1	2736.73	3797.96	3054.09
9	GROUND	2797.82	3850.79	3124.55

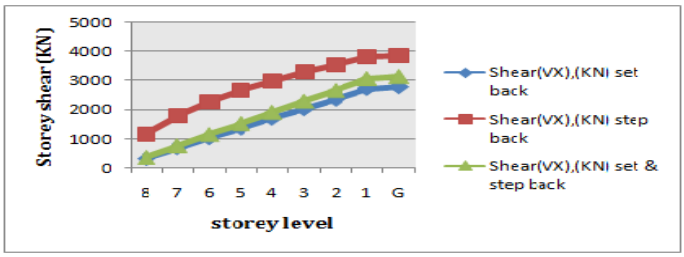

Fig 19: Storey shear values for 8 storey building

Table-13: Storey shear values for 9 storey building

S.No	Story	Shear(VX),(kN)		
		set back	step back	set & step back
0	9	300.41	905.36	270.18
2	8	680.53	1587.25	625.43
3	7	1028.34	2065.92	965.63
4	6	1361.36	2450.76	1297.53
5	5	1704.92	2793.08	1638.04
6	4	2047.96	3097.98	1981.05
7	3	2381.33	3371.04	2316.36
8	2	2710.4	3619.1	2642.59
9	1	3089.94	3883.05	3009.19
10	GROUND	3151.01	3946.09	3094.88

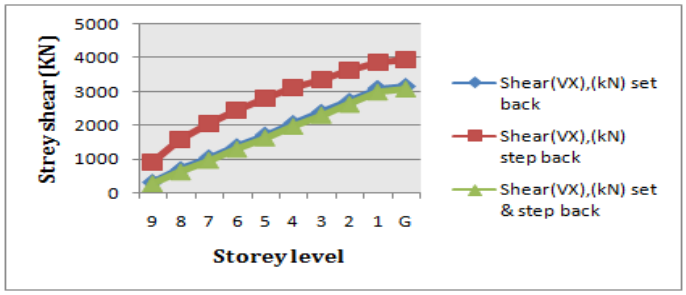

Fig 20: Storey shear values for 9 storey building

Table-14: Storey shear values for 10 storey building

S.No	Story	Shear(VX),(kN)		
		set back	step back	set & step back
1	10	294.79	939.76	265.06
2	9	674.56	1659.12	620.06
3	8	1019.7	2163.59	958.65
4	7	1351.83	2574.2	1290.56
5	6	1684.04	2931.37	1621.53
6	5	2025.24	3255.16	1959.41
7	4	2358.86	3546.15	2292.58
8	3	2688.75	3814.83	2624.7
9	2	3013.65	4057.15	2946.48
10	1	3398.24	4321.64	3317.4
11	GROUND	3459.38	4385.13	3404.84

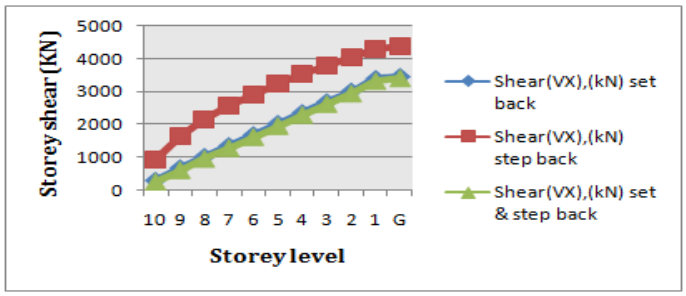

Fig 21: Storey shear values for 10 storey building

4.4 Bending moment

Discussion on Bending Moments For Column(C141)

Table-15: Bending moment for the column (C141) for Storey 8.

	Storey	Column	M3
SET BACK	STOREY8	C141	30.795
	STOREY7	C141	53.235
	STOREY6	C141	59.684
	STOREY5	C141	63.014
	STOREY4	C141	65.273
	STOREY3	C141	66.346
	STOREY2	C141	66.668
	STOREY1	C141	70.505
	GROUND	C141	62.492
STEP BACK	STOREY8	C141	31.561
	STOREY7	C141	47.811
	STOREY6	C141	59.62
	STOREY5	C141	69.492
	STOREY4	C141	77.743
	STOREY3	C141	84.681
	STOREY2	C141	90.14
	STOREY1	C141	93.962
	GROUND	C141	126.209
SET & STEP BACK	STOREY8	C141	36.702
	STOREY7	C141	59.165
	STOREY6	C141	65.985
	STOREY5	C141	70.073
	STOREY4	C141	72.755
	STOREY3	C141	74.394
	STOREY2	C141	74.837
	STOREY1	C141	75.682
	GROUND	C141	103.44

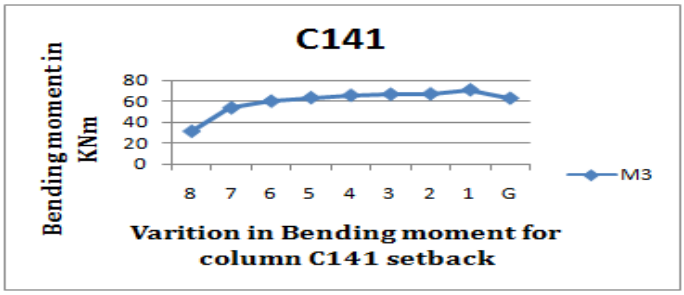

Fig 23: Bending moment for the column (C141) Storey 8 of set back

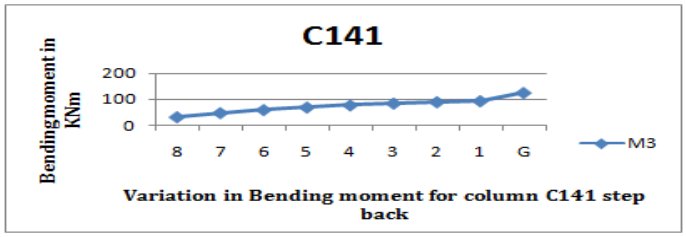

Fig 24: Bending moment for the column (C141) Storey 8 of step back

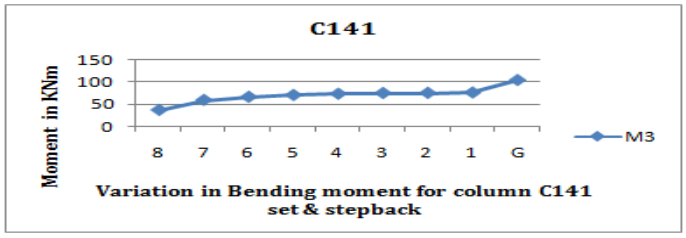

Fig 25: Bending moment for the column (C141) Storey 8 of set & step back

Table-16: Bending moment for C141 for Storey 9.

	Storey	Column	M3
SET BACK	STOREY9	C178	31.972
	STOREY8	C178	48.378
	STOREY7	C178	53.78
	STOREY6	C178	55.86
	STOREY5	C178	57.313
	STOREY4	C178	58.047
	STOREY3	C178	58.02
	STOREY2	C178	57.373
	STOREY1	C178	53.685
	GROUND	C178	55.363
STEP BACK	STOREY9	C178	26.076
	STOREY8	C178	37.205
	STOREY7	C178	45.349
	STOREY6	C178	51.615
	STOREY5	C178	57.069
	STOREY4	C178	61.799
	STOREY3	C178	65.749
	STOREY2	C178	70.156
	STOREY1	C178	53.128
	GROUND	C178	137.487
SET & STEP BACK	STOREY9	C178	29.083
	STOREY8	C178	45.039
	STOREY7	C178	51.11
	STOREY6	C178	53.86
	STOREY5	C178	55.688
	STOREY4	C178	56.8
	STOREY3	C178	57.062
	STOREY2	C178	57.42
	STOREY1	C178	41.664
	GROUND	C178	108.704

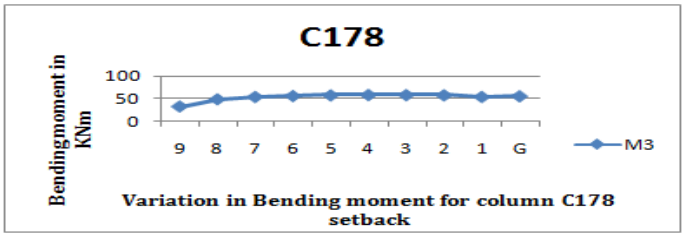

Fig 26: Bending moment for the column (C178) Storey 9 of set back

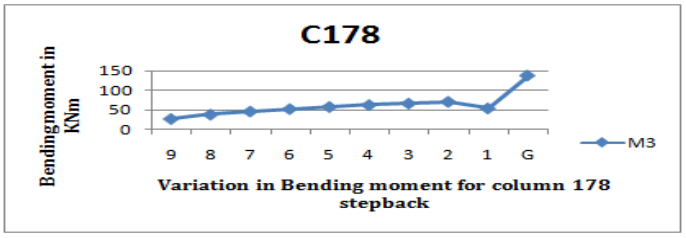

Fig 27: Bending moment for the column (C178) Storey 9 of step back

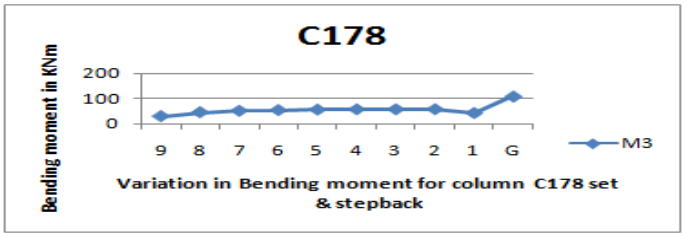

Fig 28: Bending moment for the column (C178) Storey 9 of set & step back

Table-17: Bending moment for the column (C197) for Storey 10.

	Storey No.	Column	M3
SET BACK	STOREY10	C197	31.606
	STOREY9	C197	48.729
	STOREY8	C197	54.269
	STOREY7	C197	56.536
	STOREY6	C197	57.732
	STOREY5	C197	58.573
	STOREY4	C197	58.674
	STOREY3	C197	58.372
	STOREY2	C197	57.477
	STOREY1	C197	53.618
	GROUND	C197	55.050
STEP BACK	STOREY10	C197	26.604
	STOREY9	C197	36.953
	STOREY8	C197	44.632
	STOREY7	C197	50.651
	STOREY6	C197	55.745
	STOREY5	C197	60.258

	STOREY4	C197	64.143
	STOREY3	C197	67.496
	STOREY2	C197	71.373
	STOREY1	C197	52.856
	GROUND	C197	142.261
SET & STEP BACK	STORY10	C197	28.777
	STOREY9	C197	45.415
	STOREY8	C197	51.674
	STOREY7	C197	54.621
	STOREY6	C197	56.253
	STOREY5	C197	57.352
	STOREY4	C197	57.755
	STOREY3	C197	57.689
	STOREY2	C197	57.811
	STOREY1	C197	41.262
	GROUND	C197	111.457

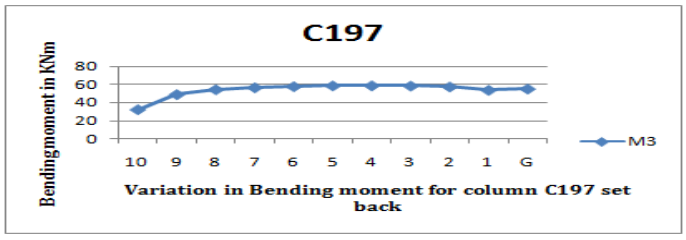

Fig 29: Bending moment for the column (C197) Storey 10 of set back

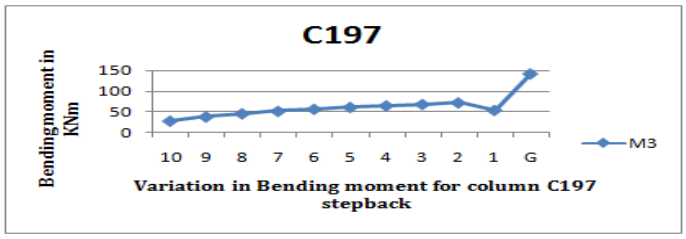

Fig 30: Bending moment for the column (C197) Storey 10 of step back

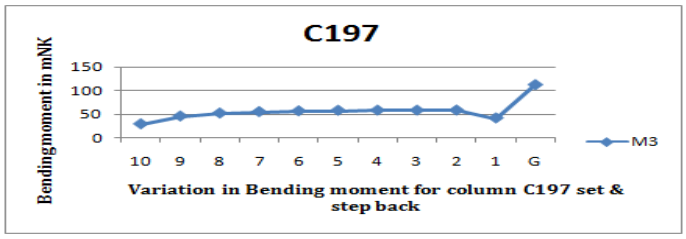

Fig 31: Bending moment for the column (C197) Storey 10 of set & step back.

4.5 SHEAR FORCE

Table-18: Shear force for the column (C141) of Storey 8

	Story	Column	V2
SET BACK	STOREY8	C141	15.12
	STOREY7	C141	27.14
	STOREY6	C141	29.9
	STOREY5	C141	31.58
	STOREY4	C141	32.68
	STOREY3	C141	33.2
	STOREY2	C141	33.43
	STOREY1	C141	35.98
	GROUND	C141	37.09
STEP BACK	STOREY8	C141	16.38
	STOREY7	C141	24.27
	STOREY6	C141	30.11
	STOREY5	C141	35.01
	STOREY4	C141	39.1
	STOREY3	C141	42.54
	STOREY2	C141	45.35
	STOREY1	C141	49.08
	GROUND	C141	82.08
SET & STEP BACK	STOREY8	C141	18.01
	STOREY7	C141	30.12
	STOREY6	C141	33.06
	STOREY5	C141	35.12
	STOREY4	C141	36.42
	STOREY3	C141	37.23
	STOREY2	C141	37.53
	STOREY1	C141	39.54
	GROUND	C141	67.32

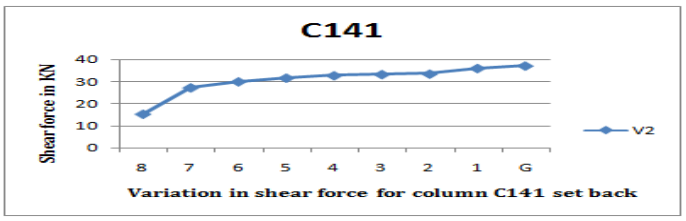

Fig 32: Shear force for the column (C141) storey 8 of set back

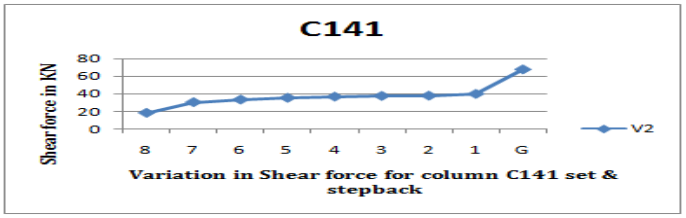

Fig 33: Shear force for the column (C141) storey 8 of step back

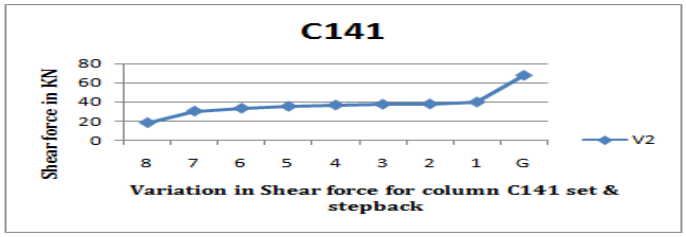

Fig 34: Shear force for the column (C141) storey 8 of set & step back

Table-19: Shear force for the column (C178) of Storey 9

	Storey	Column	V2
SET BACK	STOREY9	C178	17.44
	STOREY8	C178	24.62
	STOREY7	C178	27.11
	STOREY6	C178	28.06
	STOREY5	C178	28.79
	STOREY4	C178	29.12
	STOREY3	C178	29.09
	STOREY2	C178	28.83
	STOREY1	C178	28.39
	GROUND	C178	29.26
STEP BACK	STOREY9	C178	14.03
	STOREY8	C178	19.14
	STOREY7	C178	23.12
	STOREY6	C178	26.2
	STOREY5	C178	28.91
	STOREY4	C178	31.24
	STOREY3	C178	33.21
	STOREY2	C178	35.3
	STOREY1	C178	31.08
	GROUND	C178	77.73
SET & STEP BACK	STOREY9	C178	15.9
	STOREY8	C178	22.98
	STOREY7	C178	25.82
	STOREY6	C178	27.09
	STOREY5	C178	28
	STOREY4	C178	28.52
	STOREY3	C178	28.64
	STOREY2	C178	28.76
	STOREY1	C178	24.39
	GROUND	C178	61.68

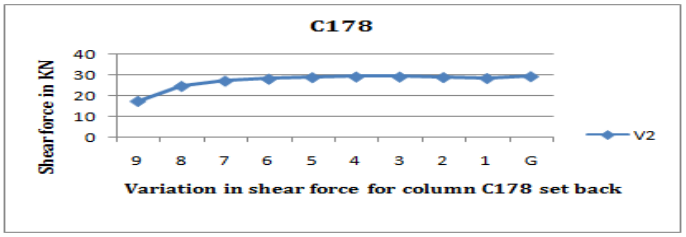

Fig 35: Shear force for the column (C178) storey 9 of set back

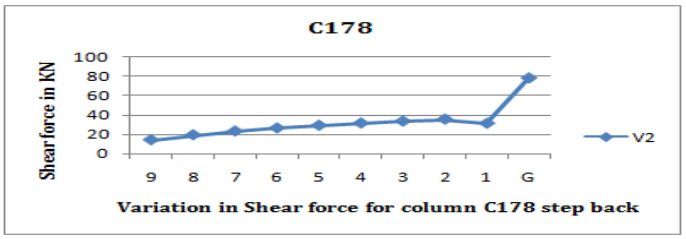

Fig 36: Shear force for the column (C178) storey 9 of step back

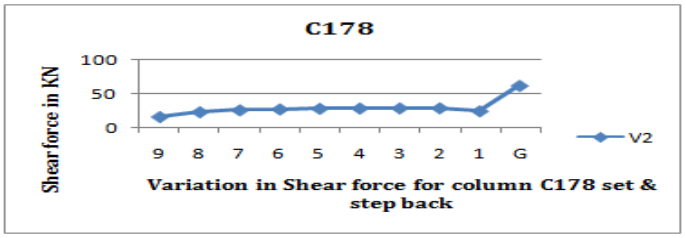

Fig 37: Shear force for the column (C178) storey 9 of set & step back

Table-20: Shear force for the column (C197) of Storey 10

	Storey	Column	V2
SET BACK	STOREY10	C197	17.25
	STOREY9	C197	24.82
	STOREY8	C197	27.36
	STOREY7	C197	28.39
	STOREY6	C197	28.99
	STOREY5	C197	29.39
	STOREY4	C197	29.43
	STOREY3	C197	29.26
	STOREY2	C197	28.89
	STOREY1	C197	28.34
	GROUND	C197	29.1
STEP BACK	STORY10	C197	14.29
	STOREY9	C197	18.98
	STOREY8	C197	22.74

	STOREY7	C197	25.7
	STOREY6	C197	28.23
	STOREY5	C197	30.46
	STOREY4	C197	32.39
	STOREY3	C197	34.06
	STOREY2	C197	35.88
	STOREY1	C197	31.11
	GROUND	C197	80.59
SET & STEP BACK	STORY10	C197	15.74
	STOREY9	C197	23.19
	STOREY8	C197	26.11
	STOREY7	C197	27.47
	STOREY6	C197	28.26
	STOREY5	C197	28.79
	STOREY4	C197	28.98
	STOREY3	C197	28.95
	STOREY2	C197	28.95
	STOREY1	C197	24.3
	GROUND	C197	63.36

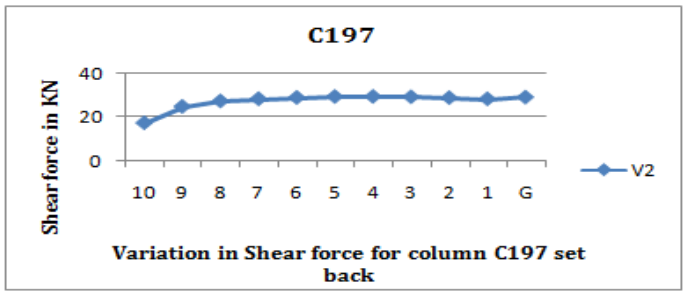

Fig 38: Shear force for the column (C197) storey 10 of set back

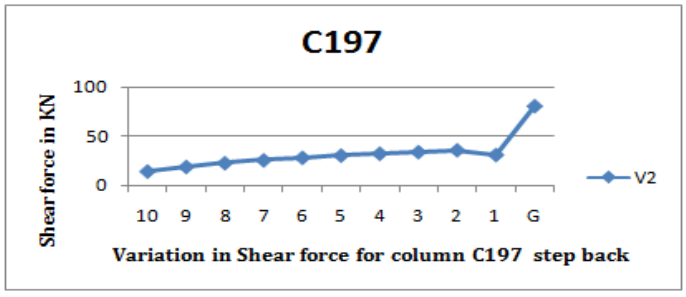

Fig 39: Shear force for the column (C197) storey 10 of step back

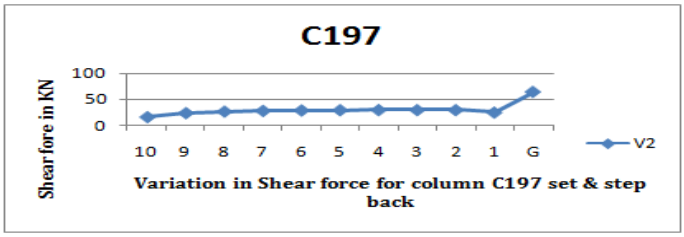

Fig 40: Shear force for the column (C197) storey 10 of set & step back

5. CONCLUSIONS

The Following conclusions are made from the present study

- Since the mass is not varying with the increased ground slope, it can be concluded that the stiffness of the building is getting reduced where length of the columns is higher, relative to the other extreme end.
- There is a considerable variation in the distribution of storey shears. The maximum variation in storey shear is about 55%. Hence it is advisable to adopt response spectrum method for building with sloping ground.
- The variation in bending moment between long column and short column is about 22%.This is due to presence of ground-slope is making one side of the building stiffer than the other side, which leads to variation in bending moment due to short column effect.
- The variation in bending moment, shear force and storey displacement of particular column in step back building are 75 KN-m, 82.08 KN and 0.1535mm respectively. The performance of STEP back building during seismic excitation could prove more vulnerable than other configurations of buildings.
- The variation of torsion moments in Step back buildings is 2% higher compared to set back buildings. Hence, Step back Set back buildings are found to be less vulnerable than Step back building against seismic ground motion.
- In Step back buildings and Step back-Set back buildings, it is observed that extreme left column at ground level, which are short, are the worst affected. Special attention should be given to these columns in design and detailing.
- Although, the Set back buildings on plain ground attract less action forces of 777.56KN as compared to Step back Set back buildings of 812.08KN, overall economic cost involved in leveling the sloping ground and other related issues needs to be studied in detail.

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