SEISMIC PERFORMANCE OF STEP-BACK AND STEP BACK- SET BACK BUILDING RESTING ON A HILL SLOPE

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Abstract:- *From the past few decades the population of the world has been increasing abruptly, due to this there is scarcity of land. To overcome this drawback structures of different configurations such as Step-back and Step back-set back has been adopted on hilly regions. This adopted configurations has led to different irregularities in the structures such as torsion and increased shear due to seismic ground motion.*

To understand the real behaviour of buildings on hill slope a 3D analysis of the building is required. In the present study non-linear static pushover analysis and Response spectrum analysis (RSA) have been conducted using SAP2000 software for step- back and step back-set-back buildings for a sloping ground of 27^0 and for different soil conditions(hard, medium and soft) by equivalent springs. Different response parameters have been studied with respect to fixed base and equivalent springs.

***Key Words*: Step-back Configuration, Step back-Set Back configuration, SAP2000, Pushover Analysis, Response Spectrum Analysis, Response Parameters**.

1. INTRODUCTION

The scarcity of plain ground in hilly areas has led to construction on sloping ground. The behavior of building during earthquake depends on the mass and stiffness in both horizontal and vertical planes of the buildings. Majority of buildings constructed on hill slopes are irregular and asymmetric due to step back and set back type construction. Such buildings are prone to have special structural and constructional problems such as shear, torsion and unequal column heights within a storey, which results in drastic variation in stiffness of columns of the same storey. The short column attracts much higher lateral forces and are prone to damage. In order to highlight the differences in behavior, which may further be influenced by the characteristics of the locally available foundation material, a parametric study has been conducted on five different buildings i.e step back and step back-set back buildings using SAP 2000.

Current building codes including IS :1893 (Part 1) :2002 and IS: 1893 (Part 1):2016 suggest detailed dynamic analysis of these type of buildings on different soil (hard, medium and soft soil) types. To asses acceptability of the design it is important to predict the force and deformation demands imposed on structures and their elements by severe ground motions by means of static pushover analysis.

2. LITERATURE REVIEW

Pandey A.D et.al(2011):Static pushover analysis and response spectrum analysis(RSA) have been conducted on five buildings for different configuration with varying soil conditions. These buildings were analysed for different soil conditions (hard, medium and soft) by equivalent springs. The displacement from both pushover analysis and RSA was considered and response correction factor was obtained. Displacement obtained from pushover analysis was greater than displacement from that of RSA. The value of T increase with the decrease in the correction factor.

Y.Singh et.al(2012): Dynamic analysis of hill structure of different configuration of sloping angle 45º was compared with regular structure on a plain ground with respect to, inter story drift ,fundamental period of vibration, plastic hinge formation and column shear. Linear and non-linear time history analysis was carried out. Hill buildings have different dynamic characters compared to structures on plain ground. Due to vertical and horizontal irregularity on a slopping ground torsional irregularity was observed due to shifting of centre of stiffness and centre of mass with floor level. Story shear was higher on hill slope which resulted in shear failure.

2.1 OBJECTIVES

1. In the current investigation, Static and Dynamic analysis has been regulated. In Static analysis non-linear pushover analysis is carried out and in dynamic analysis Response Spectrum Analysis (RSA) is carried out.
2. Analysis is carried out on five buildings i.e three step back buildings and two step back set back buildings with a sloping ground of 27^0 with respect to horizontal.
3. Analysis was carried out for fixed base and flexible condition.
4. Analysis was done for different types of soil i.e hard soil, medium soil and soft soil and glorified by equivalent springs.
5. Over-all base shear (V), displacement from pushover analysis (δ performance point),

displacement from RSA (δelastic) response correction factor (R').

6. Lateral displacement, storey drift and response spectrum curve has been studied for moderate seismic zone (III) for fixed base and flexible condition.

3. MODELLING AND ANALYSIS

The five different buildings (Fig 1 and Fig 2) are analyzed in SAP 2000. The gradient of ground has been taken as 27º with respect to horizontal. The characteristic of the considered building configurations in the present study are summarized below (Birajdar 2004). The structural material is assumed to be isotropic and homogenous. The joint has been modelled using diaphragm as constraints. Height of every floor: 3.5 m

Plan dimension: 7*5 m

Thickness of Floor :0.15 m

Thickness of Wall :230 mm

Thickness of Parapet wall:230 mm

Concrete Density 25kN/m^2

Poisson's Ratio:0.2

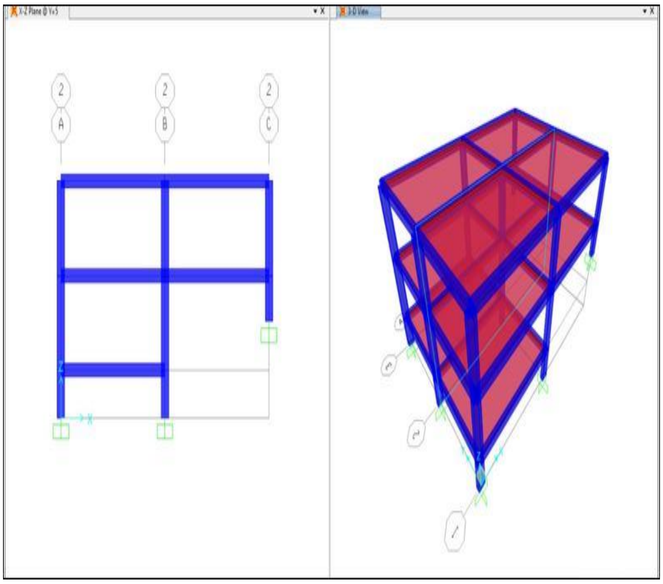
Damping:0.05

Column size:230*500 mm

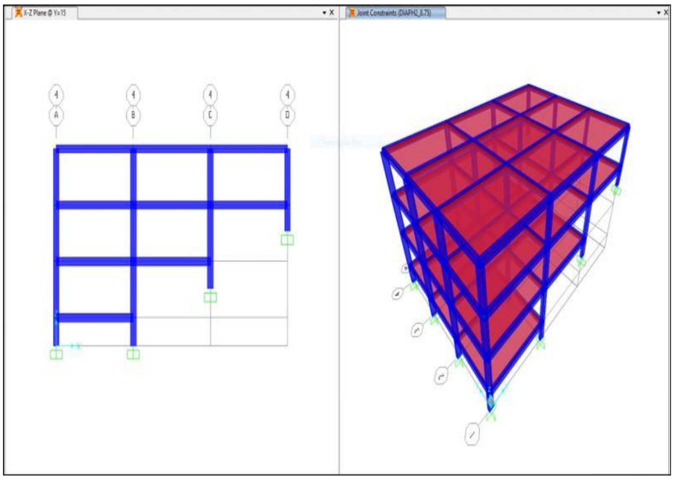
Beam Size:230*500 mm

Size of isolate footing taken 1m *1m

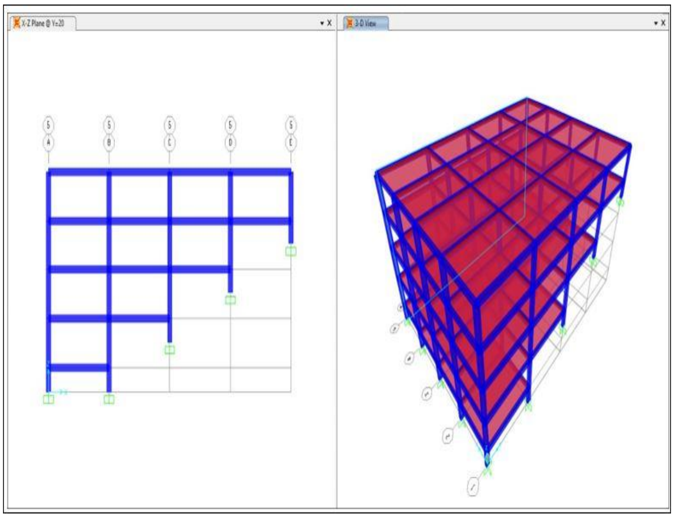
Moderate Seismic zone (III)



a) 2 Storey 2 Bay

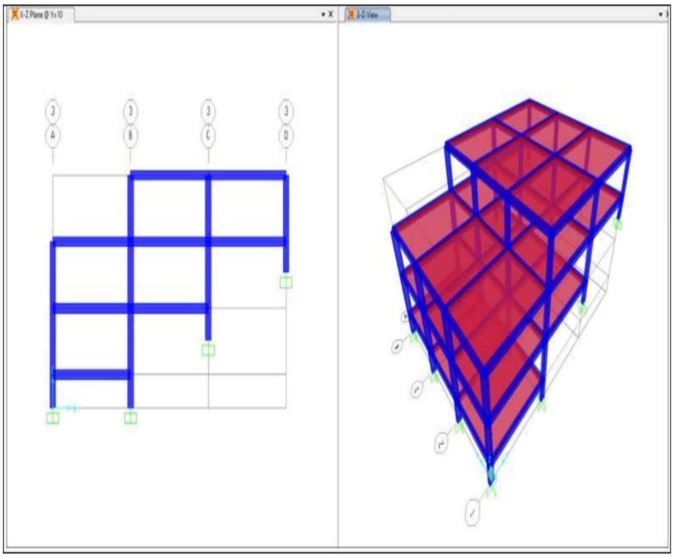


b) 3 Storey 3Bay

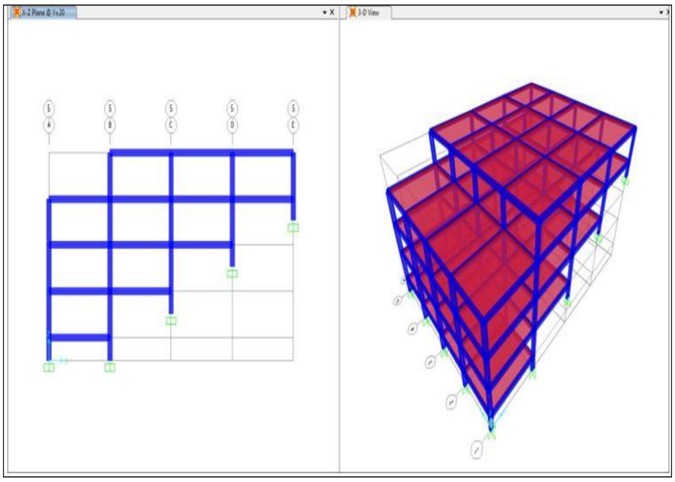


c) 4Storey 4Bay

Fig 1: Step back buildings (a,b,c) with increased number of storey and bays.



d) 3Storey-3 Bay



e) 4Storey 4Bay

Fig 2: Step back-Set back buildings(d,e) with increased number of storey and bays.

3.1 RESPONSE SPECTRUM METHOD

Response spectrum is a exceptional case of modal analysis. The modes of vibration are basically of the form of period and shape. The maximum response with respect to each mode is determined with respect to response spectrum.in the title or heads unless they are unavoidable. The seismic analysis of all buildings was carried out by response spectrum method in accordance to IS:1893 (Part 1):2002 and IS 1893 (Part 1):2016. Other parameters used in seismic analysis were, importance factor 1 and reduction factor 3. Ordinary moment resistant frame for all configurations was assumed.

3.2 Pushover Analysis

The Nonlinear static pushover analysis is a comprehensive method of evaluating earthquake seismic response of structure by considering non-linear behaviour of structural elements. The capacity spectrum method is adopted for implementing pushover analysis. The capacity spectrum method estimates peak response by expressing both structural capacity and ground shaking in terms of spectral acceleration and displacement.

3.3 Foundation Characteristics

The foundation is replaced by statically equivalent springs. According to the equations given by Wolf (1985)

$$Kx = Ky = \frac{32(1-v)GRo}{(7-8v)} \quad \text{where } Ro = \frac{Af}{\sqrt{\pi}} \quad \text{Eq. 3.1}$$

$$Kz = \frac{4GRo}{(1-v)} \quad \text{where } Ro = \frac{Af}{\sqrt{\pi}} \quad \text{Eq 3.2}$$

$$KRx = \frac{8GRo3}{3(1-v)} \quad \text{where } Ro = \frac{\sqrt[4]{4Iyf}}{\pi} \quad \text{Eq 3.3}$$

$$KRy = \frac{8GRo3}{3(1-v)} \quad \text{where } Ro = \frac{\sqrt[4]{4Ixf}}{\pi} \quad \text{Eq 3.4}$$

$$KRz = \frac{16\,GRo3}{3} \quad \text{where } Ro = \frac{\sqrt[4]{2(Iyf+Ixy)}}{\pi} \quad \text{Eq 3.5}$$

Where

G =shear modulus of the soil,

v = Poisson's ratio

R_o = equivalent radius

A_f = The area of the footing

l_{xy} and l_{yf} are moments of inertia of footing about X and Y axis respectively.

The values of Poisson's ratio (v) and shear modulus (G) for three different kinds of soil are taken from Pandey A.D et.al (2011) . The flexible properties of the foundation soil for hard, medium and soft soil are arranged in counter and numerical value of spring constants of different foundation soil for isolated footing are briefed in table 1 and table 2.

Table1: Elastic Properties of Foundation Soil

Type of Soil	Shear Modulus G(kN/m2)	Elastic Modulus E(kN/m2)	Poisson's Ratio
Hard	2700	6750	0.25
Medium	451.1	1200.0	0.33
Soft	84.5	250.0	0.48

Table 2: Spring Constants for Isolated Footing

Type of Soil	Kx (kN/m)	Ky (kN/m)	Kz (kN/m)	K_{Rx} (kN/m)	K_{Ry} (kN/m)	K_{Rz} (kN/m)
Hard	7309.4	7309.4	8121.6	1777.8	1777.8	2666.7
Medi-um	1251.1	1251.1	1518.9	334.1	334.1	444.5
Soft	251.0	251.0	366.6	80.3	80.3	83.5

4. Results and Discussion

Hinges are defined by selecting default hinge properties based on FEMA -273/356 or ACT-40 criteria. Default hinge PMM for end to end moment frame columns and default M3 hinges for beams was assigned.

The below tables clearly show that the total base shear in X- direction for all the considered building models were higher than the base shear in Y- direction

Except for soft soil. Further it can be observed that the displacement in x-direction was less than that of y-direction. The building in X-direction is stiffer hence showed lesser displacements and attracted greater shear forces in the short column. The building in Y-direction is less stiffer due to this there is higher displacement and less shear forces.

Table 3: Results From pushover analysis (Step Back Building)

Building Configuration	Values of Vpp and δ_{pp} (kn and mm)	Fixed Support	Flexible Base		
			Hard soil	Medium soil	Soft soil
2 storey 2 bay	Vx	1183.8	625	526.15	334.9
	Vy	660.24	480	440.12	242
	δx	21	50	125	277.12
	δy	34	61	146	310.6
3 storey 3bay	Vx	2101.7	1280.7	649.01	160.6
	Vy	882.6	765.8	300	257
	δx	24	61	171	583
	δy	40	85	*	910
4 storey 4 bay	Vx	2935.5	2032	1628.2	857.56
	Vy	1603.2	1367.6	975.8	50.961
	δx	24	67	134	502
	δy	42	89	154	461

Table 4: Results From pushover analysis (Step Back -Set Back Building)

Building Configuration	Values of Vpp and δ_{pp}(kN and mm)	Fixed Support	Flexible Base		
			Hard soil	Medium soil	Soft soil
3 storey 3bay	Vx	2615.3	1428.7	*	*
	Vy	1468.54	1043.7	100.1	*
	δx	24	48	*	*
	δy	40	83	27	*
4 storey 4 bay	Vx	3030.5	2396.9	1901.7	501.39
	δx	14	58	162	290
	Vy	*	*	*	*
	δy	*	*	*	*

(pp) -Performance Point V is the total base shear,δ is the displacement , * Results not available.

The displacements from pushover analysis ($\delta_{\text{performance point}}$,(δ_{pp})) and response spectrum analysis($\delta_{elastic}$) have been tabulated below for step-back and step-back-set back buildings. The displacement obtained from the pushover curve is higher than the displacement obtained from the response spectrum analysis. Correction factor has been used because as,($\delta_{pp} > \delta_{elastic}$) and when the number of storeys increases the ratio ($\delta_{pp} / \delta_{elastic}$) becomes less than 1 and hence correction factor has been used.

The correction factor R' has been calculated by

$$R' = (\delta_{pp} / \delta') \qquad \text{Eq 4.1}$$

δp = Displacement obtained from Pushover analysis

$$\delta' = R * \delta_{elastic} \qquad \text{Eq 4.2}$$

R = response reduction factor

$\delta_{elastic}$ = Displacement obtained from response spectrum

Table 5: Displacement from Pushover analysis and response spectrum analysis (Step back building)

Support	Building configuration	δelastic(mm)		δ_{pp}(mm)		δ'= R*δ elastic(mm)		t	R'= (δ_{pp}/δ')	t	R'= (δ_{pp}/δ')
		X-dir	Y-Dir	X-dir	Y-Dir	X-dir	Y-Dir	(sec)	X-dir	(sec)	Y-Dir
Fixed base	2 storey-2bay	5.79	4.5	21	34	17.37	13.5	0	1.209	0.25	2.519
	3 storey-3bay	5.89	18.3	22	40	17.67	54.9	0.5	1.245	0.5	0.729
	4storey-4bay	7.363	31.699	24	42	22.089	95.097	1	1.087	1	0.442
Hard soil	2 storey-2bay	17.11	38.26	50	61	51.33	114.78	1.5	0.974	1.5	0.531
	3 storey-3bay	22.1	62.8	61	85	66.3	188.4	2	0.920	2	0.451
	4storey-4bay	30.719	82.344	67	89	92.157	247.032	2.5	0.727	2.5	0.360
Medium Soil	2 storey-2bay	70.5	120.8	125	146	211.5	362.4	3	0.591	3	0.403
	3 storey-3bay	75.7	126.3	199	*	227.1	378.9	3.5	0.876	3.5	0.300
	4storey-4bay	102.4	224.5	134	154	307.2	673.5	4	0.436	4	0.229
Soft Soil	2 storey-2bay	209.2	333.4	242	310.6	627.6	1000.2	4.5	0.386	4.5	0.311
	3 storey-3bay	298.3	587.2	413	442	894.9	1761.6	5	0.462	5	0.251
	4storey-4bay	404.4	817.8	502	461	1213.2	2453.4	5.5	0.414	5.5	0.188

(pp) -Performance Point V is the total base shear, δ is the displacement , * Results not available.

Table 6: Displacement from Pushover analysis and response spectrum analysis (Step back -Set back building)

Support	Building configuration	δelastic(mm) X-dir	δelastic(mm) Y-Dir	δ_{pp} X-dir	δ_{pp} Y-Dir	δ'=R*δ elastic X-dir	δ'=R*δ elastic Y-Dir	t (sec)	R'= (δ_{pp}/δ') X-dir	t (sec)	R'= (δpp/δ') Y-Dir
Fixed base	3 storey-3bay	5.71	16.6	24	40	17.13	49.8	0.25	1.401	0.25	0.8032
	4storey-4bay	6.88	21	28	*	20.64	63	0.5	1.357	0.75	*
Hard soil	3 storey-3bay	20.1	41.6	48	83	60.3	124.8	0.75	0.796	1	0.6650
	4storey-4bay	26.4	69.3	58	*	79.2	207.9	1	0.732	1.5	*
Medium Soil	3 storey-3bay	65.2	105.4	120	*	195.6	316.2	1.25	0.613	2	*
	4storey-4bay	89.3	171.4	162	*	267.9	514.2	1.5	0.605	2.5	*
Soft Soil	3 storey-3bay	271.1	397.6	*	*	813.3	1192.8	1.75	*	3	*
	4storey-4bay	361.7	640.4	290	*	1085.1	1921.2	2	0.267	3.5	*

(pp) -Performance Point V is the total base shear, δ is the displacement, * Results not available.

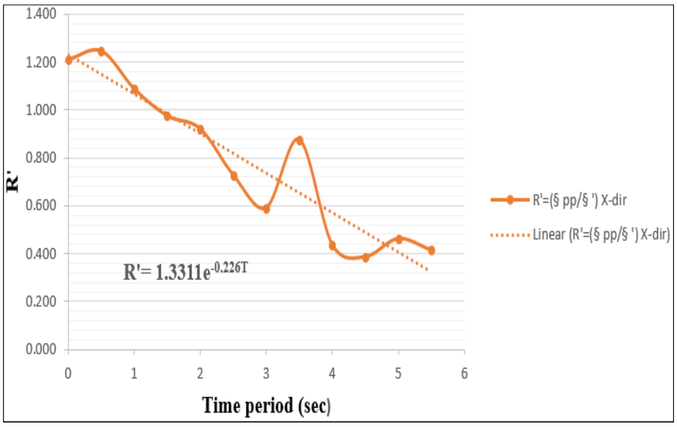


Fig 3: Correction Factor for Steep back Building in X-Direction

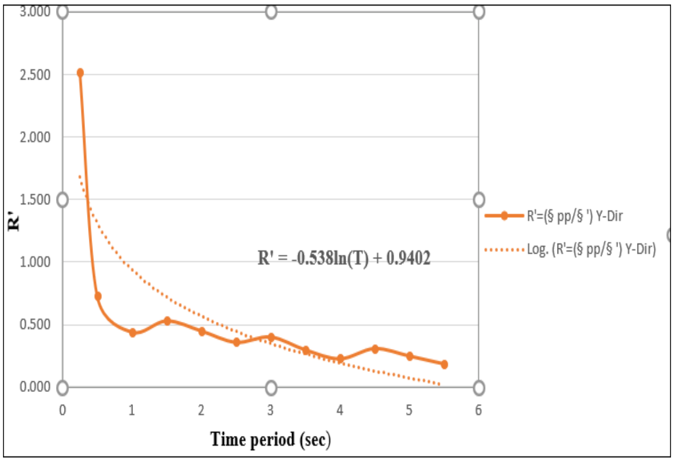


Fig 4: Correction Factor for Step- back Building in Y-Direction

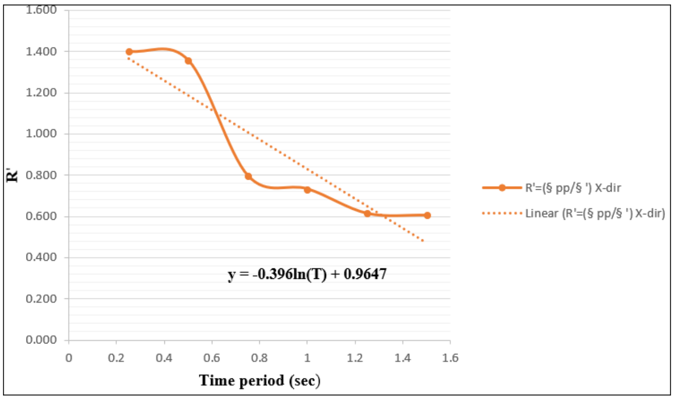


Fig 5: Correction Factor for Step Back -Set Back Building in X- Direction

4.1 Storey Drift

Storey drift is defined as the displacement of one level relative to the other level above or below. Drift can vary according to each direction.

Table 7 : Storey Drift for Step -back Building

Step Back Configuration									
Storey Drift in X- Direction					Storey Drift in Y- Direction				
2 Bay 2 Storey	Fixed	Hard	Medium	Soft	2 Bay 2 Storey	Fixed	Hard	Medium	Soft
Base	0	0	0	0	Base	0	0	0	0
Storey1	0.51	2.3	5.82	18.17	Storey1	1.8	4.4	20	34
Storey2	1.4	2.4	5.45	17.6	Storey2	2.88	4.25	10.11	33.3
3 Bay 3 Storey	Fixed	Hard	Medium	Soft	3 Bay 3 Storey	Fixed	Hard	Medium	Soft
Base	0	0	0	0	Base	0	0	0	0
Storey1	0.42	5.45	15.1	44.11	Storey1	2.71	12.42	27.82	81.37
Storey2	1.65	6.25	14.1	41.4	Storey2	5.85	13.54	27.4	79
Storey 3	3.97	6.34	12.82	39.25	Storey 3	8.25	11.45	24.1	75.1
4 Bay 4 Storey	Fixed	Hard	Medium	Soft	4 Bay 4 Storey	Fixed	Hard	Medium	Soft
Base	0	0	0	0	Base	0	0	0	0
Storey1	0.076	2.05	6.4	18	Storey1	0.4	5.25	12	32.82
Storey2	0.3142	2.45	6.14	17.14	Storey2	1	6.34	12.4	32.74
Storey 3	0.885	2.82	5.82	16.2	Storey 3	1.8	6.42	11.8	31.74
Storey 4	1.771	2.71	5.02	14.85	Storey 4	2.08	4.94	9.68	28.9

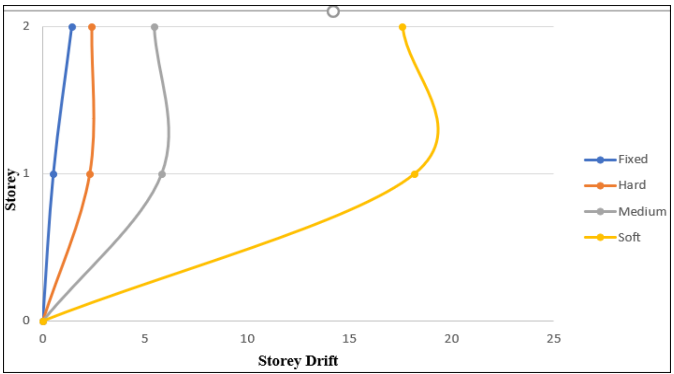


Fig 6: Storey Drift For 2 Storey Step Back Building along X- direction

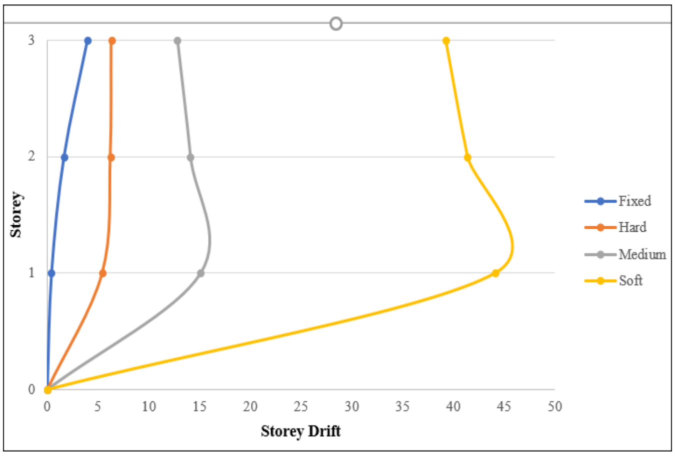


Fig 7: Storey Drift For 3 Storey Step Back Building along X- direction

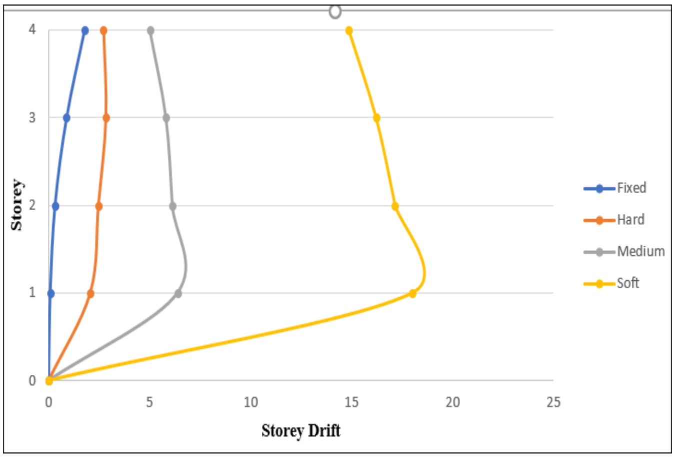


Fig 8: Storey Drift For 4 Storey Step Back Building along X- direction

Table 8 : Storey Drift for Step -back Building

Step Back Set Back Configuration									
Storey Drift in X- Direction					Storey Drift in Y- Direction				
3 Bay 3 Storey	Fixed	Hard	Medium	Soft	3 Bay 3 Storey	Fixed	Hard	Medium	Soft
Base	0	0	0	0	Base	0	0	0	0
Storey 1	0.428	4.77	12.97	37.88	Storey 1	0.102	0.4	20	63.6
Storey2	1.428	5.31	12.02	35.34	Storey2	0.2	0.428	21.1	63
Storey 3	2.5	6.17	11.22	33.25	Storey 3	0.4	0.485	21	61.8
4 Bay 4 Storey	Fixed	Hard	Medium	Soft	4 Bay 4 Storey	Fixed	Hard	Medium	Soft
Base	0	0	0	0	Base	0	0	0	0
Storey 1	0.076	1.85	5.77	16.3	Storey 1	0.457	2.2	6.2	27.4
Storey2	0.257	2.2	5.57	15.5	Storey2	1.2	6.54	8.14	27.9
Storey 3	0.742	2.48	5.17	14.6	Storey 3	2.25	5.11	12.3	27.3
Storey 4	1.8	4	4.54	13.3	Storey 4	3.85	4.94	9	25.9

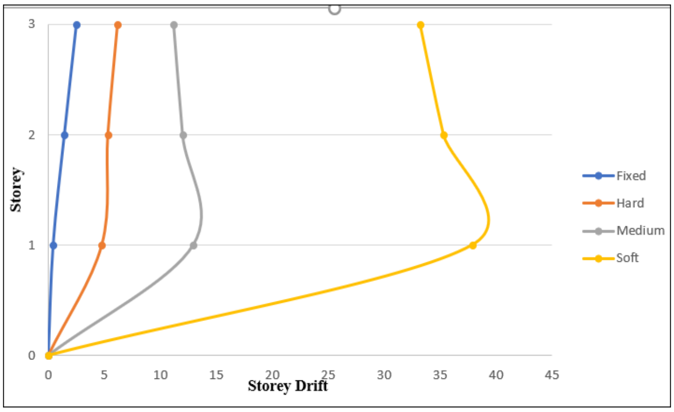


Fig 9: Storey Drift For 3 Storey Step Back Set Back Building along Ex

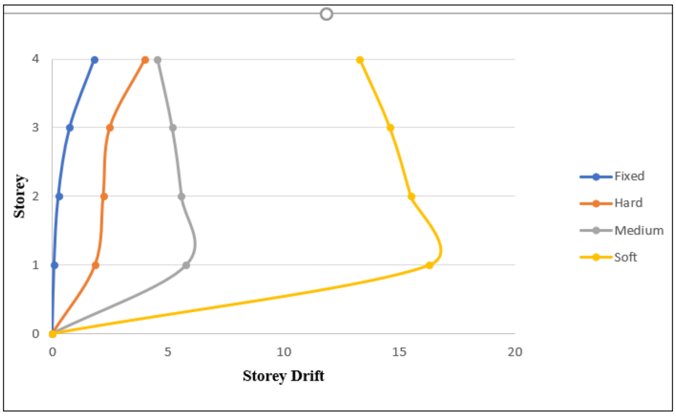


Fig 10: Storey Drift For 4 Storey Step Back Set Back Building along Ex

4.2 RESPONSE SPECTRUM CURVE

Response spectrum curve is plotted by taking the time period of different soil conditions from response spectrum analysis and interpolating Sa/g for the required time period.

Table 9 : Response Spectrum for 2 Storey Step -Back building

RESPONSE SPECTRUM FOR 2 STOREY							
FIXED BASE		HARD SOIL		MEDIUM SOIL		SOFT SOIL	
time	acc	time	acc	time	acc	time	acc
0.062	0.308	0.259	0.4	0.311	0.4	0.326	0.4
0.063	0.311	0.271	0.4	0.315	0.4	0.331	0.4
0.079	0.349	0.272	0.4	0.343	0.4	0.376	0.4
0.081	0.354	0.292	0.4	0.399	0.4	0.420	0.4
0.090	0.376	0.324	0.4	0.419	0.4	0.465	0.4
0.136	0.4	0.342	0.4	0.429	0.4	0.477	0.4
0.147	0.4	0.387	0.4	0.795	0.274	1.606	0.1664
0.151	0.4	0.416	0.389	0.804	0.27	1.659	0.1617
0.263	0.4	0.508	0.328	1.118	0.196	2.253	0.12
0.437	0.4	0.764	0.212	1.240	0.176	2.441	0.11
0.482	0.4	0.927	0.175	1.758	0.124	3.558	0.0751
0.722	0.311	1.222	0.1333	2.156	0.101	4.226	0.0668

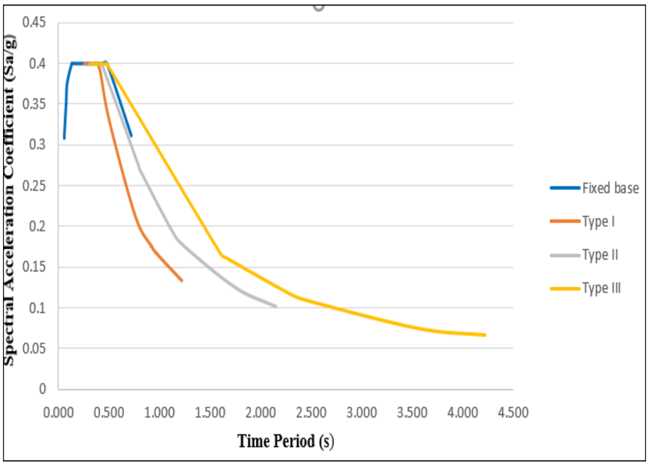


Fig 11: Response Spectrum for 2 Storey Step Back building

Table 10: Response Spectrum for 3 Storey Step Back building

RESPONSE SPECTRUM FOR 3 STOREY							
FIXED BASE		HARD SOIL		MEDIUM SOIL		SOFT SOIL	
time	acc	time	acc	time	acc	time	acc
0.102	0.400	0.325	0.400	0.382	0.400	0.394	0.400
0.108	0.400	0.338	0.400	0.412	0.400	0.429	0.400
0.122	0.400	0.341	0.400	0.448	0.400	0.484	0.400
0.135	0.400	0.355	0.400	0.504	0.400	0.551	0.400
0.155	0.400	0.364	0.400	0.537	0.400	0.566	0.400
0.168	0.400	0.445	0.371	0.572	0.388	0.634	0.400
0.169	0.400	0.468	0.356	1.067	0.205	1.982	0.134
0.245	0.400	0.519	0.323	1.119	0.196	1.985	0.134
0.330	0.400	0.624	0.265	1.549	0.141	2.751	0.098
0.445	0.400	0.844	0.209	1.613	0.134	2.827	0.095
0.506	0.400	1.024	0.178	2.242	0.098	4.079	0.066
0.810	0.269	1.495	0.128	3.141	0.071	4.940	0.066

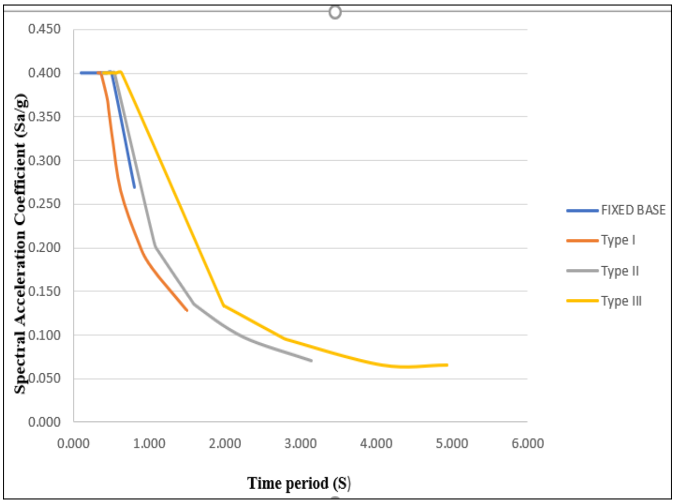


Fig 12: Response Spectrum for 3 Storey Step Back building

Table 11: Response Spectrum for 4 Storey Step Back building

RESPONSE SPECTRUM FOR 4 STOREY							
FIXED BASE		HARD SOIL		MEDIUM SOIL		SOFT SOIL	
time	acc	time	acc	time	acc	time	acc
0.134	0.400	0.409	0.394	0.510	0.400	0.545	0.400
0.151	0.400	0.417	0.389	0.522	0.400	0.557	0.400
0.159	0.400	0.418	0.388	0.543	0.400	0.623	0.400
0.160	0.400	0.422	0.385	0.606	0.371	0.705	0.382
0.192	0.400	0.450	0.368	0.665	0.341	0.739	0.364
0.197	0.400	0.550	0.304	0.709	0.318	0.848	0.317
0.243	0.400	0.556	0.300	1.113	0.197	2.259	0.119
0.293	0.400	0.620	0.266	1.166	0.187	2.319	0.116
0.391	0.400	0.726	0.237	1.584	0.137	3.170	0.085
0.479	0.400	0.936	0.192	1.598	0.136	3.176	0.084
0.543	0.400	1.135	0.163	2.212	0.099	4.526	0.066
0.909	0.242	1.762	0.111	2.932	0.077	5.578	0.066

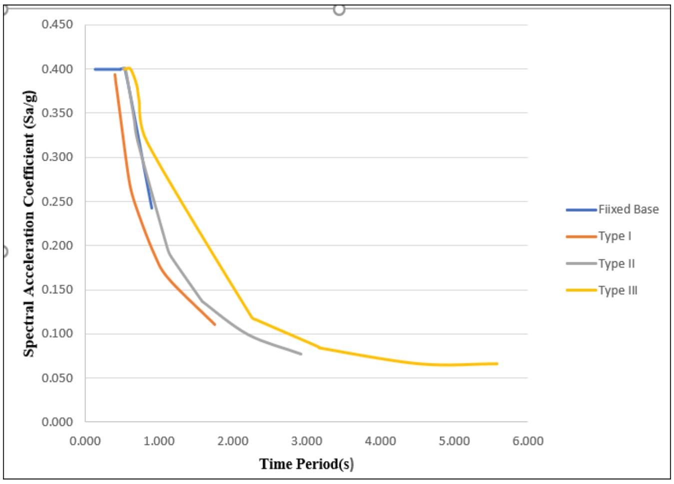


Fig 13: Response Spectrum for 4 Storey Step Back building

Table 12: Response Spectrum for 3 Storey Step Back Set Back Building

RESPONSE SPECTRUM FOR 3 STOREY STEP BACK SET BACK							
FIXED BASE		HARD SOIL		MEDIUM SOIL		SOFT SOIL	
time	acc	time	acc	time	acc	time	acc
0.092	0.380	0.316	0.400	0.379	0.400	0.406	0.400
0.097	0.392	0.327	0.400	0.395	0.400	0.415	0.400
0.126	0.400	0.343	0.400	0.424	0.400	0.474	0.400
0.137	0.400	0.362	0.400	0.495	0.400	0.529	0.400
0.155	0.400	0.368	0.400	0.544	0.400	0.635	0.400
0.170	0.400	0.429	0.381	0.569	0.390	0.683	0.393
0.170	0.400	0.453	0.366	0.943	0.233	1.907	0.140
0.250	0.400	0.491	0.341	0.947	0.232	1.931	0.138
0.330	0.400	0.591	0.277	1.288	0.169	2.578	0.104
0.411	0.400	0.809	0.215	1.359	0.160	2.706	0.099
0.475	0.400	0.932	0.193	1.821	0.119	3.742	0.071
0.692	0.327	1.285	0.147	2.236	0.099	4.377	0.066

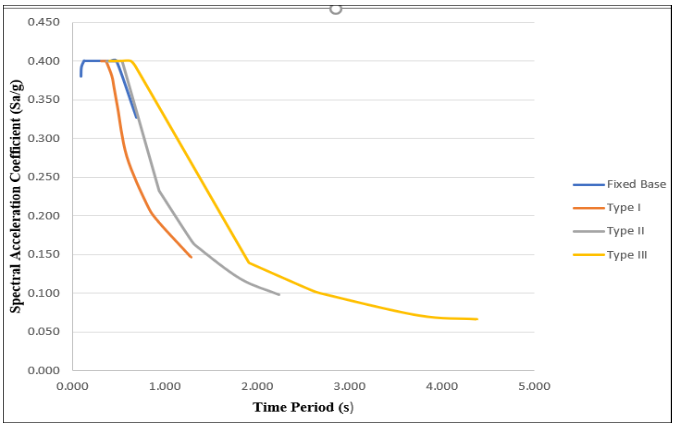


Fig 14: Response Spectrum for 3 Storey Step Back Set Back building

Table 13 : Response Spectrum for 4 Storey Step Back Set Back Building

RESPONSE SPECTRUM FOR 4 STOREY STEP BACK SET BACK							
FIXED BASE		HARD SOIL		MEDIUM SOIL		SOFT SOIL	
time	acc	time	acc	time	acc	time	acc
0.132	0.400	0.398	0.400	0.496	0.400	0.530	0.400
0.154	0.400	0.409	0.394	0.518	0.400	0.554	0.400
0.159	0.400	0.421	0.386	0.540	0.400	0.621	0.400
0.161	0.400	0.421	0.386	0.631	0.358	0.697	0.386
0.193	0.400	0.443	0.372	0.636	0.355	0.755	0.356
0.198	0.400	0.535	0.313	0.713	0.316	0.882	0.306
0.244	0.400	0.538	0.311	1.095	0.200	2.222	0.122
0.301	0.400	0.591	0.277	1.134	0.193	2.259	0.119
0.383	0.400	0.699	0.245	1.522	0.143	3.040	0.088
0.452	0.400	0.915	0.196	1.558	0.140	3.093	0.086
0.524	0.400	1.065	0.172	2.083	0.105	4.277	0.066
0.805	0.270	1.582	0.122	2.671	0.083	5.128	0.066

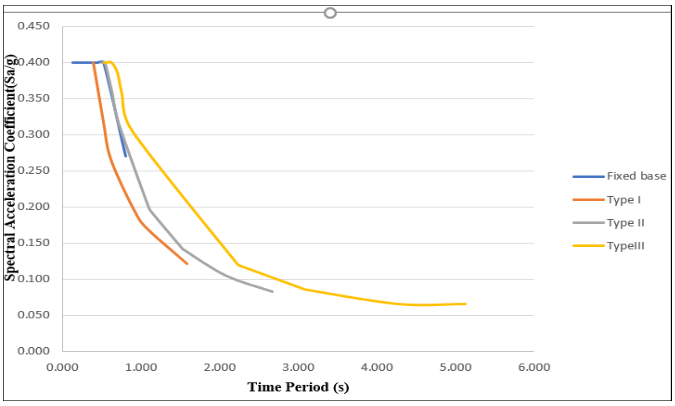


Fig 15 : Response Spectrum for 4 Storey Step Back -Set Back Building

5. CONCLUSIONS

1. The base shear carried out by the step back buildings and the step back set back buildings for slope $27^0$when pushed in X-direction was higher than that of Y- direction. This is influenced by the orientation of columns.
2. Pushover analysis can be tested on existing structure for earthquake forces. If the structure fails by this forces retrofitting measures can be adopted.
3. The displacement obtained from pushover analysis is always greater than displacement obtained from response spectrum analysis.
4. As the foundation moves from fixed condition to flexible condition. The shear forces decreases in both X and Y direction but the displacement increases in X and Y direction.
5. As the foundation moves from the fixed base to flexible base the reduction factor decreases in both the directions.
6. In many cases it can be seen that Step back set back configuration is better.

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