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SEISMIC ANALYSIS OF BUILDINGS RESTING ON SLOPING GROUND

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SUMMARY

Results from seismic analyses performed on 24 RC buildings with three different configurations like, Step back building, Step back Set back building and Set back building are presented. 3 –D analysis including torsional effect has been carried out by using response spectrum method. The dynamic response properties *i.e.* fundamental time period, top storey displacement and, the base shear action induced in columns have been studied with reference to the suitability of a building configuration on sloping ground. It is observed that Step back Set back buildings are found to be more suitable on sloping ground.

1. INTRODUCTION

In some parts of world, hilly area is more prone to seismic activity; e.g. northeast region of India. In this hilly regions, traditionally material like, the adobe, brunt brick, stone masonry and dressed stone masonry, timber reinforced concrete, bamboo, etc., which is locally available, is used for the construction of houses. A scarcity of plain ground in hilly area compels the construction activity on sloping ground. Hill buildings constructed in masonry with mud mortar/cement mortar without conforming to seismic codal provisions have proved unsafe and, resulted in loss of life and property when subjected to earthquake ground motions [1].

The economic growth and rapid urbanization in hilly region has accelerated the real estate development. Due to this, population density in the hilly region has increased enormously. Therefore, there is popular and pressing demand for the construction of multistorey buildings on hill slope in and around the cities.

2. 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)][1], 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

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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.

3. SCOPE OF STUDY

Three dimensional space frame analysis is carried out for three different configurations of buildings ranging from 4 to 11 storey (15.75 m to 40.25 m height) resting on sloping and plain ground under the action of seismic load. Dynamic response of these buildings, in terms of base shear, fundamental time period and top floor displacement is presented, and compared within the considered configuration as well as with other configurations. At the end, a suitable configuration of building to be used in hilly area is suggested.

4. BUILDING CONFIGURATION

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 two are step back buildings and step back-setback buildings; and third is the set back building. The slope of ground is 27 degree with horizontal, which is neither too steep or 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 7 m x 5 m x 3.5 m. The depth of footing below ground level is taken as 1.75 m where, the hard stratum is available.

The buildings shown in figure 4.1, having step back configuration are labeled as STEP 4 to STEP11 for 4 to 11 storey. Step back -Set back configuration of buildings is shown in figure 4.2 , are designated as STPSET 4 to STPSET 11, according to height of building. Set back buildings resting on plain ground having 4 to 11 number of bays and labeled as SET 4 to SET 11, as shown in figure 4.3.The building with equal number of storeys/bays have same floor area in all three configurations. The properties of frame members of buildings that are considered for analysis are given in table 4.1.

Table 4.1 : Geometrical properties of members for different configurations of building.

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.

5. METHOD OF ANALYSIS

The analysis is based on following assumptions.

i) Material is homogenous, isotropic and elastic.

ii) The values of modulus of elasticity and Poisson's ratio are 25000 N/mm^2 and 0.20, respectively.

iii) Secondary effect P-Δ , shrinkage and creep are not considered.

iv) The floor diaphragms are rigid in their plane.

v) Axial deformation in column is considered.

vi) Each nodal point in the frame has six degrees of freedom, three translations and three rotations.

vii) Torsional effect is considered as per IS : 1893 (I) –2002.

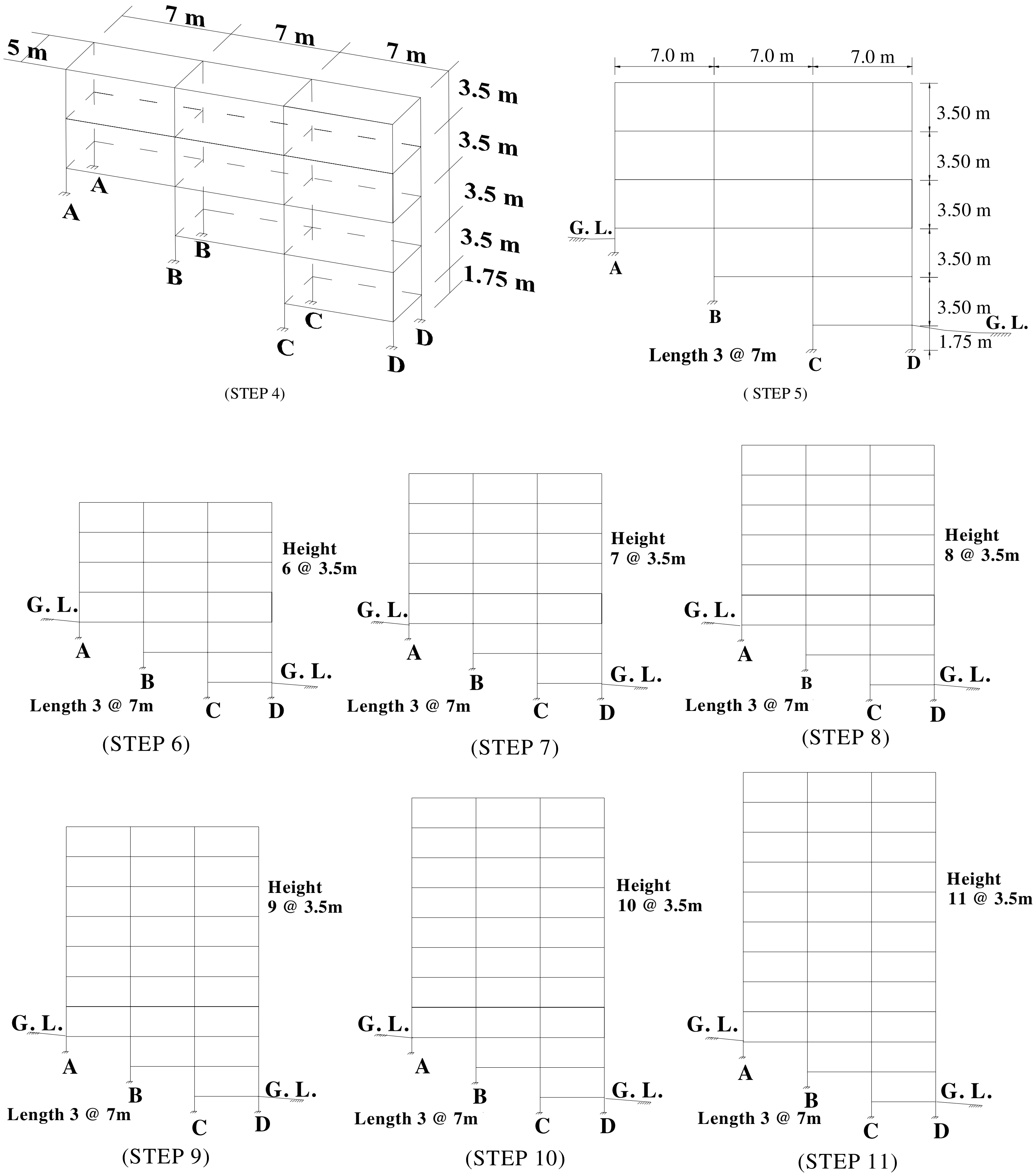
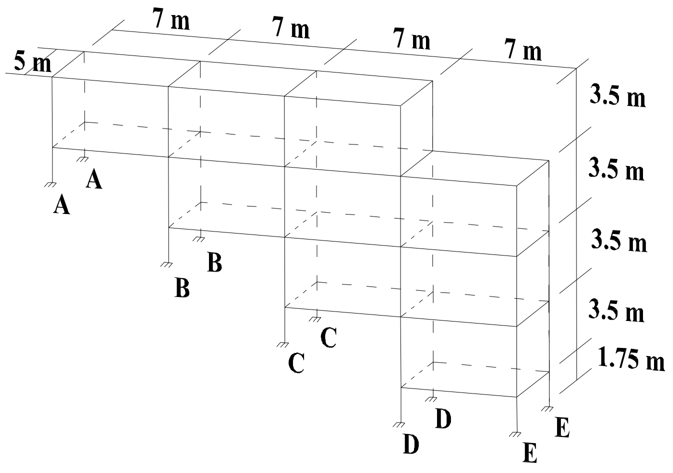
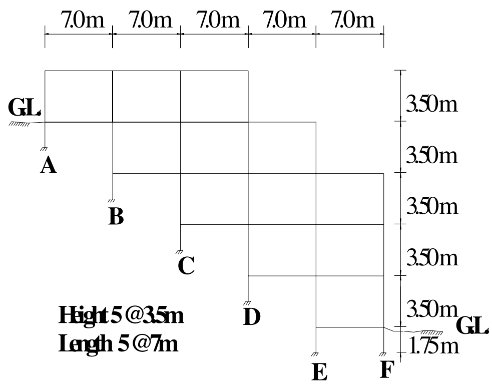


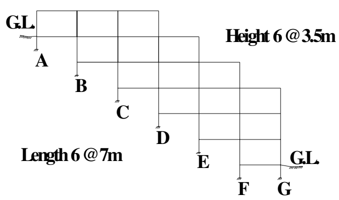
Figure 4.1: STEP BACK BUILDINGS ON SLOPING GROUND (4 TO 11 STOREY)



(STPSET 4)



(STPSET 5)



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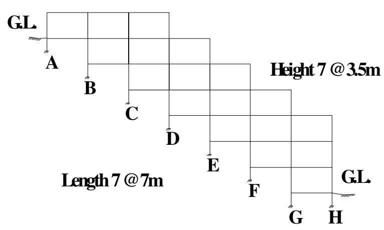

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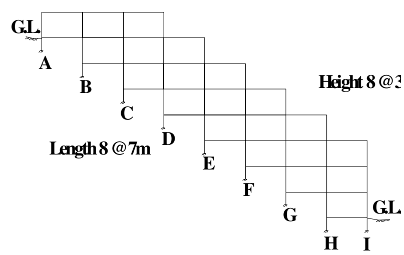

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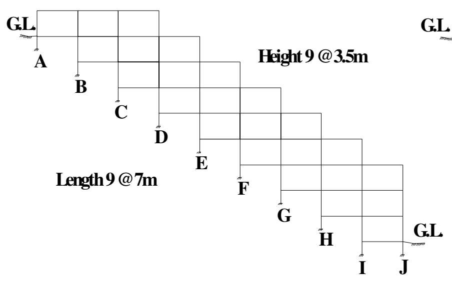

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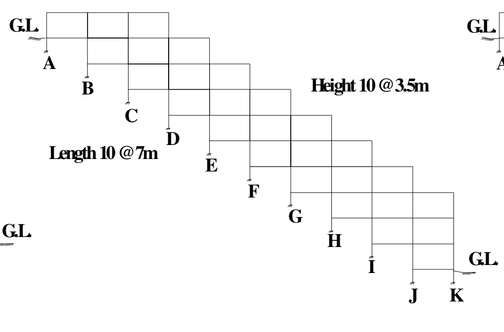
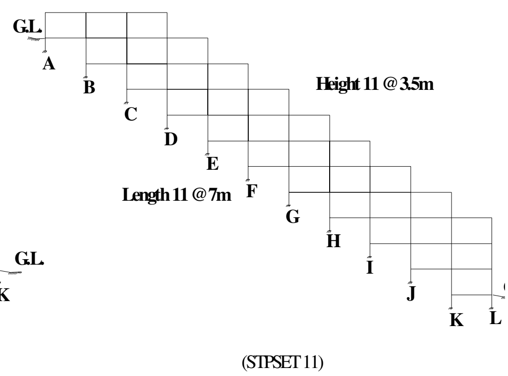


(STPSET 10)



(STPSET 11)

Figure 4.2: STEP BACK SET BACK BUILDINGS ON SLOPING GROUND (4 to 11 storey)

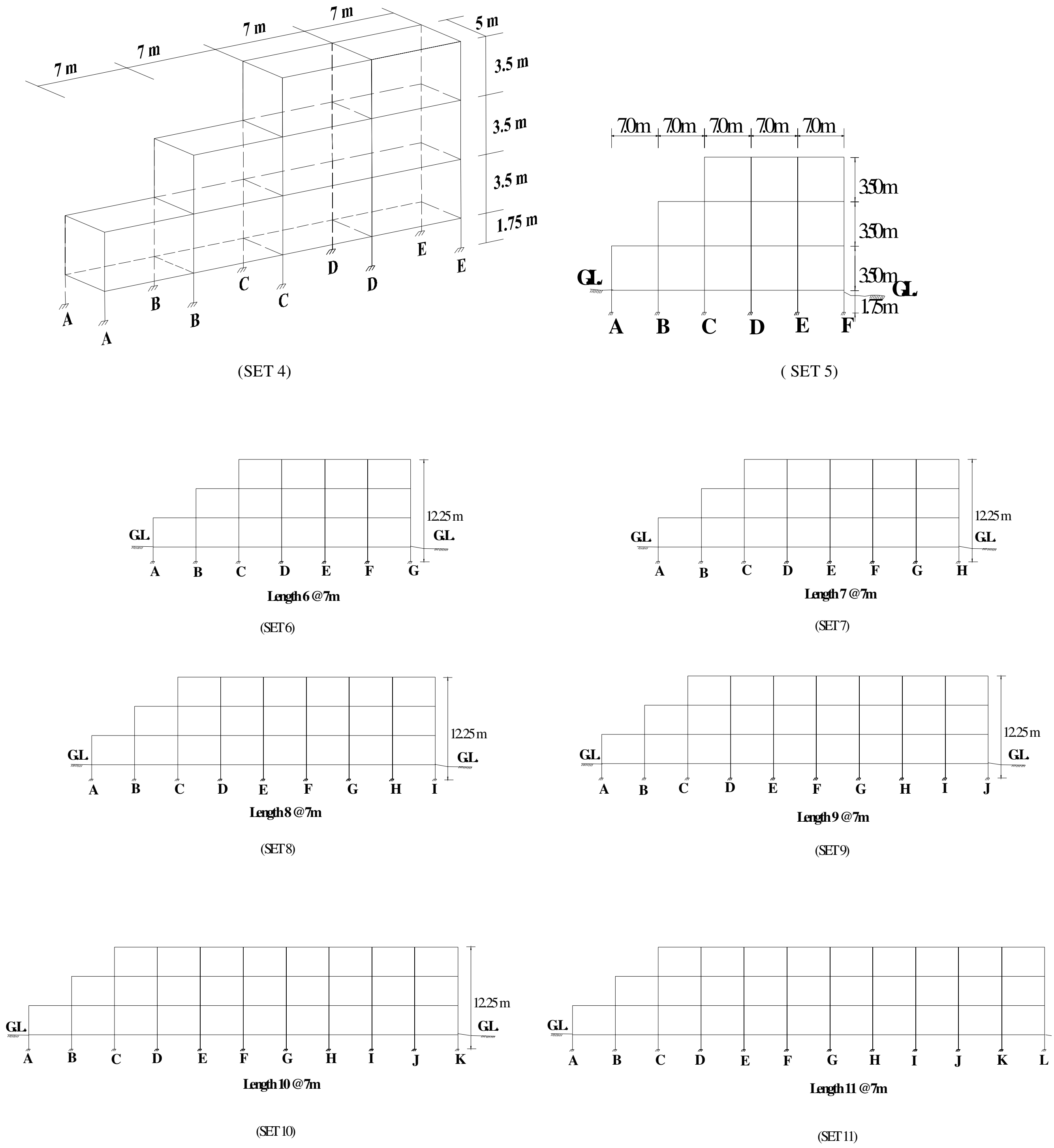


Figure 4.3: SET BACK BUILDINGS ON PLAIN GROUND

5.1 Response Spectrum Analysis (RSA) :

The seismic analysis of all buildings are carried out by response spectrum method by using IS : 1893 (I) –2002, [2] including the effect of eccentricity (static + accidental). The other parameters used in seismic analysis are, moderate seismic zone (III), zone factor 0.16, importance factor 1.0, 5 % damping and response reduction factor 3.0, presuming ordinary moment resistant frame for all configurations and height of buildings.

For each building case, adequate modes (minimum six) were considered, in which, the sum of modal masses of all modes was at least 99 % of the total seismic mass. The member forces for each contributing mode due to dynamic loading were computed and the modal responses were combined using CQC method. The following design spectrum was utilized in response spectrum analysis.

$$Sa/g = \begin{cases} 1+15\,T & \text{when } 0.00 \le T \le 0.10 \text{ seconds} \\ 2.50 & 0.10 \le T \le 0.40 \text{ seconds} \\ 1/T & 0.40 \le T \le 4.00 \text{ seconds} \end{cases}$$

5.2 Consideration of Torsional Moment due to Accidental Eccentricity:
First, the dynamic analyses of buildings without shifting the center of mass from their locations were carried out. Then the results due to the application of torsional moments at each floor level equal to the lateral force times the accidental eccentricity at that floor were superimposed on the results from dynamic analysis. The accidental eccentricity at each floor level was considered equal to 0.05 times the floor plan dimension perpendicular to the direction of seismic force.

Only selected results are presented in this paper due to space restrictions [3]. As per codal provision [2], dynamic results were normalized by multiplying with a *base shear ratio*, $\lambda = V_b/V_B$, where V_b is the base shear evaluation based on time period given by empirical equation[2] and, V_B is the base shear from dynamic analysis , if V_b/V_B ratio is more than one.

6. ANALYSIS OF RESULTS

In all, twenty-four buildings have been analyzed for seismic load with an effect of accidental eccentricity. The seismic force was applied in X direction and Y direction independently. Important results are presented in the subsequent sections.

6.1 Step Back Buildings:
In this configuration, total eight buildings have been analyzed, with varying height from 15.75 m to 40.25 m.

(a) EQ. force in X direction (along the slope line):
The dynamic response of each step back building in term of fundamental time period, top storey displacement and, base shear in columns at ground level is presented in table 6.1(a). The fundamental time period and base shear ratio (λ) as per IS : 1893 (I)-2002 [2], are evaluated and are presented in the same table. It is observed that there is linear increase in the value of top storey displacement and time period as the height of step back building increases. The value of fundamental time period by dynamic analysis is substantially higher than the values estimated by empirical equation given in IS: 1893 (I) –2002. Hence, the value of shear coefficient by dynamic analysis is less than the static method as per IS : 1893 (I)-2002.
Though the building plan is symmetrical along the sloping line and the torsional effect including accidental eccentricity is insignificant in x direction, it is observed the shear force in the column towards extreme left is *significantly higher* as compared to the rest of the columns at ground level for different heights of buildings. Comparatively, in the extreme right columns and adjacent to them (*frame D & frame C*) at ground level, normalized values of shear force are just 5 to 7 % of that of the extreme left columns.

(b) EQ force in Y direction (across the slope line):
Table 6.1 (b), shows the dynamic properties of each of the step back building for excitation in Y direction. The effect of accidental eccentricity is substantial when earthquake force is in Y direction. The torsional moments due to an accidental eccentricity on each floor, which varies from 4 kN-m to 61 kN-m, were applied at respective floor levels. The value of fundamental time period and the top storey displacement in Y direction are substantially higher than the corresponding values when the

earthquake force is in X direction. The evaluation of fundamental time period in Y direction as per IS : 1983 (I)-2002 is remarkably lower than the values obtained by response spectrum analysis in the same direction. Though the effect of torsional moment is dominant in Y direction, the corresponding normalized values of shear force in extreme left columns (*frame A*) at ground level are less than the corresponding normalized values obtained for earthquake forces in X direction. *From design point of view,it is to be noted that particular attention should be given to the size (strength), orientation (stiffness) and ductility demand of the extreme left column at ground level such that it is safe under worst possible load combinations in X and Y directions.*

Table 6.1 (a) : Dynamic response properties of STEP BACK building due to earthquake force in X direction

Designation	Number of storey *(ht. in meters)*	Funda mental time period by RSA, in sec.	Time period by IS: 1893(I)-2002 in sec.	Maxi. Top storey displac ement 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

Table 6.1 (b) : Dynamic response properties of STEP BACK building due to earthquake force in Y direction

Designation	Number of storey *(Height in m)*	Funda mental time period by RSA, in sec.	Time period by IS: 1893(I)-2002 [2] in sec.	Maxi. Top storey displac ement, 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

6.2 Step Back Set Back Buildings:

(a) EQ. force in X direction (along the slope line):

The results of dynamic analysis of step back set back buildings are presented in Table 6.2 (a). It is seen that the evaluation of fundamental time period using dynamic analysis (RSA) for 4 to 11 storey height of buildings varies in the range of 0.437 sec. to 0.499 seconds. Whereas, it has varies from 0.267 sec. to 0.413 seconds when evaluation using static method. On the whole it is observed that the value of base shear ratio varies 1.09 to 1.23, indicating that the results the results obtained from static and dynamic analysis do not differ substantially as the case of step back buildings.

Table 6.2 (a) : Dynamic response properties of STEP BACK -SET BACK Buildings due to earthquake force in X direction

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 column at ground level in kN											
						Frame A	Frame B	Frame C	Frame D	Frame E	Frame F	Frame G	Frame H	Frame I	Frame J	Frame K	Frame L
STPSET 4	4 *(15.75)*	0.437	0.267	3.61	1.092	86.26	50.74	29.06	6.52	6.83							
STPSET 5	5 *(19.25)*	0.458	0.293	3.96	1.144	93.93	63.67	54.61	28.97	6.67	6.95						
STPSET 6	6 *(22.75)*	0.475	0.316	4.18	1.188	98.1	67.0	74.36	57.20	28.78	8.02	8.28					
STPSET 7	7 *(26.25)*	0.465	0.337	4.10	1.163	96.92	62.97	76.94	77.65	54.60	27.21	7.80	8.04				
STPSET 8	8 *(29.75)*	0.475	0.358	4.19	1.188	99.07	61.48	76.32	86.45	77.39	53.93	26.67	6.72	6.96			
STPSET 9	9 *(33.25)*	0.484	0.377	4.28	1.211	100.9	60.45	73.99	88.54	89.73	76.72	53.23	26.72	8.04	8.25		
STPSET 10	10 *(36.75)*	0.492	0.395	4.35	1.231	102.6	59.93	71.87	86.95	94.64	81.69	75.78	52.70	26.70	7.13	5.26	
STPSET 11	11 *(40.25)*	0.499	0.413	4.28	1.210	103.8	57.47	67.88	81.43	87.72	96.19	85.91	74.41	56.15	26.13	6.47	6.81

Table 6.2 (b) : Dynamic response properties of STEP BACK -SET BACK Buildings due to earthquake force in Y direction

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 column at ground level in kN											
						Frame A	Frame B	Frame C	Frame D	Frame E	Frame F	Frame G	Frame H	Frame I	Frame J	Frame K	Frame L
STPSET 4	4 *(15.75)*	1.031	0.634	13.41	1.627	42.14	40.85	36.00	14.09	21.44							
STPSET 5	5 *(19.25)*	1.160	0.775	13.52	1.497	35.31	41.15	37.45	32.02	11.66	19.29						
STPSET 6	6 *(22.75)*	1.242	0.915	13.62	1.356	30.29	36.85	37.84	33.60	28.60	11.45	17.32					
STPSET 7	7 *(26.25)*	1.134	1.056	13.61	1.073	22.95	21.80	30.19	29.85	26.24	22.23	9.00	13.54				
STPSET 8	8 *(29.75)*	1.202	1.197	13.52	1.000	20.59	25.56	27.68	28.45	27.61	24.11	20.43	8.34	12.50			
STPSET 9	9 *(33.25)*	1.174	1.338	13.42	0.877	19.96	24.89	27.08	28.32	28.47	27.37	23.56	20.15	8.29	12.38		
STPSET 10	10 *(36.75)*	1.208	1.479	13.45	0.817	19.92	24.31	26.48	27.96	28.60	28.37	27.20	23.70	19.92	15.39	8.93	
STPSET 11	11 *(40.25)*	1.230	1.620	13.50	0.739	18.24	23.29	26.96	27.24	28.29	28.59	28.23	26.95	23.41	15.59	8.90	12.12

Table 6.3 (a) : Dynamic response properties of SET BACK Buildings due to earthquake force in X direction

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)	Normalized value of shear force in column at ground level in kN											
						Frame A	Frame B	Frame C	Frame D	Frame E	Frame F	Frame G	Frame H	Frame I	Frame J	Frame K	Frame L
SET 4	4 *(12.25)*	0.745	0.2083	12.46	1.862	27.02	40.73	40.11	40.58	29.15							
SET 5	5 *(12.25)*	0.782	0.1863	13.41	1.955	29.44	44.20	43.71	43.60	44.24	31.67						
SET 6	6 *(12.25)*	0.806	0.1701	13.62	1.955	30.20	45.29	44.80	44.71	44.71	45.29	32.41					
SET 7	7 *(12.25)*	0.822	0.1575	14.47	2.050	34.31	48.34	47.82	47.72	47.93	47.72	48.40	34.56				
SET 8	8 *(12.25)*	0.834	0.1475	14.86	2.087	33.33	49.88	49.35	49.25	44.29	49.29	49.25	49.96	35.64			
SET 9	9 *(12.25)*	0.844	0.1389	15.13	2.110	34.05	50.95	50.43	50.32	50.34	50.34	50.34	51.01	51.01	36.39		
SET 10	10 *(12.25)*	0.851	0.1317	15.33	2.130	34.35	51.85	51.31	51.31	51.31	51.31	51.31	51.31	51.31	51.31	36.97	
SET 11	11 *(12.25))*	0.857	0.1256	15.47	2.140	35.09	52.43	51.89	51.89	51.89	51.89	51.89	51.89	51.89	51.89	51.89	36.57

Table 6.3 (b) : Dynamic response properties of SET BACK Buildings due to earthquake force in Y direction

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)	Normalized value of shear force in column at ground level in kN											
						Frame A	Frame B	Frame C	Frame D	Frame E	Frame F	Frame G	Frame H	Frame I	Frame J	Frame K	Frame L
SET 4	4 *(12.25)*	1.398	0.493	41.94	2.835	44.37	42.30	41.60	42.33	56.68							
SET 5	5 *(12.25)*	1.288	0.493	39.44	2.613	43.75	41.69	40.80	42.89	48.77	55.33						
SET 6	6 *(12.25))*	1.357	0.493	45.68	2.754	48.49	46.45	44.83	43.84	48.88	54.44	60.50					
SET 7	7 *(12.25)*	1.384	0.493	47.68	2.800	51.26	49.30	47.48	46.17	47.79	52.61	57.68	63.14				
SET 8	8 *(12.25)*	1.458	0.493	51.17	2.958	55.05	53.30	51.55	50.16	49.10	53.21	57.62	62.26	67.20			
SET 9	9 *(12.25))*	1.380	0.493	40.76	2.800	54.85	53.62	51.85	50.17	48.58	49.30	52.44	55.60	58.85	62.19		
SET 10	10 *(12.25)*	1.491	0.493	53.24	3.025	59.47	57.80	55.90	54.23	52.75	51.51	55.11	58.92	62.89	67.00	71.30	
SET 11	11 *(12.25)*	1.479	0.493	53.01	3.000	59.85	59.85	56.55	55.38	53.93	52.60	53.60	57.08	60.12	64.28	64.50	71.43

Observations from Table 6.2 (a) indicates that,
i) the columns at extreme left (frame A) attracts maximum shear varying between 86 to 103 kN.
ii)Adjacent frames (frame B onwards) and but last two frames attract shear force varying between 26 to 97 kN.
iii) the last two frames to the extreme right are subjected to least shear forces.

(b) EQ force in Y direction (across the slope line):
When earthquake force is applied in Y direction, it is observed from Table 6.2 (b) that,
i)Variation of shear force in all frames is found to be less significant.
ii) Unlike the behaviour due to earthquake force in X direction extreme left *frame A* is not severely stressed, indicating the lateral forces in Y direction cause in significant effect due to torsion.
iii) For building having height 8 to 11 storey, the results obtained from dynamic analysis governed the design as against the results obtained from static analysis.
iv) The fundamental time period in Y direction by dynamic analysis is not much affected by the height of step back set back buildings, whereas, IS: 1893(I)-2002 predicts the time period value which varies linearly with the height of building.

It is perceived that in step back set back building configuration, the actions required for design purpose are pre-dominant when earthquake force is in X direction. Moreover, the top storey displacement is comparatively higher (about 3.8 to 4 times) in Y direction than the corresponding values in X direction, under the seismic action.

From design point of view, the uniform section (having constant area of steel and concrete through out) from bottom to top for extreme left column (*frame A)*, would be sufficient to fulfil the design requirements for different heights of step back set back buildings considered. A similar trend is observed more or less for the rest of the columns.

6.3 Set Back Buildings on Plain Ground:

A total of eight buildings on plain ground have been analyzed for seismic force in X as well as in Y directions in this configuration of building. The floor area of each set back building on plain ground is same as that of the corresponding type of Step back building and Step Back Set back building resting on sloping ground, *i.e.* floor area of SET 4 = STEP 4 = STPSET 4 and so on. This configuration is intended to create a plain ground in a natural sloping terrain. The cost involved in preparing leveled ground on a sloping terrain would be additional. In the present study, only structural behaviour under the action of seismic load has been carried out without any emphasis on cost construction.

(a) EQ. force in X direction :
Table 6.3 (a) shows the results obtained from dynamic analysis of set back building. It is observed that the time period by RSA for SET 4 to SET 11 buildings has increased from 0.745 sec. to 0.857 seconds, whereas for the same buildings, the value of time period predicted by IS:1893(I) –2002 has decreased from 0.2083 sec. to 0.1256 seconds. The base shear ratio (λ) is found to vary between 1.862 to 2.140. It is to note that the peripheral frames are found to carry fewer shears as compared to interior frames.

(b) EQ. force in Y direction:
Due to action of earthquake in Y direction, it is noticed that shear force in columns at ground level for different frames is more or less same. The fundamental time period as predicted by IS: 1893(I)-2002 is constant for all set back buildings, whereas, prediction using RSA are found to yield higher value of time period. The top storey displacement in y direction is 3.5 times the higher than the corresponding values in X direction. The base shear ratio has been found to vary between 2.835 to 3.025, which is significantly high. This indicates that in set back buildings the design of column will primarily be controlled by actions induced in Y direction.

7. COMPARISON OF THREE CONFIGURATIONS

7.1 Step back building Vs. Step back Set Back Building:

In Step back buildings; frame A has attracted much higher base shear force than the frames B, C, and D. This uneven distribution of shear force in the various frames suggests development of torsional moment due to static and accidental eccentricity, which has caused profound effect in Step back buildings.

An uneven distribution of base shear in various frames was also observed in Step back –Set back buildings. However, this uneven distribution of shear forces is low to moderate, indicating torsional moments of lesser magnitude under the action of seismic forces.

Based on the above observations, it can be stated that Step back buildings are subjected to higher amount of torsional moments as compared to Step back Set back buildings and may prove more vulnerable during the seismic excitation. The configuration of Step back Set back building has an advantage in neutralizing the torsional effect, resulting into better performance than the Step back building during the earthquake ground motion, provided the short columns are taken care of in design and detailing.

7.2 Step back- set back buildings Vs. Set back buildings:

Shear action induced in Step back Set back buildings is moderately higher as compared to Set back buildings on plain ground. It is to be noted that in Step back Set back buildings, higher stiffness is required in X direction whereas, in Set back buildings more stiffness is required in Y direction.

If, cost component of cutting the sloping ground and other related issues, is within the acceptable limits, set back buildings on plain ground may be preferred than the step back Set back buildings. In addition to this, issues viz. stability of slopes and vulnerability during the earthquake ground motion are less concerned in set back building.

8. CONCLUSIONS

Based on dynamic analysis of three different configurations of buildings, the following conclusions can be drawn.

1) The performance of STEP back building during seismic excitation could prove more vulnerable than other configurations of buildings.
2) The development of torsional moments in Step back buildings is higher than that in the Step back Set back buildings. Hence, Step back Set back buildings are found to be less vulnerable than Step back building against seismic ground motion.
3) 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.
4) Although, the Set back buildings on plain ground attract less action forces as compared to Step back Set back buildings, overall economic cost involved in leveling the sloping ground and other related issues needs to be studied in detail.

9. REFERENCES

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