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Research Article

Seismic Analysis of RCC Building Resting on Sloping Ground with varying Number of Bays and Hill Slopes

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Abstract

Generally, building frames are analyzed for gravity loads in vertical direction and lateral loads like earthquake load and wind load in lateral direction. The analysis of structure depends on idealization of geometry of structure and idealization of load system on the structure. The behavior of buildings during earthquake depends upon the distribution of mass and stiffness in both horizontal and vertical planes of the buildings. General behavior is shattered when the structure has irregularities. These kinds of irregularities are especially seen in hilly regions, where the structure rests on the sloping ground. In the present study, the response spectrum method is carried out on the type of structure that rests on the sloping ground. Building frames which occurs in hilly regions are narrowed down to two basic formats such as step back frames and step back-set back frames. And dynamic responses have been studied for various building configuration.

Keywords: *Seismic Analysis, RCC Building etc.*

1. Introduction

Seismic forces acts more sever in hilly regions due to the structural irregularity. Also it has been studied that the earthquake actions are prone in hilly areas. In India, for example, the north-east states. 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. The behavior of buildings during earthquake depends upon the distribution of mass and stiffness in both horizontal and vertical planes of the buildings. In hilly region both these properties varies with irregularity and asymmetry. Such constructions in seismically prone areas make them exposed to greater shears and torsion.

The economic growth and rapid urbanization in hilly region has accelerated the real estate development. Because of which, population density in the hilly region has increased. Therefore, there is popular and pressing demand for the construction of multi-storey buildings on hill slope. While considering the fast and economic constructions, precast construction technique is most suitable in every angle as far as the project size is not small. Hence the combination of both the concepts is made to carry with dissertation.

Future prospects of these structures are high as having no damage during earthquakes. The fast economic growth of the country in recent past and the need of infrastructural development emphasize to use precast concrete structures. Advantages of precast concrete construction from Indian point of view, in addition to earlier mentioned are uniformity of construction, planned and well managed cities. Standardization of precast concrete elements will also be able to control the non-engineered practice of Reinforced Concrete construction. 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.

2. Relevance of Work

Hill buildings are different from those in plains. They are very irregular and unsymmetrical in horizontal and vertical planes. Hence, they are susceptible to severe damage when affected by earthquake ground motion. The approach and the accuracy of analytical results depend upon the idealization of geometry of the structure and the loading on the structure.

The present work aims at providing an analytical approach for finding out the displacements, storey drifts, natural frequency, time period, base shear for a multistory building resting on a sloping ground

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subjected to seismic load. Response spectrum analysis based on the IS (1893:2002) codal provisions is to be performed on the FE model using suitable FEA platform. Using the displacement characteristics various structural outputs such as natural frequency, time period, storey drift, base shear are to be computed.

3. Objectives of the Proposed Work

Response of building frame on sloping ground depends on many parameters such as number of Bays, hill slope angle and number of stories etc. In the study, two building configurations are considered namely step back frames and step back- set back frames.

The proposed objectives of study are as follows:

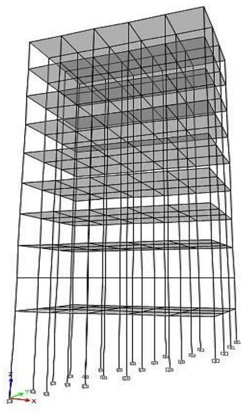
1. To study the effectiveness of configuration of building frames such as step back and step back-set back frames.
2. To study the variation of base shear with respect to variation in number of bays, hill slope angle, storey height for different configurations of building frames.
3. To study the variation of time period with respect to variation in number of bays, hill slope angle, storey height for different configurations of building frames.
4. To study the variation of top storey displacement with respect to variation in number of bays, hill slope angle, storey height for different configurations of building frames.

4. Problem Formulation

A study of seismic behavior of an unsymmetrical multistory buildings resting on sloping ground is done considering different structural configurations. Building Configuration will be specified by following factors

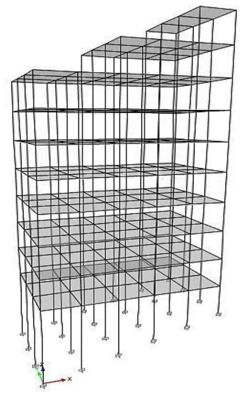
4.1 Type of Frame

- Step Back type of Building frame structure (STP-FRAME)



STEP BACK TYPE FRAME

- Step Back-Set Back type of building frame structure (STP-SET-FRAME)



STEP BACK-SET BACK TYPE FRAME

4.2 Number of storeys

The model used to scrutinize in the dissertation have 3 distinct storey numbers.

Most of the buildings in the region are considered to have 6, 8 and 10 stories and hence are used to configure the models. Three story configurations are considered such as 6-story, 8-story and 10-story.

4.3 Number of the Bays

To compare more generalized building figure two types of bay configuration are considered both are unsymmetrical and give excruciating results in both planar axis. Two bay configurations are, 1. 3X5 Bay-system and 3X7 Bay-system.

4.4 Slope of the hills

Most noted hill slop angles as per the records registered with national terrain data are alanysed and four most feasible hill slopes are considered in vicinity of optimized earthwork process. Such as, 16.32°, 21.58°, 26.56° and 31.56°.

These factors are of variable nature and dynamic analysis has been carried out to evaluate the parameters such as Fundamental Time Period (FTP), Top Storey Displacement (TSD) and Base Shear Induced etc. by using IS code provisions and the response is to be evaluated using the FE software package for the considered building.

5. Methodology

In the present content, RCC framed structure is considered for studying the behavior of multi-storey structure resting on sloping ground. The approach and accuracy of the analytical results depends on the idealization of the geometry and loading of the structure.

In the present study, idealization of the structure is to be done as per various IS code provisions. The seismic analysis of all buildings are carried out by Seismic coefficient method by using IS 1893(part I) 2002. The other parameters used in seismic analysis are as follows,

1) Moderate seismic zone III
2) Zone Factor 0.16.
3) Importance Factor 1
4) Response Reduction Factor 5

To understand the behavior of a structure, 48 models of different configurations were developed in Finite Element Method Based software package ETABS_2013. The stated software is later validated in the context. This analysis and design software s professionally used worldwide and gives most accurate results in author's opinion. These models are tabulated as follows:

Model no	Configuration			
	Frame type	Hill slope angle in °	Bay system	Noof storey
1	STP BACK	16.32	3X5	10
2	STP BACK	16.32	3X5	8
3	STP BACK	16.32	3X5	6
4	STP BACK	16.32	3X7	10
5	STP BACK	16.32	3X7	8
6	STP BACK	16.32	3X7	6
7	STP BACK	21.58	3X5	10
8	STP BACK	21.58	3X5	8
9	STP BACK	21.58	3X5	6
10	STP BACK	21.58	3X7	10
11	STP BACK	21.58	3X7	8
12	STP BACK	21.58	3X7	6
13	STP BACK	26.56	3X5	10
14	STP BACK	26.56	3X5	8
15	STP BACK	26.56	3X5	6
16	STP BACK	26.56	3X7	10
17	STP BACK	26.56	3X7	8
18	STP BACK	26.56	3X7	6
19	STP BACK	31.56	3X5	10
20	STP BACK	31.56	3X5	8
21	STP BACK	31.56	3X5	6
22	STP BACK	31.56	3X7	10
23	STP BACK	31.56	3X7	8
24	STP BACK	31.56	3X7	6
25	STP-SET BACK	16.32	3X5	10
26	STP-SET BACK	16.32	3X5	8
27	STP-SET BACK	16.32	3X5	6
28	STP-SET BACK	16.32	3X7	10
29	STP-SET BACK	16.32	3X7	8
30	STP-SET BACK	16.32	3X7	6
31	STP-SET BACK	21.58	3X5	10
32	STP-SET BACK	21.58	3X5	8
33	STP-SET BACK	21.58	3X5	6
34	STP-SET BACK	21.58	3X7	10
35	STP-SET BACK	21.58	3X7	8
36	STP-SET BACK	21.58	3X7	6
37	STP-SET BACK	26.56	3X5	10
38	STP-SET BACK	26.56	3X5	8
39	STP-SET BACK	26.56	3X5	6
40	STP-SET BACK	26.56	3X7	10
41	STP-SET BACK	26.56	3X7	8
42	STP-SET BACK	26.56	3X7	6
43	STP-SET BACK	31.56	3X5	10
44	STP-SET BACK	31.56	3X5	8
45	STP-SET BACK	31.56	3X5	6
46	STP-SET BACK	31.56	3X7	10
47	STP-SET BACK	31.56	3X7	8
48	STP-SET BACK	31.56	3X7	6

The dynamic analysis of each structural model with different building configuration and ground slope has been done for the results such as Fundamental Time Period (FTP), Top Storey Displacement (TSD), and Base Shear Induced in Columns (BSIC) etc. these obtained result parameters have scrutinized to state the conclusions.

6. Results and Comparative Discussions

Software analysis of all the 48 models is done and result obtained is tabulated in parametric values of Base Shear, Top Story Displacement and Fundamental Time Period.

ETABS results for base shear or story shears reported in the global coordinate system as P, VX, VY, T, MX and MY. The forces are reported at the top of the story, just below the story level itself, and at the bottom of the story, just above the story level below. The sign convention for story level forces is exactly the same as that for frame elements with the bottom of the story corresponding to the i-end of the frame element and the top of the story corresponds to the j-end of the frame element. The story shears and overturning moments are always reported at the following locations; Global X=0, Global Y=0 and Global Z.

ETABS results for Top story Displacement or any generalized displacement is a named displacement measure that is user defined. It is simply a linear combination of displacement degrees of freedom from one or more joints. For example, a defined generalized displacement named "DRIFTX" could be the difference of the UX displacements at two joints on different stories of a building. Another defined generalized displacement named AVGRZ could be the sum of three rotations about the Z axis, each scaled by 1/3. Generalized displacements are primarily used for output purposes, except that a generalized displacement also can be used to monitor a displacement-controlled nonlinear static analysis.

ETABS results for Fundamental Time Period are obtained from the codal provision, as described below. Response Spectrum Analysis (RSA):

The seismic analysis of all buildings are carried out by response spectrum method by using IS: 1893 (I) – 2002, 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. 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 = 1+15 T *when* 0.00 ≤ T ≤ 0.10 seconds
Sa/g = 2.50 0.10 ≤ T ≤ 0.40 seconds
Sa/g = 1/T 0.40 ≤ T ≤ 4.00 seconds

All the 48 models were analyzed for the seismic load in both X-axis and Y-axis. The important results are stated in subsequent section.

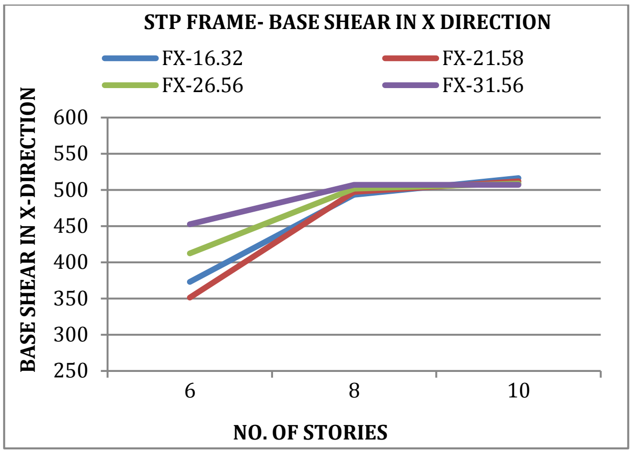
Model no	Base shear in KN		Top storey displacement in mm		Fundamental time period
	FX	FY	X-direction	Y-Direction	In seconds
1	516.16	284.65	19.3	27.5	1.439
2	492.97	278.01	13.8	22.1	1.184
3	372.84	266.41	7.5	16.9	0.935
4	580.13	286.33	13.8	22.4	1.621
5	529.91	260.2	9.2	17	1.635
6	365.03	221.46	4.5	11.8	1.161
7	511.67	273.36	20.7	28.3	1.509
8	497.33	265.07	14.9	22.9	1.253
9	377.19	251.66	8.2	17.7	1.001
10	575.08	267.14	15.3	24.1	1.758
11	538.17	240.89	10.4	18.6	1.492
12	373.29	203.66	5.2	13.3	1.225
13	508.68	264.07	22.1	29.1	1.573
14	501.76	254.69	15.9	23.7	1.316
15	381.63	240.24	8.8	18.5	1.061
16	572.32	252.35	16.9	25.7	1.883
17	543.71	226.54	11.5	20.1	1.612
18	381.7	190.96	5.9	14.7	1.335
19	506.77	256.98	23.7	29.9	1.635
20	506.77	245.98	17.1	24.4	1.376
21	506.62	230.41	9.5	18.5	1.118
22	386.48	240.41	18.6	27.2	2.002
23	543.40	215.30	12.6	21.6	1.724
24	390.99	181.43	6.6	16	1.439
25	518.2	284.16	16.5	24	1.284
26	425.86	276.21	10.6	18.7	1.03
27	305.73	262.23	5.7	13.7	0.779
28	659.3	327.03	12.3	18.2	1.362
29	501.68	305.48	7.3	13.2	1.097
30	336.80	272	3.7	8.6	0.827
31	513.39	272.98	17.6	23.4	1.347
32	430.22	263.5	11.4	18.1	1.091
33	310.08	248.0	6.2	13.2	0.835
34	652.01	304.48	14.2	17.7	1.481
35	509.95	282.11	8.5	12.9	1.208
36	345.07	249.7	4.2	8.5	0.923
37	510.27	263.67	18.7	22.8	1.406
38	434.65	253.67	12.2	17.7	1.147
39	341.51	263.93	6.6	12.8	0.887
40	647.78	286.70	15.3	17.4	1.592
41	518.35	264.27	9.4	12.7	1.31
42	353.47	233.19	4.7	8.1	1.013
43	508.37	255.64	19.9	22.4	1.462
44	439.50	244.44	13.1	17.2	1.201
45	319.36	227.79	7.1	12.6	0.937
46	645.83	272.25	16.6	17.2	1.699
47	527.55	250.17	10.3	12.7	1.409
48	362.67	220.50	5.3	8.7	1.099

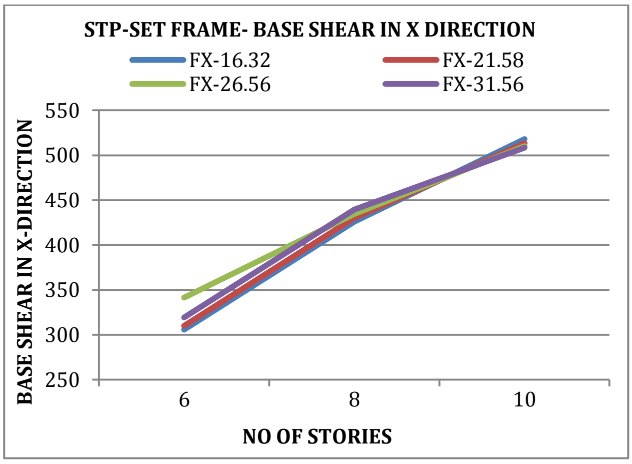
These results are compared in two parts first the two model configurations i.e., STEP BACK FRAME and STEP BACK-SET BACK FRAME with respect to the hill slope angles and same configuration with respect to Bay configuration system.

The graphs of such comparisons are generated and described their plot behavior. This scrutinizing process involves the 8 different sets of comparison statements which leads the objectives to the conclusions.

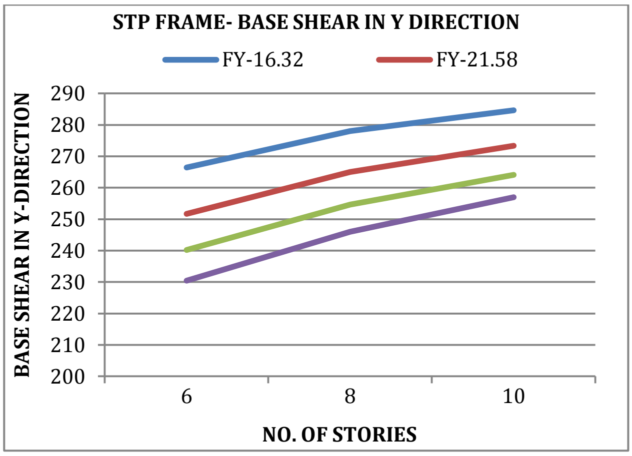
Comparison Set 1

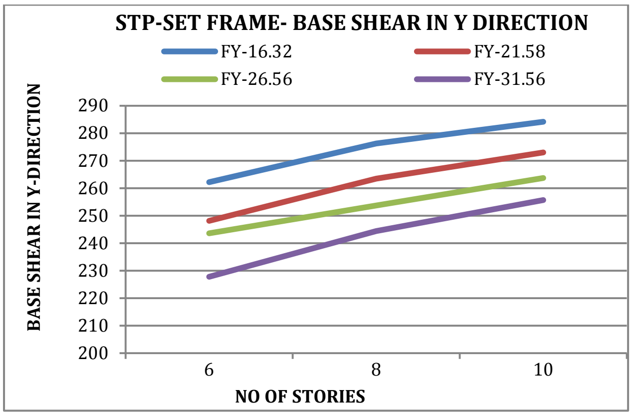
Comparison between the Step back frame and Step back-Set back frame with respect to Base shear (in X-Direction) and Hill Slope angle.





Comparison between the Step back frame and Step back-Set back frame with respect to Base shear in (Y-Direction) and Hill Slope angle.



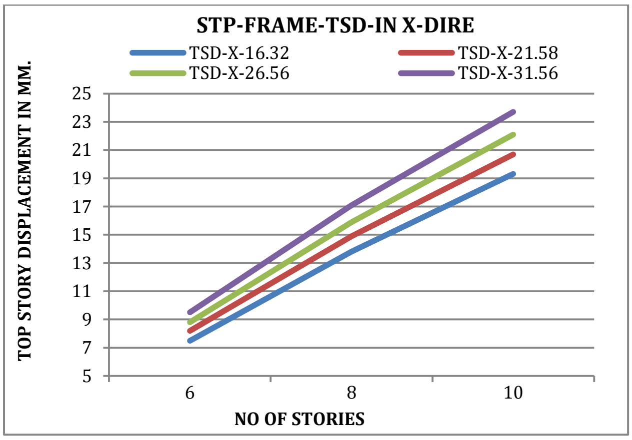


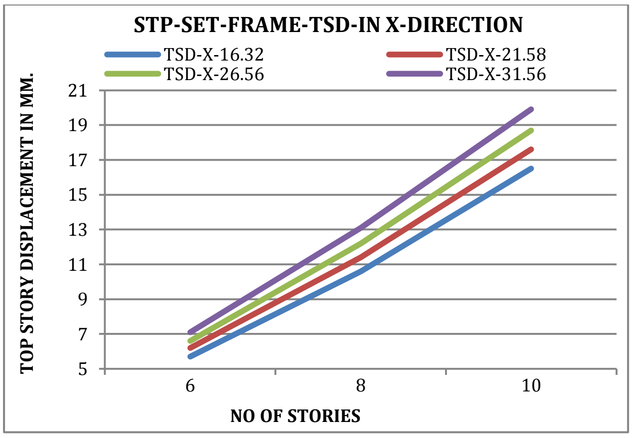
There is rise in base shear value with respect to the increase in the storey height. It's clearly seen that the increase in base shear in x direction is more from 6 stories to 8 stories than the 8 story to 10 story. But in case of Base shear in y direction the rate of increase is almost the same. We can see the effect of no bays influencing the base shear value.

But eventually the base shear value is increasing in both the Step back frame and step back-set back frame as well. When we judge the values of base shear for the frame type we can see that, there is less values of base shear are obtained in Step back-Set back frames.

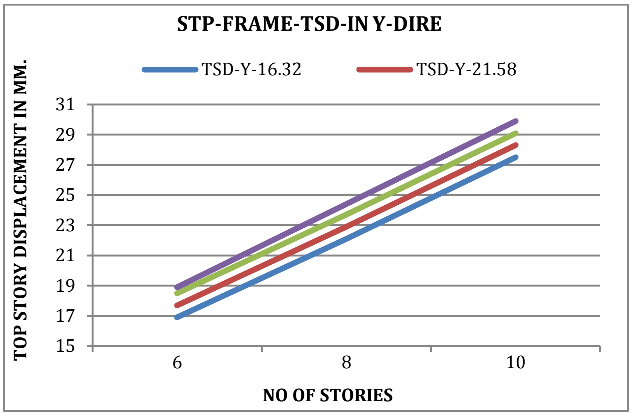
Comparison Set 2

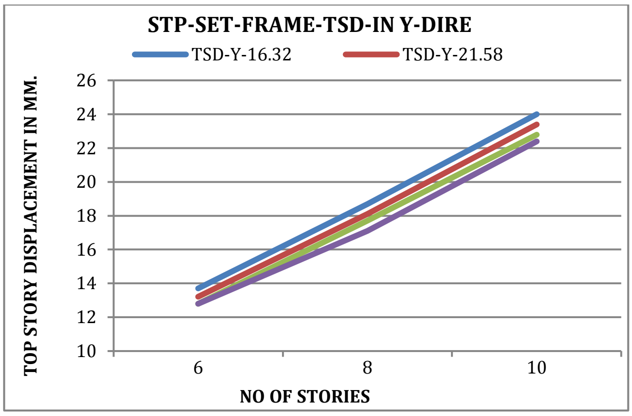
Comparison between the Step back frame and Step back-Set back frame with respect to Top Story Displacement in (X-Direction) and Hill Slope angle.





Comparison between the Step back frame and Step back-Set back frame with respect to Top Story Displacement (in Y-Direction) and Hill Slope angle.

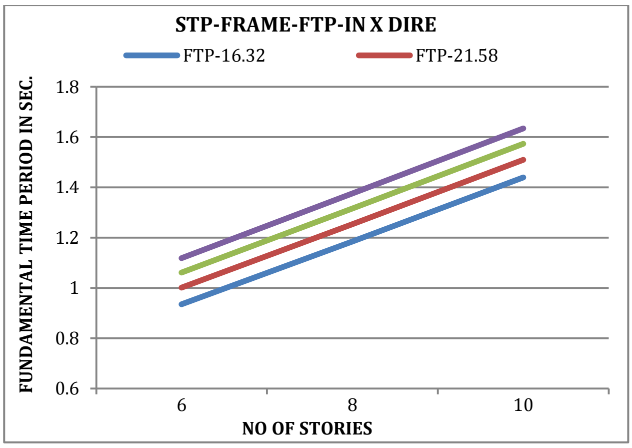


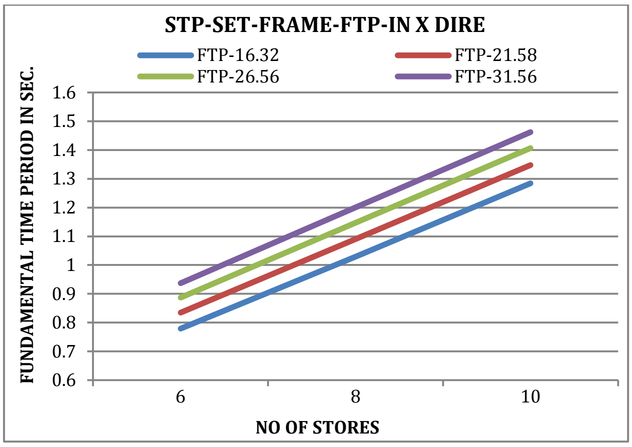


The rate of increase in top story displacement is proportional to the height of the building or in other word, the no of stories in consideration. The slop angle influences the displacement values. It can be seen that the 26.56 degrees and 31.56 degrees at the 6 story height does not make significant difference but as the story height increases the values are clearly distinct.

Comparison Set 3

Comparison between the Step back frame and Step back-Set back frame with respect to Fundamental Time Period and Hill Slope angle.

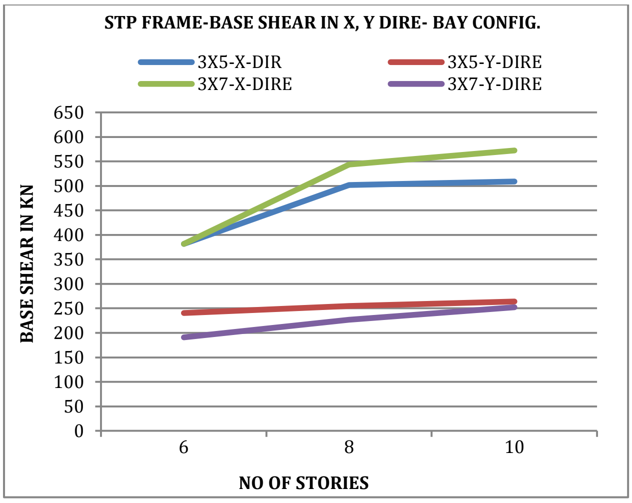


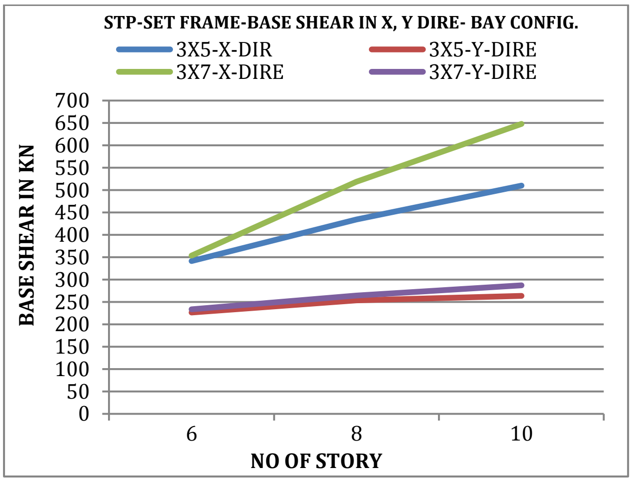


The linear rise in fundamental time period is seen with respect to the rise in number of stories. Also here we can see the difference in time period values in both types of frames. As earlier comparisons, here also, the vales of the fundamental time period are seen less than that of the step back frames.

Comparison Set 4

Comparison between the Step back frame and Step back-Set back frame with respect to Base shear in (X and Y-Direction) and Bay Configuration System.

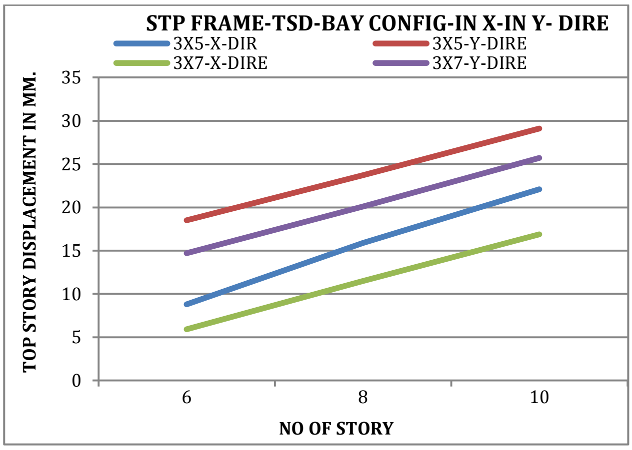


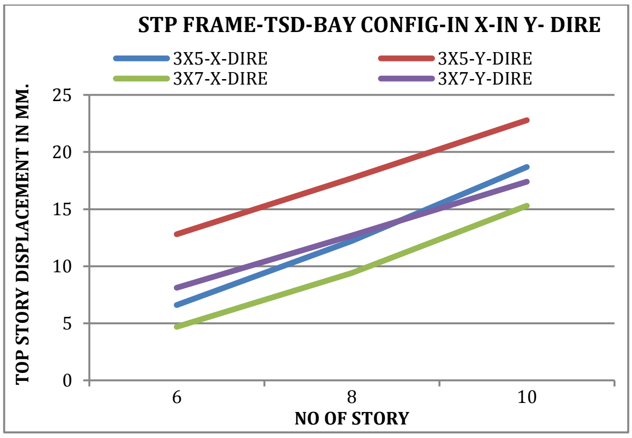


As the number of stories increases with the increase in the number of bays, significant rise is seen in the base shear value. The rate of increase is non-linear in nature. The base shear in y direction for both type of frames seen similar at the less number of stories, but after the story 8 values it seems distinct.

Comparison Set 5

Comparison between the Step back frame and Step back-Set back frame with respect to Top Story Displacement (in X and Y-Direction) and Bay Configuration System.

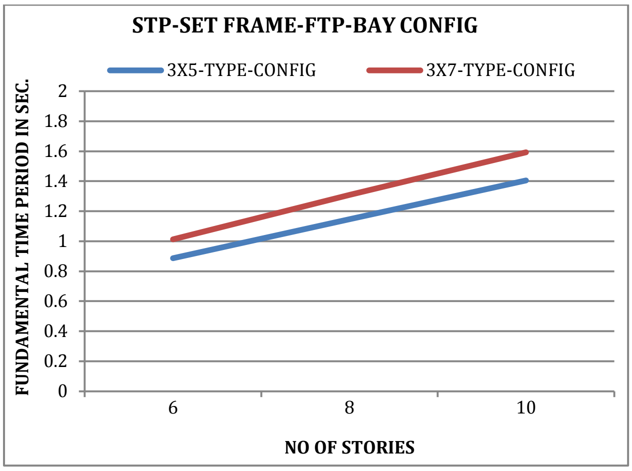


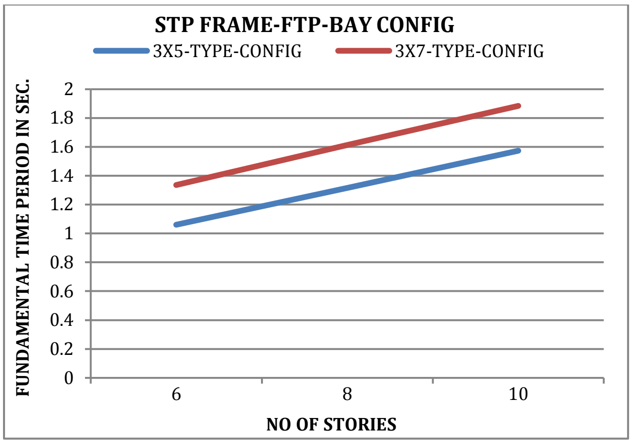


The top story displacement values are seen variant for the bay values as the no of bay increases the displacement changes. This change can be encountered as, as the difference between the number of bays in x and y direction increases the displacement seen increased when the rest of the parameters are same. Also the number of stories increases the top story displacement increases.

Comparison Set 6

Comparison between the Step back frame and Step back-Set back frame with respect to Fundamental Time Period and Bay Configuration System.





For a given number of bay, the time period increases with increase in number of storey. For a given number of storey, the time period increases with increase in number of bay. The time period increases mildly with increase in number of bay. The nature of variation observed is nonlinear for all number of bays.

Conclusion

1)Step back frames produce greater base shear as compared to step back-set back frames. The step back building frames give greater values of time period as compared with step back-set back frames.

2)The step back building frames give greater values of top storey displacement as compared with step back-set back frames.

3)In step back and step back-set back frames; it is observed that extreme left columns, which are on the higher side of the sloping ground and are short, are the most affected. Special attention is required while designing these short columns.

4)The performance of step back frames during seismic excitation could prove more vulnerable than other configurations of building frames, hence step back-set back frames are more desirable than step back frames.

5)As number of bays increases time period & top storey displacement decreases. Therefore, it is concluded that greater number of bays are observed to be better under seismic conditions.

6)As hill slopes increases time period & top storey displacement decreases.

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