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Seismic Response of Multi-Storey RCC Buildings Located on Hilly Slopes

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Abstract— In most of the northern earthquake prone hilly part of the India, due to local topography constraint engineered construction is resulting in the adoption of either a step back or step back & set back configuration as a structural form for buildings. The adopted form is generally irregular, torsionally coupled & hence, susceptible to serve damage when affected by earthquake ground motion. Such building shave mass & stiffness varying along the vertical & horizontal planes, resulting the centre of mass & centre of rigidity do not coincide on various floors, torsional analysis, in addition to lateral forces under the action of earthquakes. In this paper seismic analysis performed on 48 RC buildings with three different configurations like, Step back building, Step back Set back building and Set back building are presented. 3 –D response spectrum analysis including torsional effect has been carried out by considering the dynamic response properties i.e. fundamental time period, top storey displacement and, the base shear action induced in columns 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.

Index Terms— Building, Etab, Response Spectrum Analysis, Seismic, Sloping ground.

I. INTRODUCTION

In some parts of world, hilly region is more prone to seismic activity; e.g. northeast region of India. In hilly regions, locally available traditional material like, the adobe, brunt brick, stone masonry and dressed stone masonry, timber reinforced concrete, bamboo, etc., is used for the construction of houses. The scarcity of plain ground in hilly areas compels construction activity on sloping ground resulting in various important buildings such as reinforced concrete framed hospitals, colleges, hotels and offices resting on hilly slopes Since, the behavior of buildings during earthquake depends upon the distribution of mass and stiffness in both horizontal and vertical lanes of the buildings, both of which vary in case of hilly buildings with irregularity and a symmetry due to step back frame and step back & set back frame configuration. Such constructions in seismically prone areas make them exposed to greater shears and torsion as compared to conventional construction.

Hill buildings constructed in masonry with mud mortar or cement mortar without conforming to seismic codal provision shave prove dun safe and resulted in loss of life and property when subjected to earthquake ground motions. 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 multi storey buildings on hill slope in and around the cities.

II. SIGNIFICANCE OF STUDY

It is observed during the past earth quakes, buildings in hilly regions have experienced high degree of damage leading to collapse though they have been designed for safety of the occupants against natural hazards. Hence, while adopting practice of multistory buildings in these hilly and seismically active areas, utmost care should be taken for making these buildings earthquake resistant to meet codal provisions.

III. SCOPE OF STUDY

Three dimensional space frame analysis is carried out for three different configurations of buildings ranging from 4 to 19storey (15.75 mto 68.25 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.

IV. BUILDING CONFIGURATION

Three different configurations are considered,
1) Step back (Resting on sloping ground)
2) Step back–.Setback (Resting on sloping ground)
3) Setback.(Resting on plain ground)
The height & length of building in a particular pattern are, in multiple blocks, the size of block is being maintained at 7x5x3.5m. The depth of footing belowground level is taken as 1.75 m, where hard strata available.

The buildings shown in figure 4.1 having step back configuration are labeled STEP4 to STEP19.Step back Setback configuration of buildings is shown in fig 4.2, are designed as STPSET4 to STPSET19 Setback buildings restingonplainground&labeledSET4toSET19,asshownin fig 4.3

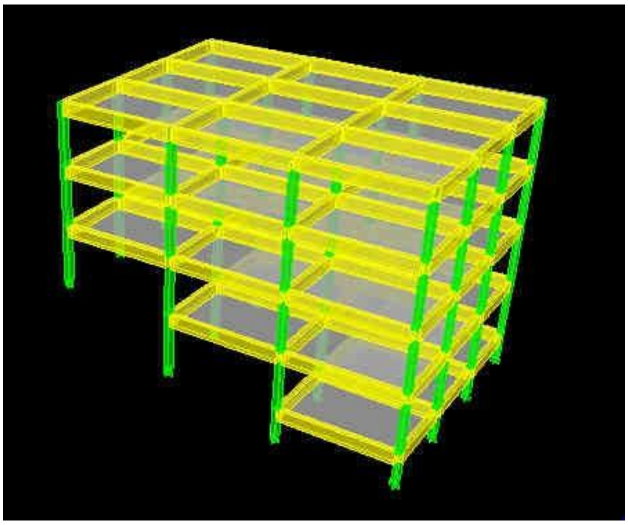

Fig.1Stepbackbuilding

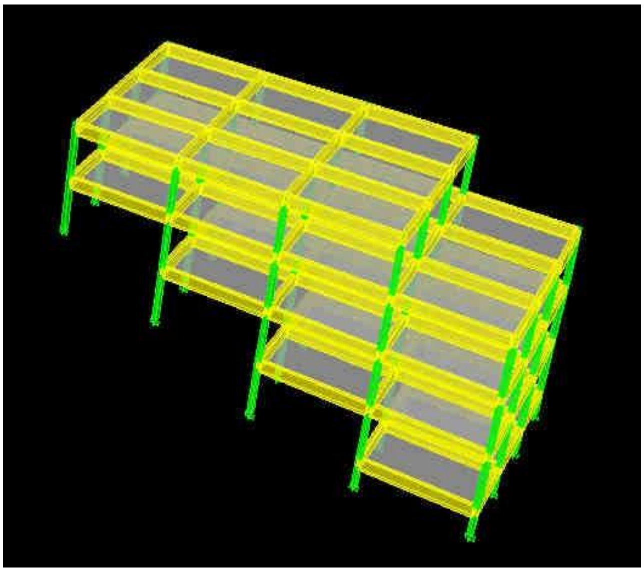

Fig.2Stepback-setback building

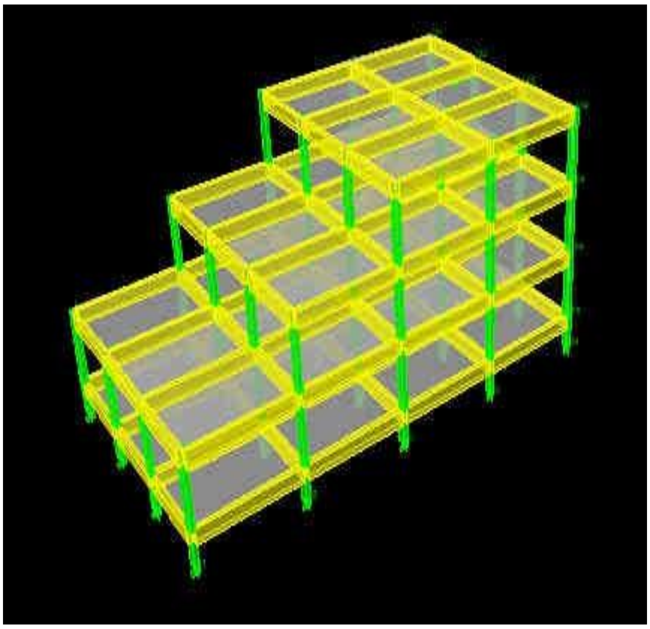

Fig.3SetbackBuilding

Table4.1:Geometrical properties of members for different configurations of building.

Building Configuration	Size of column	Size
Step back Buildings	STEP 4 & STEP - 400 mm x 500 mmSTEP6&STEP 7- 300mm x650mm STEP8&STEP 9- 300mm x650mm STEP10&STEP11- 350mm x850mm STEP12&STEP15- 350mm x900mm STEP16&STEP 19-350mm x1000mm	400 mmx 850mm
Step back & Setback Buildings	STEPSET4to19200x500mm	300 mmx 750mm
Setback Buildings	SET4to19200x 500mm	300 mmx 750mm

V. METHODOFANALYSIS

The analysis is based on following assumptions

1. Material is homogenous ,isotropic and elastic.
2. The values of modulus of elasticity and Poisson's ratio are 25000 N/mm2 and 0.20, respectively.
3. Secondary effectP-Δ,shrinkage and creep are not considered.
4. The floor diaphragms are rigid in their plane.
5. Axial deformation in column is considered.
6. Each nodal point in the farm chassis degrees of freedom, three translations and three rotations.
7. TorsionaleffectisconsideredasperIS:1893(I)–2002.

RESPONSE SPECTRUM ANALYSIS(RSA):

The seismic analysis of all buildings are carried out by response spectrum method byusingIS:1893 (I)–2002,The other parameters used in seismic analysis are, moderate seismic zone(IV),zonefactor0.24,importancefactor1.0,5 % damping and response reduction factor 5.0, presuming special moment resistant frame for all configurations and height of buildings. For each building case, adequate modes (minimumsix) were considered, in which, the sumof modal masses of all modes was at least 90 % 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 SRSS method Only selected results are presented in this paper due to space restrictions. Aspercodal provision,dynamic results were normalized by multiplying with a bases hear ratio,λ=Vb/VB,whereVbisthebaseshear evaluation based on time period given by empirical equation and, VB is the base shear from dynamic analysis, if Vb/VB ratio is more than one. The following design spectrum was utilized in response spectrum analysis.

$$Sa/g = \begin{cases} 1+1.7 & \text{when} 0.00 \le T \le 0.10 \text{seconds} \\ 2.60 & 0.10 \le T \le 0.40 \text{seconds} \\ 1/T & 0.40 \le T \le 4.00 \text{seconds} \end{cases}$$

VI. ANALYSISOFRESULTS

In all, forty eight buildings have been analyzed for seismic load. The seismic force was applied in X direction and Y direction in dependently. Important results are presented inthe subsequent sections.

Table6.1:DynamicresponsepropertiesofSTEPBACKbuildingduetoearthquakeforceinX&Y direction

STEP	TimePeriodByRSA(SEC)		TopStoreyDisplacement (MM)		DynamicBaseShear(KN)	
	SPECX	SPECY	SPECX	SPECY	SPECX	SPECY
4	0.86	0.65	11.35	9.83	412.50	431.60
5	1.07	0.68	14.25	13.19	517.90	562.00
6	1.17	0.70	15.07	11.41	622.80	691.50
7	1.38	0.72	20.76	14.03	737.40	819.80
8	1.58	0.73	22.65	15.71	831.60	947.10
9	1.80	0.74	27.81	18.45	936.60	1073.00
10	1.83	0.74	25.86	17.38	1140.00	1199.00
11	2.03	0.75	30.47	19.65	1143.00	1424.00
12	1.89	0.75	25.36	19.26	1147.00	1349.00
13	2.06	0.76	28.29	21.28	1351.00	1473.00
14	2.33	0.76	31.39	23.35	1444.00	1598.00
15	2.50	0.76	34.61	25.50	1548.00	1822.00
16	2.40	0.77	35.92	26.21	1661.00	1946.00
17	2.69	0.77	39.19	28.42	1665.00	1946.00
18	2.9	0.77	42.58	30.58	1774.00	2221.00
19	3.03	0.77	46.05	32.83	1877.00	2219.00

Table6.2:Dynamic response properties of STEP-SETBACKbuildingduetoearthquakeForceinX&Ydirection.

STEP	Time Period By RSA(SEC)		Top StoreyDisplacement (MM)		Dynamic Base Shear(KN)	
	SPECX	SPECY	SPECX	SPECY	SPECX	SPECY
4	0.66	0.54	7.80	5.82	433.5	442.9
5	0.72	0.59	6.68	6.43	545.6	553.6
6	0.71	0.61	6.41	5.69	665.4	645.3
7	0.75	0.67	6.69	5.47	757.4	797.5
8	0.77	0.65	6.63	5.33	856.0	912.0
9	0.76	0.67	6.47	5.22	952.2	1046.0
10	0.76	0.67	6.32	5.12	1245.0	1153.0
11	0.77	0.67	6.57	5.03	1134.0	1257.0
12	0.75	0.68	6.72	4.94	1220.0	1374.0
13	0.77	0.68	6.82	4.83	1208.0	1492.0
14	0.75	0.69	7.02	4.74	1295.0	1610.0
15	0.75	0.69	7.15	4.65	1382.0	1738.0
16	0.77	0.70	7.26	4.55	1589.0	1747.0
17	0.76	0.70	7.35	4.46	1657.0	1964.0
18	0.77	0.70	8.94	3.60	1756.0	2082.0
19	0.75	0.70	9.02	3.53	1837.0	2178.0

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Table6.3:DynamicresponsepropertiesofSETBACKbuildingduetoearthquakeforceinX&Y direction.

STEP	TimePeriodByRSA(SEC)		TopStoreyDisplacement (MM)		DynamicBaseShear(KN)	
	SPECX	SPECY	SPECX	SPECY	SPECX	SPECY
4	0.65	0.48	12.44	8.19	325.10	354.00
5	0.68	0.50	13.04	8.80	331.00	358.60
6	0.70	0.51	13.43	9.19	371.60	437.90
7	0.72	0.52	13.71	9.47	373.40	444.20
8	0.71	0.52	13.92	9.69	373.80	448.30
9	0.74	0.51	14.09	9.86	373.00	458.40
10	0.74	0.53	14.22	9.98	415.60	524.30
11	0.75	0.53	14.33	10.10	417.30	534.40
12	0.76	0.54	14.41	10.18	493.90	600.40
13	0.74	0.53	14.47	10.27	495.70	608.30
14	0.76	0.54	14.55	10.33	497.60	617.40
15	0.76	0.53	14.61	10.39	494.10	623.40
16	0.77	0.54	14.65	10.45	508.50	649.60
17	0.76	0.54	14.70	11.16	510.70	651.40
18	0.77	0.54	14.80	10.48	509.20	655.60
19	0.75	0.55	14.84	10.65	504.30	663.50

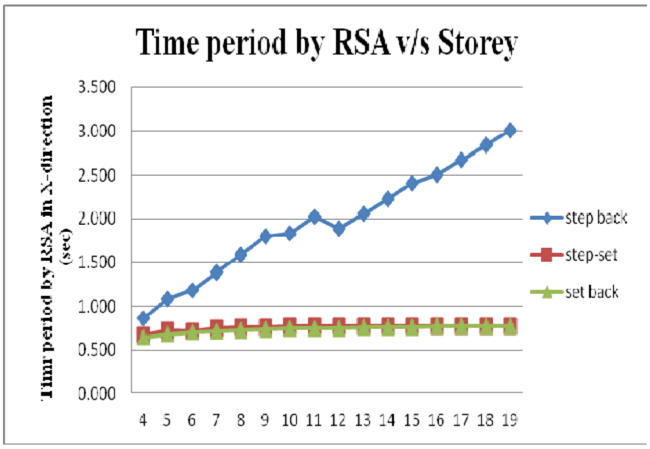

Fig.6.1:Relation between time period by RSA in X direction and storey.

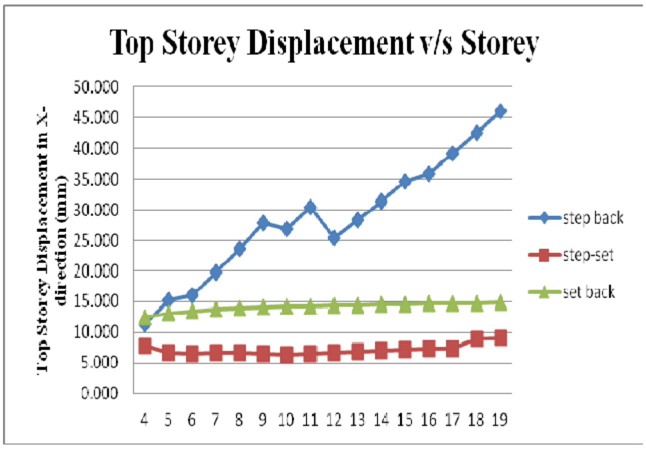

Fig.6.3:Relation between top storey displacement in X direction and storey.

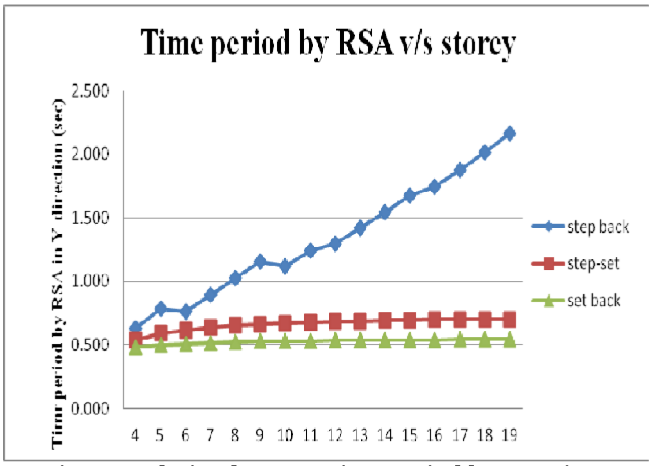

Fig.6.2:Relation between time period by RSA in Y Direction and storey.

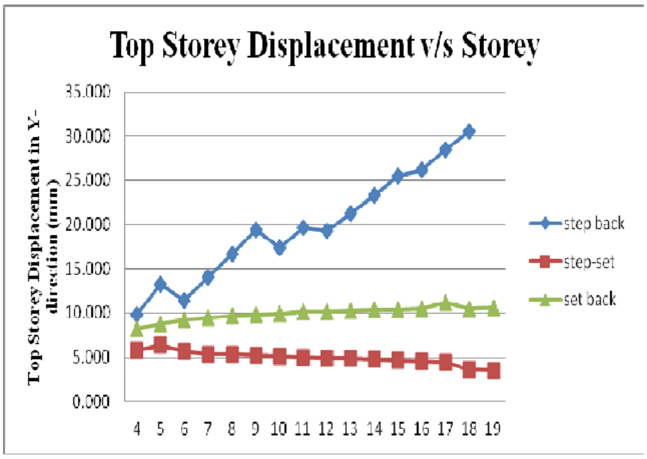

Fig.6.4:Relation between top storey displacement in Y Direction and storey.

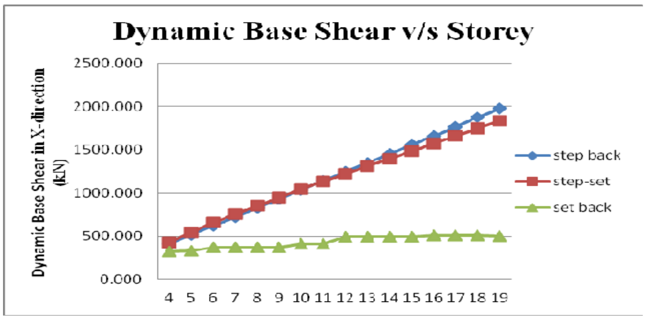

Fig.6.5:RelationbetweendynamicbaseshearinX direction and storey.

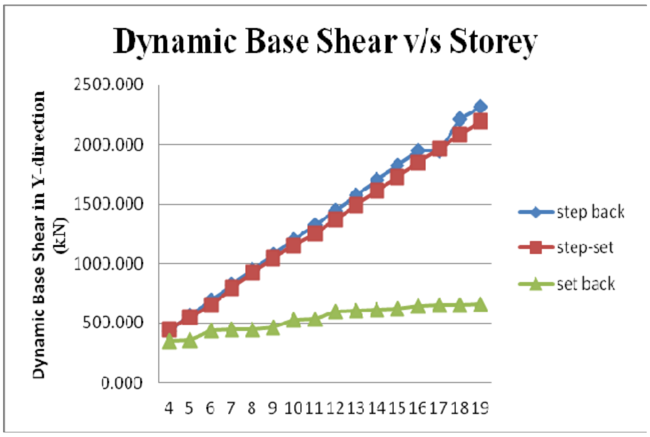

Fig.6.5:RelationbetweendynamicbaseshearinY direction and storey.

VII. COMPARISONOFTHREECONFIGURATIONS

Step back building Vs. Step back-Set Back Building: It is observed that there is increase in the value of top storey displacement and time period as the height of step back building increases. The uneven distribution of shear force in the various frames uggests development of torsional moment due to static eccentricity, which has caused profound effect in Step back buildings.

An uneven distribution of bases hear in various frames was also observed in Step back–Set back buildings. However, this un even distribution of shearforces is low as compared to step back buildings 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 Stepback Setback 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.

Step back-set back buildings Vs. Set back buildings: Shear reaction inducedinStepbackSetbackbuildingsis moderatelyhigherascomparedtosetbackbuildingsonplain ground.If,costcomponentofcuttingtheslopinggroundand other relatedissues, is within the acceptable limits, set back buildingsonplaingroundmaybepreferredthanthestep back- Set back buildings. In addition to this, issues viz. stability of slopes and vulnerability during the earthquake ground motion are less concerned in setback building.

VIII. CONCLUSIONS

1. During earthquake STEP back buildings are more vulnerable than other building configuration.
2. Extreme left short column at ground level are damaged most during earthquake in case of Step back and Step back-Set back buildings.
3. Less damage occurs in case of Setbackbuildinginflatsoil.
4. Detailed study of economic cost for lleveling sloping soil and other issues need to be studied.
5. Base shear is higher for Step back-Setback building and lower for Setback building.
6. Lateral displacement of top storey is maximum for Step backbuilding. onslopingsoilSetback-Stepbackbuilding is favoured.

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