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Seismic Behaviour of Buildings Resting on Sloping Ground

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Abstract - *In hilly regions engineered construction is constrained by local topography resulting in adoption of either step back or step back - set back building configuration with varying column heights, this condition leads to torsion and increased shear during seismic ground motion. The buildings situated on sloping grounds have mass and stiffness varying along vertical and horizontal planes. Centre of mass and center of rigidity do not coincide on various floors.*

In this study an attempt have been made to study the effects five storey and ten storey step back and step back - set back buildings. The results in terms of storey displacement, base shear, storey drift, time period and modal frequencies are obtained.

***Key Words*: Sloping ground, storey displacement, storey drift, step back and step back - set back building**

1. INTRODUCTION

Any sudden shaking of the ground caused by the passage of seismic waves through earth's rocks is termed as an Earthquake. In some parts of the world it is noticed that hilly areas are more prone to seismic activities. A scarcity of plain ground in hilly area compels the construction activity on sloping ground. The behaviour of buildings resting on the slopes are asymmetric which imparts irregularity in both horizontal and vertical plane. The distribution of mass and stiffness in horizontal and vertical planes plays a significant role in the seismic behaviour of building during an earthquake. These buildings have significant torsional response when they are subjected to lateral forces and also at the setback location there is an increase in stress concentration during an earthquake. Due to the unequal column height within the storey leads to the drastic variation in the stiffness in the storey.

2. SCOPE AND OBJECTIVES

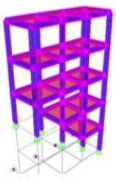
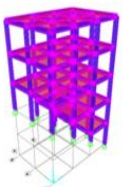
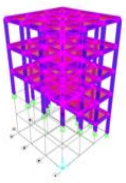
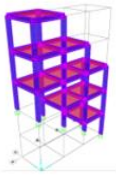
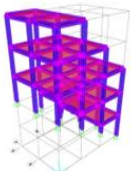
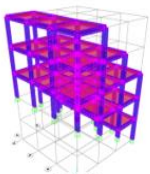
1. Step back and step back-set back buildings of 5 storey and 10 storey are studied.
2. Modal analysis has been carried out to obtain resonant frequency or fundamental frequency of considered buildings using finite element software SAP.2000.
3. Storey displacements and storey drifts are to be obtained using Time history analysis using BHUJ Earthquake Data.
4. A sloping angle of 27˚ with respect to horizontal has been considered to observe the seismic performance of the step back and step back-set back buildings.
5. The effect of bays in step back and step back-set back buildings are studied by varying number of bays in Y direction. (3-Bays).

3. DESIGN SPECIFICATION OF BUILDING

A medium rise and high-rise step back and step back–set back buildings resting on sloping ground of angle of 27^0 has been modelled and analysed using FEM based software SAP 2000. The model consists of five storey and ten storey with a storey height of 3 m having 3 bays along longitudinal direction and 1 bay with a spacing 4 m along transverse direction and increased accordingly with a spacing of 4 m.

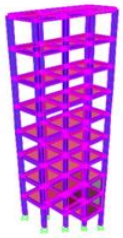
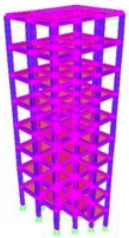
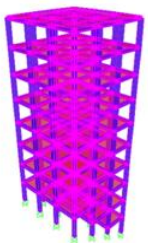
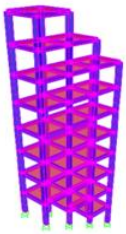
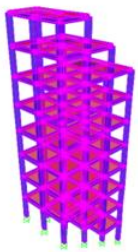
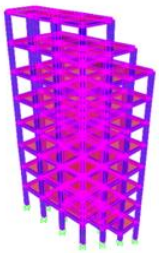
TABLE 1 and Table 2 represents 5-storey and 10 storey building nomenclature.

TABLE 1: 5-storey building nomenclature

STEP BACK BUILDING		
 SB-1	 SB-2	 SB-3
Frequency = 1.939Hz	**Frequency = 1.769 Hz**	**Frequency = 1.700 Hz**
STEPBACK -SET BACK BUILDING		
 SSB-1	 SSB-2	 SSB-3
Frequency = 2.422 Hz	**Frequency = 2.2332 Hz**	**Frequency = 2.14773 Hz**

Where, **SB** represents **Step back building** and **SSB** represents **Step back – set back building.**

TABLE 2: 10-storey building nomenclature

TEN STOREY STEP BACK BUILDING		
		
TSB-1	TSB-2	TSB-1
Frequency = 1.0041 Hz	Frequency = 1.020 Hz	Frequency = 0.990 Hz
TEN STOREY STEPBACK -SET BACK BUILDING		
		
TSSB -2	TSB-2	TSSB-2
Frequency = 1.155 Hz	Frequency = 1.146 Hz	Frequency = 1.1133 Hz

Where, **TSB** represents **Ten storey step back** building and **TSSB** represents **Ten storey step back - set back** building.

In total twelve buildings out of which six buildings are analysed by considering step back type and the remaining six are analysed as step back - set back type buildings as shown in Table 1 and 2. All these buildings are investigated for their dynamic response considering 27^0 sloping grounds.

Both dead load and live loads are considered as per IS 875 part II and the details are shown in Tables 4 and 5. Structural elements have been designed as per IS 456-2000 and IS 1893:2016 by considering M 25 grade concrete and Fe 415 grade steel. The dynamic parameters considered for the analysis is given in Table 5. Table 6 indicates the designed dimensions of the building components.

Table-3: Details of load for 5- storey buildings

STOREY	DEAD LOAD (kN/m^2)	LIVE LOAD (kN/m^2)
1,2,3,4	1 kN/m^2	3 kN/m^2
Roof	2 kN/m^2	1.5 kN/m^2

Table-4: Details of load for 10- storey buildings

STOREY	DEAD LOAD (kN/m^2)	LIVE LOAD (kN/m^2)
1-9	1 kN/m^2	3 kN/m^2
Roof	2 kN/m^2	1.5 kN/m^2

TABLE 5: Details of dynamic parameters

Sl.No.	Contents	Description
1	Seismic Zone	V
2	Soil Type	TYPE-I
3	Importance Factor	1
4	Response Reduction Factor	5

Table -6: Details of Dimensions of Building Components

Structural element	5-STOREY (in mm)	10-STOREY (in mm)
COLUMN	250×600 mm	400×600 mm
BEAM	300×400 mm	300×400 mm
SLAB	150 mm thick	150 mm thick

3. RESULTS AND DISCUSSION

Table 7 and 8 shows displacements for step back buildings, base shear is represented in Table 9. Table 10 and 11 Shows displacements for Step back - Set back buildings. Base shear is represented in Table 12 for both the directions of the buildings.

Storey drift at each storey of all considered buildings are graphically presented in Fig.3 and 4 for Step back buildings and Fig.8 and 9 for Step back-set back buildings respectively.

Table 13 and 14 shows displacements of ten Storey Step back buildings, Base shear is represented in table 15. Table 16 and 17 Shows displacements of ten storey Step back - set back Buildings. Base shear of the buildings in both directions are represented in Table 18.

Fig.13 and 14 represents the storey drift at each storey for Ten Storey step back buildings. Fig. 18 and 19 represents the storey drift at each storey for for Ten Storey step back - set back buildings respectively.

TABLE 7: Storey Displacement(mm) of Step-Back Buildings along X-Direction

Number of storey	SB-1	SB-2	SB-3
5	25.329	30.157	26.162
4	21.044	24.488	21.076
3	13.22	14.840	12.520
2	5.526	5.947	4.891
1	0.883	0.913	0.723

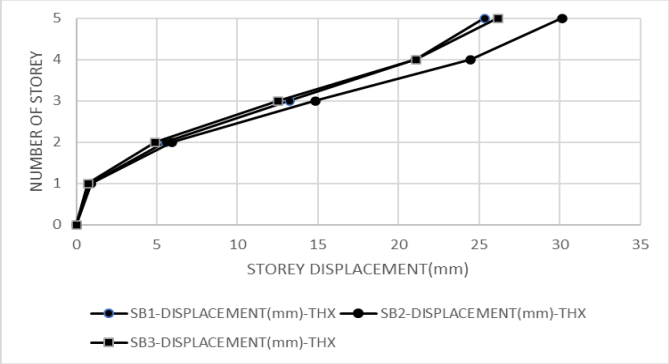


Fig -1: Storey displacement(mm) of buildings along X-Direction

Table 8: Storey Displacement(mm) of Step-Back Buildings along Y-Direction

Number of storey	SB-1	SB-2	SB-3
5	10.349	10.891	10.424
4	8.769	9.611	9.193
3	6.462	7.341	6.934
2	3.729	4.192	3.81
1	1.032	0.962	0.767

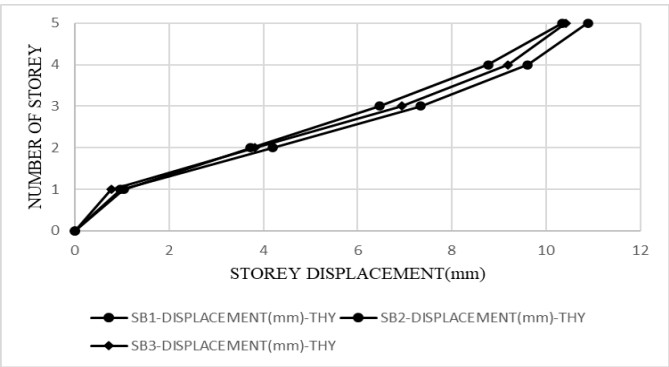


Fig 2: Storey displacement(mm) of buildings along Y-Direction

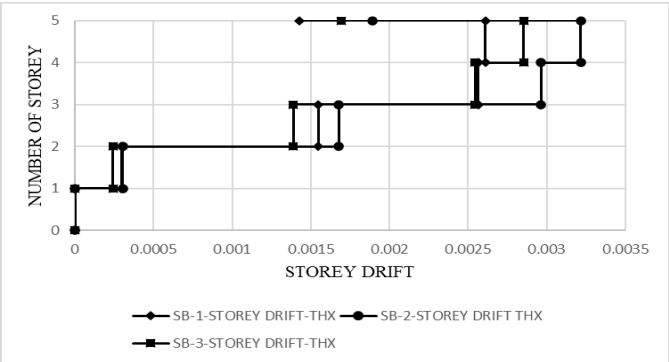


Fig -3: Storey drift of buildings along X-Direction

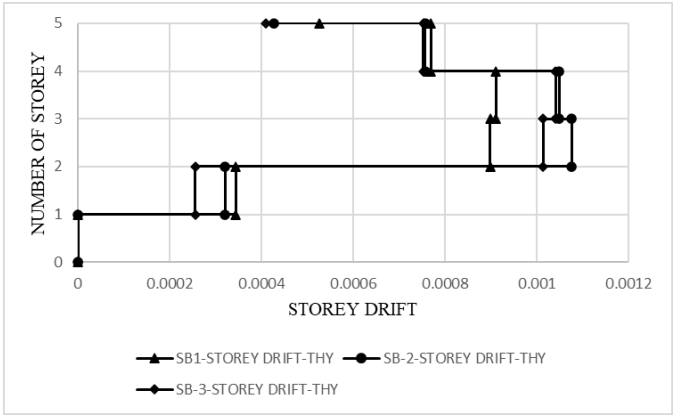


Fig -4: Store Drift of buildings along Y-Direction

TABLE 9: Base shear(kN) of Step-Back buildings

SB-1	SB-2	SB-3
THX =360.10 kN	THX =637.24 kN	THX =803.255 kN
THY = 254.53 kN	THY = 489.38 kN	THY = 697.03 kN

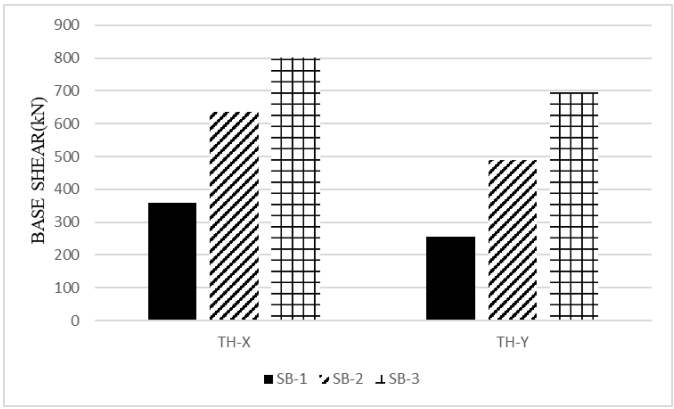


Fig 5: Base shear (THX, THY) in SB1, SB2 and SB3 Buildings

TABLE 10: Storey Displacement(mm) of Step-Back Set-Back Buildings along X-Direction.

Number of storey	SSB-1	SSB-2	SSB-3
5	10.228	10.477	12.197
4	8.274	8.179	9.556
3	5.430	5.890	6.884
2	2.834	3.360	3.841
1	0.655	0.7458	0.745

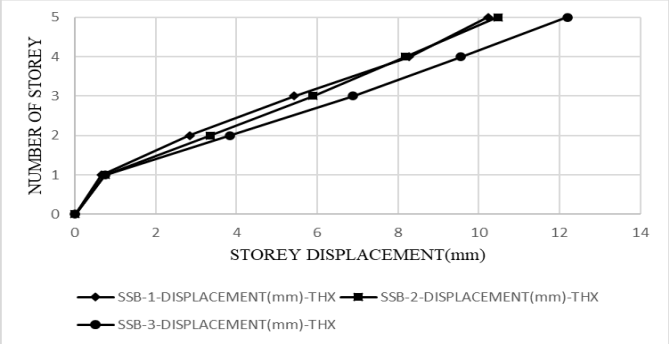


Fig -6: Storey displacement(mm) for SSB1, SSB2 and SSB3 buildings

TABLE 11: Storey Displacement of Step Back - Set-Back Buildings along Y-Direction

Number of storey	SSB-1	SSB-2	SSB-3
5	11.639	11.425	10.967
4	10.975	10.414	10.172
3	9.303	8.460	8.230
2	5.251	4.568	4.300
1	1.402	0.986	0.814

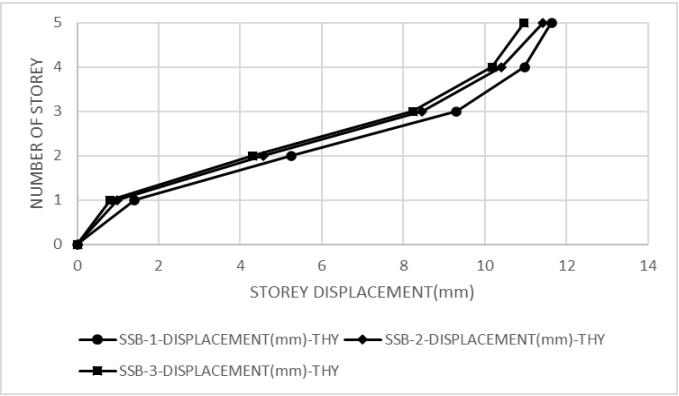


Fig -7: Storey displacement(mm) of SSB1, SSB2 and SSB3 buildings

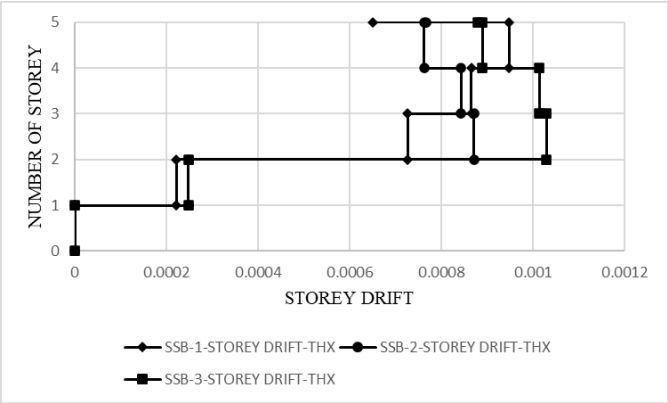


Fig 8: Storey drift of SSB1, SSB2 and SSB3 buildings

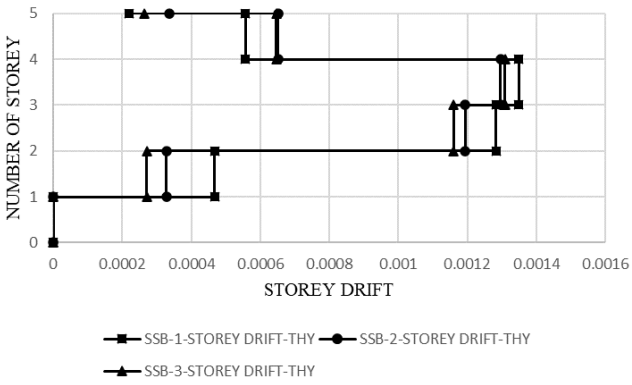


Fig 9: Storey drift for SSB1, SSB2 and SSB3 buildings

TABLE 12: Base shear of SSB-1, SSB-2, SSB-3

BASE SHEAR		
SSB-1	**SSB-2**	**SSB-3**
THX =210.22 kN	THX =336.50 kN	THX =478.30 kN
THY = 368.37 kN	THY = 643.9 kN	THY = 917.60 kN

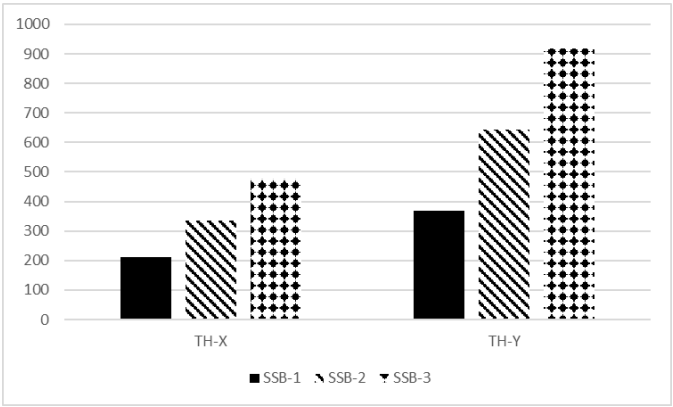


Fig 10: Base shear for SSB1, SSB2 and SSB3 buildings

TABLE 13: Storey Displacement(mm) of Ten Storey Step-Back Buildings along X-Direction

Number of storey	TSB-1	TSB-2	TSB-3
10	66.103	68.033	67.183
9	63.484	64.670	63.689
8	59.044	59.228	58.172
7	52.643	51.910	50.985
6	44.426	43.238	42.605
5	34.732	33.682	33.440
4	24.034	23.577	23.729
3	12.997	13.41	13.869
2	4.811	5.495	5.816
1	0.788	0.904	0.8995

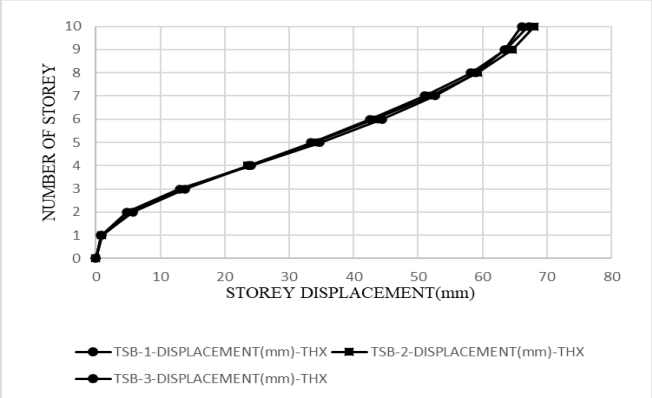


Fig -11: Storey displacement(mm) of TSB1, TSB2 and TSB3 buildings

TABLE 14: Storey Displacement(mm) of Ten Storey Step-Back Buildings along Y-Direction

Number of storey	TSB-1 Storey	TSB-2 Storey	TSB-3 Storey
10	71.556	70.654	68.516
9	66.892	67.125	65.597
8	60.847	62.039	61.062
7	53.413	55.265	54.697
6	44.807	46.905	46.585
5	35.340	37.267	36.991
4	25.437	26.797	26.359
3	15.795	16.327	15.619
2	7.328	7.113	6.408
1	1.500	1.202	0.970

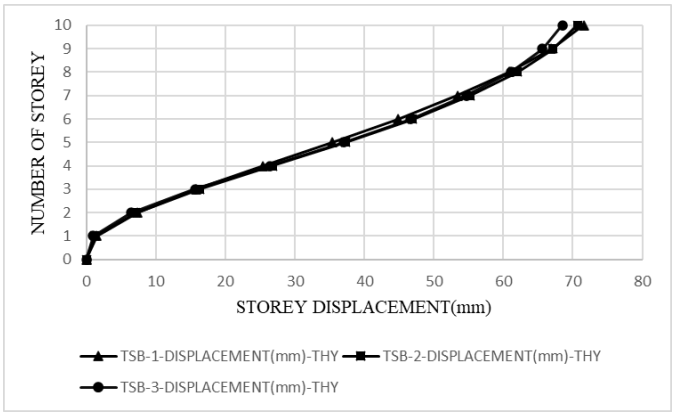


Fig -12: Storey displacement(mm) of TSB1, TSB2 and TSB3 buildings

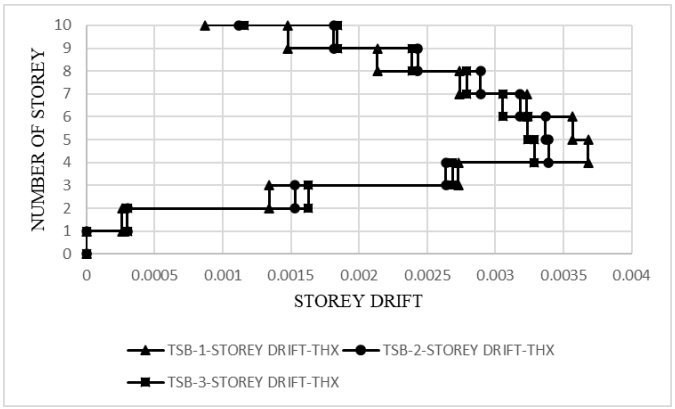


Fig -13: Storey drift of TSB1, TSB2 and TSB3 -Time History (THX)

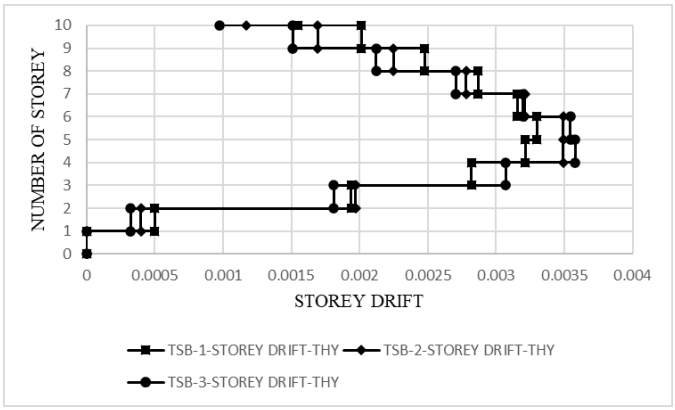


Fig -14: Storey drift of TSB1, TSB2 and TSB3 -Time History (THY)

Table 15: Base shear of Ten Storey Step-Back buildings

BASE SHEAR		
TSB-1	**TSB-2**	**TSB-3**
THX =816.88 kN	THX =1231.0 kN	THX =1644.37 kN
THY = 650.95 kN	THY = 1377.23 kN	THY = 2128.78 kN

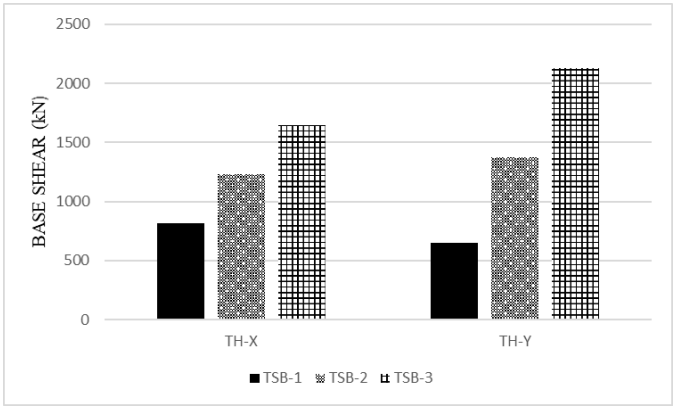


Fig 15: Base shear of TSB1, TSB2 and TSB3 buildings

Table 16: Storey Displacement(mm) of Ten Storey Step-Back Set-Back Buildings along X-Direction

Number of storey	TSSB-1 Storey	TSSB-2 Storey	TSSB-3 Storey
10	56.263	60.699	65.833
9	53.296	58.077	63.177
8	49.281	54.324	59.319
7	44.086	49.148	53.832
6	37.355	42.048	46.154
5	29.404	33.325	36.522
4	20.912	23.401	25.496
3	11.342	13.0161	14.020
2	4.280	5.070	5.241
1	0.751	0.785	0.682

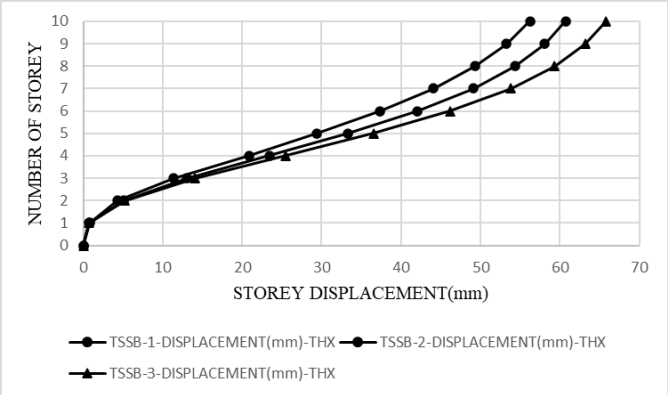


Fig -16: Storey displacement(mm) of TSSB1, TSSB2 and TSSB3 buildings

Table 17: Storey Displacement(mm) of Ten Storey Step-Back Buildings along Y-Direction

Number of storey	TSSB-1 Storey	TSSB-2 Storey	TSSB-3 Storey
10	60.941	54.473	52.024
9	60.091	53.120	50.678
8	58.271	50.981	48.287
7	52.327	46.221	43.586
6	44.786	39.892	37.358
5	35.817	32.095	30.728
4	25.931	23.245	22.590
3	16.053	14.140	13.548
2	7.358	6.091	5.488
1	1.488	1.014	0.805

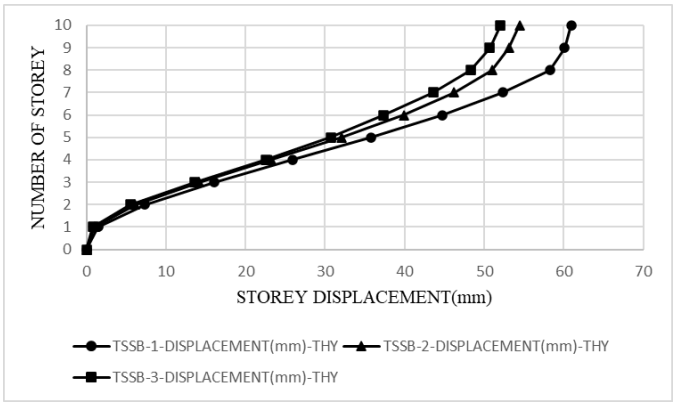


Fig -17: Storey displacement(mm) of TSSB1, TSSB2 and TSSB3 buildings

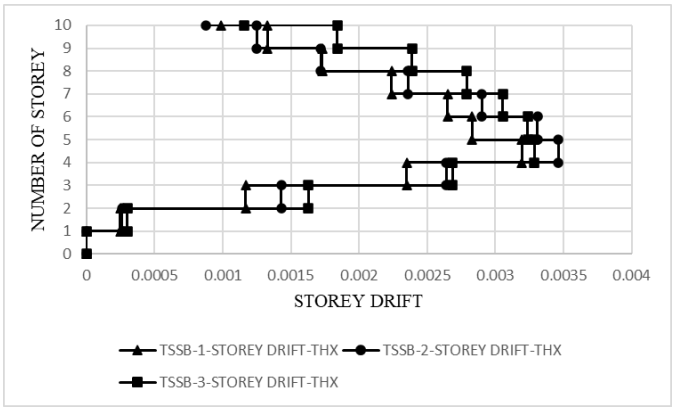


Fig -18: Storey drift of TSSB1, TSSB2 and TSSB3 -Time History (THX)

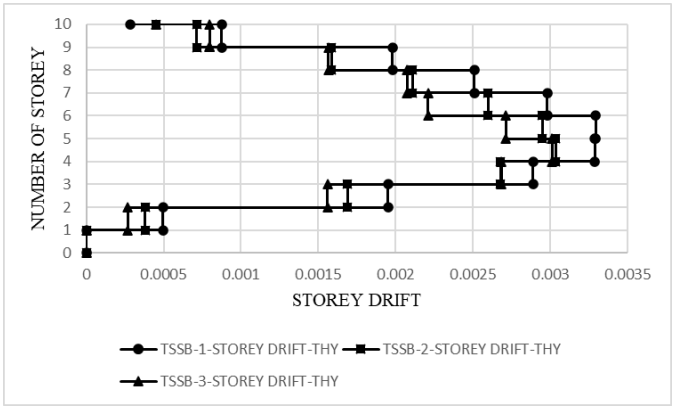


Fig -19: Storey drift of TSSB1, TSSB2 and TSSB3 -Time History (THY)

Table 18: - Base shear of (TSSB-1, TSSB-2, TSSB-3) buildings

BASE SHEAR		
TSSB-1	**TSSB-2**	**TSSB-3**
THX =850.55 kN	THX =1444.61 kN	THX =188.95 kN
THY = 848.06 kN	THY = 1607.76 kN	THY = 2247.03 kN

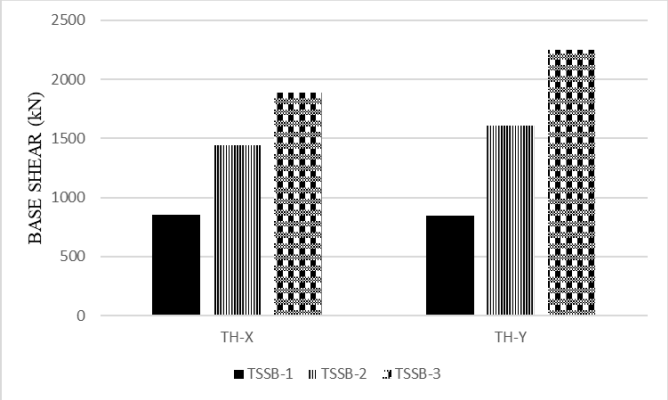


Fig 21: Base shear (THX, THY) of TSSB1, TSSB2 and TSSB3 Buildings

4. CONCLUSIONS

1. From the modal analysis high-rise buildings, it is found that as the bay increases the fundamental frequency of the considered buildings decreases.
2. It is also observed that the fundamental frequency of step back building is lower compared to step back set back building.
3. It is observed that for high-rise buildings storey displacement increases in X-direction and decreases in Y-direction for time history analysis.
4. The storey displacement is more for with 3-bays for step back set back building compared with the two bay and one bay along transverse direction.
5. Step back buildings have more storey displacement compared to step back set back building configuration
6. The storey drift is observed to be more for step back building configuration compared to the step back set back building for time history analysis.
7. It is also observed that the base shear is more for step back building compared with step back set back building for time history analysis for 5-storey and 10-storey buildings.
8. Base shear is observed to be more for step back set back building compared to step back building configuration for high-rise building.

REFERENCES

[1] S.A. Halkude, M. G Kalyanshetti and V.D. Ingle, "Seismic analysis of buildings resting on sloping ground with varying number of bays and hill slopes", International Journal of Engineering Research &Technology,Vol.2,pp.3632-3640,2013.

[2] S. Varadharajana, V. K. Sehgal and B. Saini (2014), "Fundamental time period of RC Setback Buildings", Concrete research letters, Vol. 5(4), December 2014.

[3] Birajdar.B.G and S. S. Nalawade (2004) "Seismic analysis of buildings resting on sloping ground", 13thWorld Conference on Earthquake Engineering, Vancouver, B.C., Canada, Paper No. 1472, 2004.

[4] Rahul Ghosh and Rama Debbarma (2017), "Performance evaluation of setback buildings with open ground storey on plain and sloping ground under earthquake loadings and mitigation of failure", This article is published with open access at Springerlink.com Int, J Adv Struct Eng (2017) 9:97–110, 14 February 2017 The Author(s) 2017.

[5] Ravikumar C M and Babu Narayan K S (2012), "Effect of Irregular Configurations on Seismic Vulnerability of RC Buildings", Architecture Research 2012.

[6] S. A. Halkude (2013), "Seismic Analysis of Buildings Resting on Sloping Ground with Varying Number of Bays and Hill Slopes", International Journal of Engineering Research and Technology ISSN:2278-0181, Vol.2, Issue 12, December-2013.

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