A Review on Seismic Analysis Of a Building on sloping ground

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Abstract

During earthquake, torsionally coupled & irregular buildings in hilly areas serves more damage.Dynamic characteristics of hill buildings are somewhat different than the buildings on flat ground.Torsional effect of such buildings is demanded for having the difference stiffness and mass along horizontal and vertical plane during earthquake ground motion.Short column of RC frame building serves damage because of attracting more forces during earthquake.

1.Introduction

Many irregular configured buildings with different foundation levels are constructed with locally available traditional material in hilly slopes due to lack of flat land in hilly regions.Becuse of population density,demand of such type of building in hilly slopes is increased.The study of earthquake resistant building on slopes becomes popular to prevent the loss of life,property during earthquake ground motion.Different height of columns are present in building on hilly slopes in a same storey,as a reslt more forces are attracted during earthquake ground motion by short columns and damage occurs.

2.Significance

It is observed from past earthquakes that the buildings on slopes serves more damage and collapse occurs.This review paper aims to analyse the dynamic characteristics of these type of buildings with three different configuration such as a) Step back,b) Step back-Setback,and c) Setback.

3.Previous Study

B.G. Birajdar1, S.S. Nalawade considered two buildings on sloping ground and one building is on flat soil. The first two are step back buildings and step back-setback buildings; and third is the set back building.The slope is taken 27 degree with horizontal.Depth of footing was taken 1.75m below ground level and the block size was considered as 7 m x 5 m x 3.5 m.The properties of beam and column is shown in table 1.

Table 1

Building Configuration	Size of Column	Size of Beam
Step Back Buildings	for STEP 4 & STEP 5 230 mm x 500 mm STEP 6 & STEP 7 230 mm x 650 mm STEP 8 & STEP 9 300 mm x 650 mm STEP 10 & STEP 11 300 mm x 850 mm	230 mm x 500 mm
Step Back and Set Back building	STPSET 4 to STPSET 11 230 mm x 500 mm	230 mm x 500 mm
Set Back building	SET 4 to SET 11 230 mm x 500 mm	230 mm x 500 mm.

S.M.Nagargoje and K.S.Sable considered same configuration of building and first two configuration of building was resting on slope soil and third configuration was taken on flat soil.Block size is taken as 7 m x 5 m x 3.4 m.Footing depth was taken as 1.6m below ground level.The properties of beams and columns were taken is shown in table 2.

Table 2

Building Configuration	Size of column	Size of beam
Step back Buildings	STEP4 to STEP5 230x500mm STEP6to STEP7 230x650mm STEP8to STEP9 300x650mm STEP10to STEP11 300x850mm STEP12to STEP15 350x900mm	230x450mm
Stepback&Setback Building	STEPSET4 to11 230x475mm STEPSET12 to 15 350x900mm	230x450mm
Setback Building	SET4to11 230x475mm SET12to15 350x900mm	230x450mm

4.Method of analysis

B.G. Birajdar1, S.S. Nalawade[1] took the materials isotropic,homogeeous in nature.Floor diaphragms are taken as rigid.M25 concrete was used and P-delta effects,creep & shrinkage effects were not considered.Axial deformation was considered for columns. Torsional effect was considered as per IS-1893:2002.Seismic analysis was performed by Response Spectra Method as per IS 1893:2002.Ordinary moment resistins frame was taken for all these types of buildings in seismic zone III.Response reduction factor and importance factor was taken as 3 and 1 respectively.5% of damping was considered.

S.M.Nagargoje and K.S.Sable[3] analysed the seismic behaviour of these building located in seismic zone III by Seismic Coefficient Method as per IS 1893:2002.Response reduction factor and importance factor was taken as 5 and 1 respectively.Minimun six modes were analysed for each type of building.

5.Analysis of Result

B.G. Birajdar1, S.S. Nalawade[1] observed that the along x direction time period and top storey displacement is increased for step back building as the height increases.Dynamic response i.e fundamental time period,base shear,top storey displacemnt for step back building along x direction is shown in table 3.

Table 3

Designation	Number of storey (ht. in meters)	Fundamental time period by RSA, in sec.	Time period by IS: 1893(I)-2002 in sec.	Maxi. Top storey displacement in mm.	Base shear ratio (λ)	Normalized value of shear force in columns at ground level in kN			
						Frame A	Frame B	Frame C	Frame D
STEP 4	4 *(15.75)*	0.6782	0.310	9.75	1.695	134.1	45.7	8.6	9.1
STEP 5	5 *(19.25)*	0.9775	0.378	19.86	2.443	178.5	57.1	11.3	10.9
STEP 6	6 *(22.75)*	1.1041	0.446	23.07	2.471	223.2	48.3	9.7	10.1
STEP 7	7 *(26.25)*	1.3920	0.515	31.45	2.700	246.9	50.9	10.5	10.7
STEP 8	8 *(29.75)*	1.6251	0.584	37.78	2.782	274.7	48.5	10.7	10.9
STEP 9	9 *(33.25)*	1.9163	0.653	46.54	2.934	286.9	50.5	11.3	11.5
STEP 10	10 *(36.75)*	2.0130	0.721	47.54	2.792	345.2	58.2	17.6	17.7
STEP 11	11 *(40.25)*	2.2977	0.790	56.05	2.906	358.3	61.0	15.4	15.5

The value of fundamental time period estimated by empirical formula as per IS 1893:2002 is lower than the value of fundamental time period obtained in dynamic analysis.

The value of base shear,fundamental time period is higher in Y direction than the corresponding values when earthquake force acts in x direction.Time period in dynamic analysis is greater than that calculated by empirical formula as per IS 1893:2002.The value of normalized shear force in columns,base shear,top storey displacement,time period for step back building along Y direction is shown in table 4.

Table 4

Designation	Number of storey *(Height in m)*	Fundamental time period by RSA, in sec.	Time period by IS: 1893(I)-2002 [2] in sec.	Maxi. Top storey displacement, in mm	Base shear ratio (λ)	Normalized value of shear force in columns at ground level in kN			
						Frame A	Frame B	Frame C	Frame D
STEP 4	4 *(15.75)*	1.3706	0.633	44.29	2.635	64.7	52.1	21.4	30.6
STEP 5	5 *(19.25)*	1.8168	0.774	49.57	2.344	59.6	44.8	18.8	26.6
STEP 6	6 *(22.75)*	2.0507	0.915	50.87	2.241	71.5	47.3	16.3	22.5
STEP 7	7 *(26.25)*	2.5428	1.056	64.41	2.400	76.6	49.3	17.2	23.7
STEP 8	8 *(29.75)*	2.5434	1.197	56.92	2.124	82.2	49.6	13.3	22.4
STEP 9	9 *(33.25)*	2.9335	1.338	66.98	2.191	84.2	50.1	13.5	22.6
STEP 10	10 *(36.75)*	3.1632	1.479	73.99	2.138	101.2	50.8	11.4	17.7
STEP 11	11 *(40.25)*	3.5707	1.620	77.97	2.204	105.4	65.2	26.1	33.5

In case of Step Back Set Back Buildings,the value of base shear ratio obtained in X direction from dynamic and static analysis are almost same. Time period in dynamic analysis in X direction is greater than that calculated by empirical formula as per IS 1893:2002 for Step Back Set Back Buildings.The value of time period,base shear ratio,top storey displacement in X direction is shown in table 5.

Table 5

Designation	Number of storey *(Height in m)*	Fundamental time period by RSA in sec.	Time period by IS: 1893(I)-2002 [2] in sec.	Maxi. Top storey displacement in mm	Base shear ratio (λ)
STPSET 4	4 *(15.75)*	0.437	0.267	3.61	1.092
STPSET 5	5 *(19.25)*	0.458	0.293	3.96	1.144
STPSET 6	6 *(22.75)*	0.475	0.316	4.18	1.188
STPSET 7	7 *(26.25)*	0.465	0.337	4.10	1.163
STPSET 8	8 *(29.75)*	0.475	0.358	4.19	1.188
STPSET 9	9 *(33.25)*	0.484	0.377	4.28	1.211
STPSET 10	10 *(36.75)*	0.492	0.395	4.35	1.231
STPSET 11	11 *(40.25)*	0.499	0.413	4.28	1.210

In Y direction,variation of shear force is found less significant.Time period in dynamic analysis of this type of building is not affected by the height of building.Uniform section for columns from top to bottom is sufficient. The value of time period,base shear ratio,top storey displacement in Y direction is shown in table 6.

Table 6

Designation	Number of storey (*Height in m*)	Fundamental time period by RSA in sec.	Time period by IS: 1893(I)-2002 [2] in sec.	Maxi. Top storey displacement in mm	Base shear ratio (λ)
STPSET 4	4 (*15.75*)	1.031	0.634	13.41	1.627
STPSET 5	5 (*19.25*)	1.160	0.775	13.52	1.497
STPSET 6	6 (*22.75*)	1.242	0.915	13.62	1.356
STPSET 7	7 (*26.25*)	1.134	1.056	13.61	1.073
STPSET 8	8 (*29.75*)	1.202	1.197	13.52	1.000
STPSET 9	9 (*33.25*)	1.174	1.338	13.42	0.877
STPSET 10	10 (*36.75*)	1.208	1.479	13.45	0.817
STPSET 11	11 (*40.25*)	1.230	1.620	13.50	0.739

For Set Back Buildings on Plain Ground,time period is increased in dynamic analysis in X direction and base shear varies between 1.862 to 2.140.Table 7 shows the results for set back building in X direction.

Table 7

Designation	Number of Bays (*Height in m*)	Fundamental time period by RSA in sec.	Time period by IS: 1893(I)-2002 [2] in sec.	Maxi. Top storey displacement in mm
SET 4	4 (*12.25*)	0.745	0.2083	12.46
SET 5	5 (*12.25*)	0.782	0.1863	13.41
SET 6	6 (*12.25*)	0.806	0.1701	13.62
SET 7	7 (*12.25*)	0.822	0.1575	14.47
SET 8	8 (*12.25*)	0.834	0.1475	14.86
SET 9	9 (*12.25*)	0.844	0.1389	15.13
SET 10	10 (*12.25*)	0.851	0.1317	15.33
SET 11	11 (*12.25*))	0.857	0.1256	15.47

Earthquake in Y direction in case of set back building on plane ground top storey displacement is 3.5 times the higher than the corresponding values in X direction. The base shear ratio has been found significantly high. Table 8 shows the results for set back building in Y direction.

Table 8

Designation	Number of Bays (*Height in m*)	Fundamental time period by RSA in sec.	Time period by IS: 1893(I)-2002 [2] in sec.	Maxi. Top storey displacement in mm	Base shear ratio factor (λ)
SET 4	4 (*12.25*)	1.398	0.493	41.94	2.835
SET 5	5 (*12.25*)	1.288	0.493	39.44	2.613
SET 6	6 (*12.25*))	1.357	0.493	45.68	2.754
SET 7	7 (*12.25*)	1.384	0.493	47.68	2.800
SET 8	8 (*12.25*)	1.458	0.493	51.17	2.958
SET 9	9 (*12.25*))	1.380	0.493	40.76	2.800
SET 10	10 (*12.25*)	1.491	0.493	53.24	3.025
SET 11	11 (*12.25*)	1.479	0.493	53.01	3.000

S.M.Nagargoje and K.S.Sable[3] observed the base shear,top storey displacement in X and Y direction for step back,step back-set back and stepback building is shown in table 9,table 10,table 11 respectively.

Table 9

BUILDING CONFIGURATION	BASE SHEAR (KN)		TOP STOREY DISPLACEMENT(MM)	
	EQX	EQY	EQX	EQY
STEP4	398.43	181.07	07.27	10.21
STEP5	326.11	173.22	11.78	15.13
STEP6	343.29	192.79	13.73	18.40
STEP7	314.42	185.30	18.00	23.01
STEP8	309.34	221.60	21.02	22.46
STEP9	296.15	217.57	25.31	26.34
STEP10	320.61	233.66	26.94	28.61
STEP11	305.60	228.56	31.17	32.39
STEP12	310.17	250.11	33.94	33.40
STEP13	302.77	246.35	38.19	37.02
STEP14	295.35	242.35	42.57	40.71
STEP15	290.25	232.81	47.07	44.48

Table 10

BUILDING	BASE SHEAR (KN)		TOP STOREY DISPLACEMEN T (MM)	
	EQX	EQY	EQX	EQY
STEPSET4	341.32	199.73	9.75	9.91
STEPSET5	408.83	219.62	10.60	9.99
STEPSET6	473.89	224.29	11.49	9.54
STEPSET7	432.79	221.18	10.92	8.81
STEPSET8	385.51	214.27	10.60	8.10
STEPSET9	353.04	207.96	10.74	7.49
STEPSET10	330.70	202.75	11.18	6.99
STEPSET11	312.44	198.53	11.85	6.56
STEPSET12	490.26	352.52	2.85	2.79
STEPSET13	457.69	342.73	2.90	2.55
STEPSET14	441.23	339.19	2.68	2.25
STEPSET15	414.84	326.43	3.21	2.21

Table 11

BUILDING	BASE SHEAR (KN)		TOP STOREY DISPLACEMENT(MM)	
	EQX	EQY	EQX	EQY
SET4	188.56	124.25	15.93	22.85
SET5	189.93	127.70	19.18	28.04
SET6	191.84	128.78	22.43	33.21
SET7	191.06	130.25	25.70	38.40
SET8	190.73	130.98	28.98	43.65
SET9	190.57	131.56	32.25	48.96
SET10	190.03	146.66	35.51	60.46
SET11	189.78	161.15	38.74	73.41
SET12	257.80	216.71	34.64	42.68
SET13	255.29	217.25	37.48	46.41
SET14	252.76	219.71	40.31	51.14

The relationship between displacemnt and storey of Step,Step-Set,Set buildings is observed and shown in fig.1

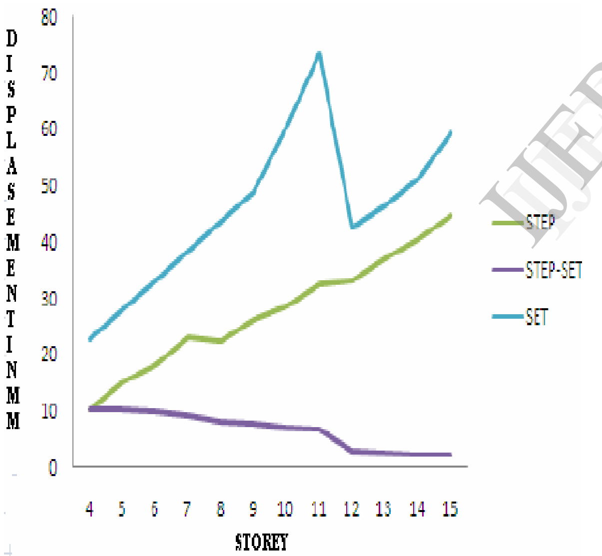

Fig. 1

6.Conclusion

Different types of building configuration are analysed and the following conclusion can be made:

a) During earthquake,STEP back buildings are more vulnerable than other building configuration.

b) Extreme left short column at ground level are damaged most during earthquake in case of Step back and Step back-Set back buildings.

c)Less damage occurs in case of Set back building in flat soil.Detailed study of economic cost for levelling sloping soil and other issues need to be studied.

d)Bse shear is higher for Step back-Setback building and lower for Setback building.

e)Lateral displacement of top storey is maximum for Step back building.

f) On sloping soil Setback- Stepback building is favored.

7.References

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