# Seismic Behaviors of RC Buildings in Slopping Ground

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**Abstract -** This thesis is the study of seismic behavior of RC building in hilly areas i.e. sloping grounds. The study of dynamic response of structure on hilly areas has been done. Almost 13 configuration of structure has been considered for analysis. Six of them are step-back and which consider ground slope. Six are set-back configuration which is like in plain land. Remaining one is plan buildings. Three models are normal step back, setback and plan buildings and remaining are combination of shear wall, steel bracings. Various literature reviews of studies on the seismic behavior of RC building on hilly areas i.e. sloping ground has been studied and presented in this thesis. All considered configuration of building is modeled using ETABS v20.0.0 and IS 1893:2016 and analyzed by using equivalent static analysis and response spectrum methods. Then considered buildings have been compared in terms of base shear, Fundamental time period, top storey displacement, drift and story stiffness. The seismic behavior of building on hilly areas (sloping ground) is found differ from building plain ground. Most of studies lead to conclusion that building on hilly areas (sloping ground) has higher displacement and base shear compared to building on plain land. Also conclude shorter column attracts more forces and cause damage when earthquake occurs. Step back configuration could prove more vulnerable to seismic activities. We also concluded that building with shear wall improves seismic behavior of building by increasing strength and stiffness and also reduce in deflection.

**Keywords:** Hilly areas, step-back configuration, step-back, set-back configuration, seismic behavior, shear wall, response spectrum methods

## 1: INTRODUCTION

Terai is features with flat and plain ground and hilly and Himalayan region is features with steep ground and small and large mountain. About 83% of total area of Nepal is covered by Hill and Himalaya Region. [1]

The Federal Democratic Republic of Nepal lies in one of the active continental collision zone of the world, the Himalaya, where the probability of Earthquake occurrence is very high. Many destructive Earthquakes have been reported in the historical records within the Himalayan arc. Out of which the 1934 Bihar-Nepal Earthquake and 2015 Gorkha Earthquake Ml 7.6 (Mw 7.8) occurred in the Nepal Himalaya. [2]
Since hilly areas are features with steep ground and small and large mountains. They lack enough plain areas like in terai. We have to encounter slope while constructing building in hilly areas unlike in terai areas. As mentioned earlier Nepal's Himalaya was formed by the tectonic activities of Indian and Eurasion plates so hilly areas of Nepal is very prone to seismic Activities. Due to lack of plain areas in hilly areas steep ground adds additional challenges to seismic analysis of RC building because it may affect the stability and performance of the building during seismic activities.
This study can provide the valuable insight into seismic behavior of RC building on sloping ground conditions, which can help to develop more effective and efficient design and construction methods. This study can help to identify the critical factors that affect the seismic performance of RC building on sloping Ground. The finding of the study can be sued to improve the safety and resilience of building in sloping ground conditions, by providing information on how to design and construct more earthquake resistant structures. The finding of this thesis work will be useful foe engineers, architectures, and researchers in the field of seismic engineering to design and construct safer and more resilient RC building in sloping ground condition, which can help to reduce the risk of loss of life and property during seismic events. This works may help in preparing guidelines for planning and layout of seismic resistant construction of building in slope ground. This work is also helpful for policymakers and building codes organizations in developing codes and regulation for design and construction of building in slope ground.

## 2: LITERATURE REVIEW

This literature includes seismic behavior of RC building in slope ground with consideration of hill slope, shear wall for different configuration. Also it compares seismic behavior of RC building in slope and plain ground. Some important things that I conclude in this work are presented below.
Some journal and their conclusion
**Anil Dangol, Gokarna Bahadur Motra (2021),** This study conclude that the performance of building is decrease with increasing number of stories in sloppy area and The displacement is increases steeply with increase in number of stories in both plain area and step back building while in step back-set back building rate of increment is found to be low [3].
**Shivanand.B, H.S.Vidyadhara (2014),** studied on Design of 3d RC Frame on Sloping Ground, in this study 3D analytical model of 12 storied building have been generated for symmetric and asymmetric case. Building models are analyzed and designed by ETABS software to study the effect of influence of bracings, shear wall at different positions. Hence they concluded that The Setback on Sloping ground possesses relatively less displacements when compared to Step back buildings on Sloping ground & Plain Ground and ,The performance of the buildings on sloping ground suggests an increased vulnerability of the structure with formation of column hinges at base level and beam hinges at each story level at performance point.[4]
**A. S. Swathi et al. (2015),** This study deals with the comparison of seismic performance of soft storey building on sloping grounds and soft storey building retrofitted with shear wall. It is concluded that the seismic performance of open ground storey buildings is very less and Addition of shear wall is an ideal solution to improve the seismic performance of open ground storey building constructed on a sloping ground. [5]
**Prasad Ramesh Vaidya et al (2015),** It is concluded that Good control over the displacement and storey drift can be

achieved if the shear walls are located symmetrically in plan and to have a good control over the forces such as shear force and bending moment it is preferable to locate the shear wall towards the shorter column side. [6]

**Nagarjuna, Shivakumar B. Patil et al (2015),** In this study the results have been compared with the results of the building with and without shear wall. The modeling and analysis of the building has been done by using structure analysis tool ETAB. The seismic analysis was done by linear static analysis and the response spectrum analyses have been carried out as per IS: 1893 (Part 1): 2002. The results were obtained in the form of top storey displacement, drift, base shear and time period. It is concluded that short column is affected more during the earthquake. The analyses showed that for construction of the building on sloping ground the setback building configuration is suitable, along with shear wall placed at the corner of the building. [7]

**Likhitharadhya Y R et al (2016),** Studied on Seismic Analysis of Multi-Storey Building Resting on Flat Ground and Sloping Ground. In this study, G+ 10 storey's RCC building and the ground slope varying from $10^0$ to $30^0$ have been considered for the analysis. A comparison has been made with the building resting on level ground. The modeling and analysis of the building has been done by using structure analysis tool ETAB 2015. The seismic analysis was done by the response spectrum analyses have been carried out as per IS: 1893 (part 1): 2002. The results were obtained in the form of top storey displacement, Storey Acceleration, Base shear and Mode period. It is concluded that short column is affected more during the earthquake. [8]

**Y. Singh and Phani Gade (2011),** in this study different configuration of the buildings on slopes are considered , and also study made on dynamic response of the building by comparing buildings on slopy ground as well as regular building on flat ground in terms of fundamental period of vibration, storey drift, column shear, seismic behavior of two typical configurations of buildings which is located on sloping ground is analysed using linear and non-linear time history analysis.[9]

**"Anjeet Singh Chauhan and Mr. Rajiv Banerjee;** studied on Seismic Analysis of Irregular Building on Hilly Area. In this study the behavior of G+10 storey step back building with mass and diaphragm irregularity on the sloping ground is analyzed in seismic zone V by Response Spectrum method. The analysis of the building is carried out by Etabs software as per IS 1893:2016 to compare the building based on their dynamic response. It was concluded that irregular building in hilly areas are critical to assess their vulnerability to seismic events. [10]

**Naveen Kumar S M et al (2017),** studied on Analysis and Comparison of Step Back RC Frame Building on Sloping Strata and Plain Strata. The seismic analysis was done by the response spectrum analyses have been carried out as per IS: 1893 (part 1): 2002. The results were obtained in the form of top storey displacement, Storey drift, and Base shear and over turning moment. It is concluded that the over turning moment gradually decreases on sloping ground than compare to flat ground. [11]

**Singh et al (2012);** studied seismic behavior of buildings located on slopes. In this study they considered 9 storey buildings, which include step back building at a slope of 45 degree with the horizontal, a RC frame located on steep slope. The seismic behavior of two typical configurations of hill buildings is investigated using linear and non-linear time history analysis. They conclude that the step back buildings are subjected to significant torsional effects under cross slope excitation. [12]

**Halkude et al (2013),** focused on seismic analysis of buildings resting on sloping ground with varying number of bays and hill slopes. It is also concluded that that greater no of bays are observed to be better under seismic excitation, as number of bays increase time period and displacement decreases. [13]

**Sreerama and Ramancharla (2013),** Studied on Dynamic characteristics of the buildings on flat ground differ to that of buildings on slope ground as the geometrical configurations of the building differ horizontally as well as vertically. The natural time period of the building decreases as the slope angle increases and short column resist almost all the storey shear as the long columns are flexible and cannot resist the loads. [14]

**Mohammad Umar Farooque etal (2014),** studied on performance study and seismic evaluation of RC building on sloping ground. Lateral displacements and storey drifts are considerably reduced while contribution of shear wall is taken into account. Also it was concluded that Lateral displacements and storey drifts are considerably reduced while contribution of shear wall is taken into account. [15]

**Birajdar and Nalawade (2004),** studied on seismic performance of buildings resting on sloping ground. In this study twenty four RC building frames with three different configurations as Step back building, Step back Set back building and Set back building situated at a slope of 27 degree with the Horizontal has been considered. In this study 3D analysis including torsional effect by using Response spectrum method has been carried out. Models and analyzed using structural analysis tool STAAD Pro V8i. It has been concluded that there were uneven distribution of shear force in various frames leads the torsional moments on building on sloping ground. [16]

**Ravikumar C. M et al (2012);** In this study vertical irregularities of buildings such as geometric irregularity and buildings resting on sloping for which two types of configurations were considered as buildings resting on sloped ground in X-direction and buildings resting on sloped ground in Y-direction. All buildings consist of 5 bays in X-direction and 4 bays in Y direction with 3 storey located in severe zone V. The performance of these buildings was studied by linear analysis using code IS 1893 (part-1) 2002 and Nonlinear analysis using ATC 40. It was conclude that the buildings resting on sloping ground are more vulnerable to earthquake than the buildings resting on plain ground. [17]

**SUJIT KUMAR et al (2014);** In this study a G+3 storey RCC building on varying slope angles i.e., $7.5^0$ and $15^0$ is studied and compared with the same on the flat ground. The seismic forces are considered as per IS: 1893:2002. The structural analysis software STAAD Pro v8i is used to study the effect of sloping ground on building performance during earthquake. It was concluded that the critical horizontal force and bending moment in footing increases significantly with increase in ground slope and the critical bending moment in the column increases significantly for sloping ground compared to plane ground [18].

## 3: METHODOLOGY

### 3.2 Selection of study area

The behavior of buildings depends upon the shape, size, plan, and arrangement of structural elements. It is important to develop the relationship between the seismic ground motion and physical damage of building which masks easy to make a seismic risk assessment of the building. Some recent earthquakes in hill region, Nepal (2015), Sikkim (2011), Kashmir (2025) and Uttarkashi (1990) had shown that serious failure of structural and nonstructural members, as well as a whole structure, maybe collapse [28]. To overcome the various problems related to hill side buildings we have use shear wall, bracing and moment resisting structure when the problem is related to earthquake effect. The steel bracing and concrete bracing is more economically sound to resist the earthquake or lateral loading as a comparison to the shear wall. Bracing is used in the retrofitting process because it increases the stiffness and capacity of the loading on the building. Also, it increases the seismic performance of the building when we use the steel and concrete bracing in the structure. The Indian hill side actually lies under geological plate boundary and fault. Which suggests that earthquake may come in these areas. Hence the structure should be earthquake resisting.

For the completion of this thesis work, study area is considered as hilly areas of Nepal geographically. Configuration of building for study are step back and step back- set back configuration in hilly areas, building on plain , combo of step back in hill sides and building on plain with and without shear wall. Base shear, fundamental time period, max storey drift, max storey displacement, overturning moments, storey stiffness is the topic of study for completion of the work.

### 3.4 Collection of data

In the present study, five groups of building *(i.e. configurations*) are considered, out of which four are resting on sloping ground i.e. hilly area and one is on plain ground with and, the first two are step back buildings and step back-setback buildings; and third is the building in plain land and last two buildings are combo building in which half building is constructed in slope whereas half of building is at plain land. 3D space frame analysis with single hill side step back building considered and seismic analysis had done. The step back building having columns, beams and slabs are constant but only the shear wall steel and RC bracing are introduced on the model. The analysis has done in ETABS finite element software and carried out the linear dynamic analysis known as response spectrum analysis. The seismic parameters are determined such as the Fundamental time period (FTP), top story displacement, story drift, story shear, story stiffness and comparative study have been done on each model. The study carried out on both side that is along the hill side and across the hill side. The concrete is assumed as homogeneous, isotropic, and elastic in nature. The modulus of elasticity of concrete is 25000 N/mm$^2$ and Poisson's ratio to be 0.2. The yield stress of reinforced steel is taken as 415 N/mm$^2$. Floor system for all floors to be considered as the rigid diaphragm. The modulus of elasticity of the steel section to be 210000 MPa. Having Poisson's ratio is 0.3. The foundation level of all support is considered as a rigid support. IS 1893 (Part-1) 2016. Criteria for Earthquake Resistant Design of Structures, Part 1 used to design the structure. The researcher uses the steel of different types of bracing like X, inverted V, diagonal (D), and also using the shear wall (S) as shown in Table 3.4.

The structure rests in the inclination of the earth's surface. The inclination of the ground is 26˚ (Figure 1 and table 1). The structural properties, size of columns, beams, bracing, are given in table 3.5. The inter-story height is taken as 3.3 meters and foundation depth are varying as slopping. The thickness of all floor slabs is as 200mm. Researchers consider the along hill slope as 5 bays (x-axis) and across the hill slope be 4 bays (y-axis). Each bays width is 5m.

The live load on the floor is taken as 3KN/m$^2$ and 25% of the imposed load to be considered in the calculation of seismic weight as per IS 1893 (Part-1) 2016, table 10. The seismic parameter is considered a response spectrum method (fig 3.3). The zone factor is assumed to be zone V with a peak ground acceleration value of 0.36g. The important factor is taken as 1.5 and response reduction factor 5 for the SMRF system assumed. These values were taken in the IS 1893 (Part-1) 2016. The damping ratio for RC building is taken as 5%.

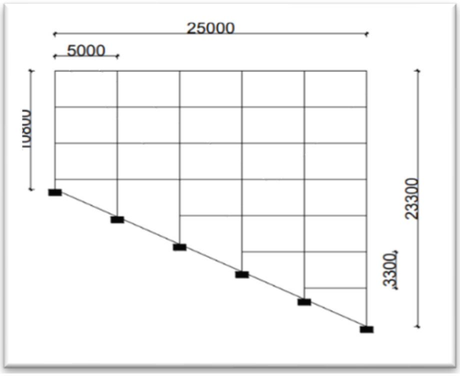


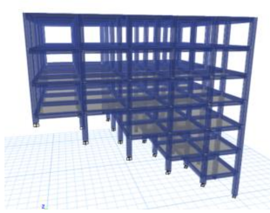
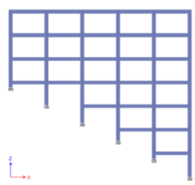

**Figure 1step back buildings with slope elevation**

### 3.5 Building frames

Step back (SB) frames

The building configuration in which horizontal plane remains same but on the lower part it will maintain slope as per terrain or topography of the area. In these type of buildings the foundation of different grid columns are at different level so that there is stiffness variation and mass irregularity (i.e. top floor level has higher mass and stiffness than ground floor) along storey-wise. Table 3.1 shows the elevation and 3D view of the step back buildings.

Table **1.** 3D Frame and elevation step back Frames

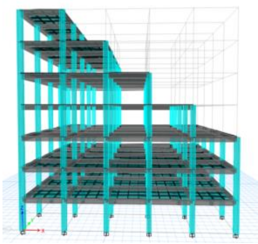
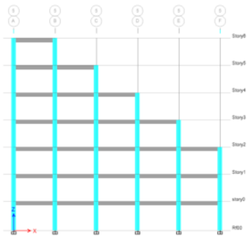
| 3D Frame | Elevation |
| --- | --- |
|  |  |

Set back (SEB) frames

Setback in buildings introduces staggered abrupt reductions in floor area along the height of the building. This building form is becoming increasingly popular in modern multi-storey building construction mainly because of its functional and aesthetic architecture. In particular, such a setback form provides for adequate daylight and ventilation for the lower storey in an urban locality with closely spaced tall buildings. Sketches needed

This setback affects the mass, strength, stiffness, centre of mass and centre of stiffness of setback building. Dynamic characteristics of such buildings differ from the regular building due to changes in geometrical and structural property. Design codes are not clear about the definition of building height for computation of fundamental period. The bay- wise variation of height in setback building makes it difficult to compute natural period of such buildings. Table 2 shows the elevation and 3D view of the set back buildings. For comparative study other sectional and other design parameter are taken same.

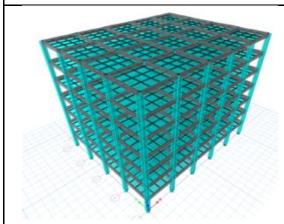
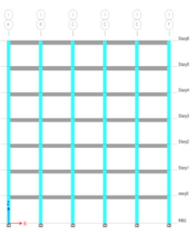
**Table 2. 3D Frame and Elevation of set back frame**

| 3D Frame | Elevation |
|---|---|
|  |  |

Building on plain land:

These types of building are normally constructed on plain land. They are regular structure with symmetry in both x and y direction. For comparative analysis, sectional and other design parameter are taken same as step back and set back buildings. Table 3 shows the plan frame structure with 3D and elevation views.

**Table 3. 3D Frames and Elevation of building on flat ground**

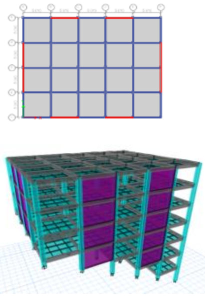
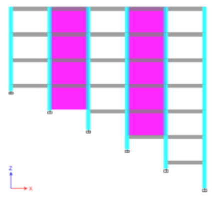
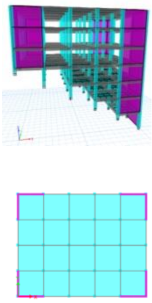
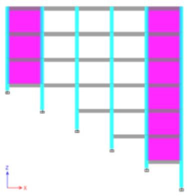
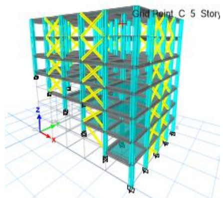
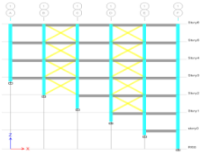
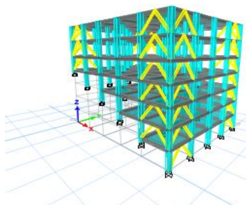
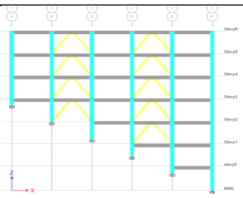
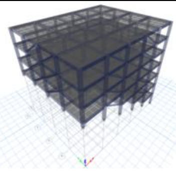
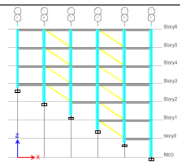
| 3D Frame | Elevation |
|---|---|
|  |  |

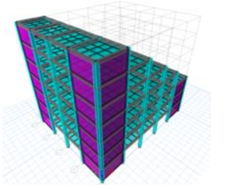
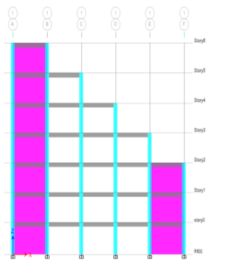
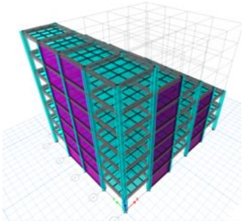
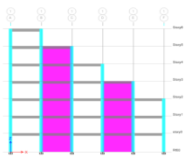
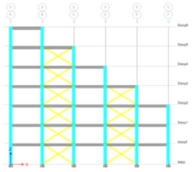
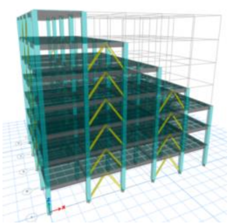
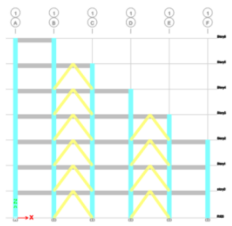
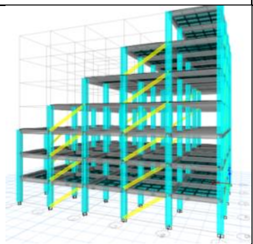
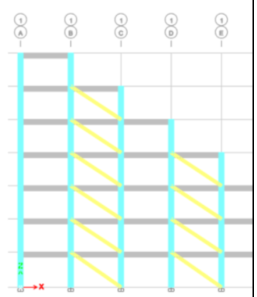
Step back and setback buildings with combo

This is the combination of step back building in slope and normal building in plain areas. It considered all factor considered on both step back building in slope and normal building in plain. In this building configuration half of the structure is arranged in stepping pattern in slope and half is like normal building in plain areas so the horizontal plane is not remains same along with lower part of the structure. In this type of structure the foundation level of different grids columns are at different level in sloping region but in plain region foundation level are at same level. This types of configuration can use where some land are in sloping pattern and some are plain.

In this work structure in sloping are studied in two ways. One is structure with shear wall at hill sides where another is without shear wall. Elevation and 3D model of such configuration is given below. The table 4 shows the set back and step back buildings with shear wall and bracings.

**Table 4. 3D frame and Elevation of combo building**

| Combo | 3D Frame | Elevation |
|---|---|---|
| SBSM (SB building with shear wall in mid protation) |  |  |
| SBSC ( shaer wall in corner of the buildings) |  |  |
| SBX ( X steel bracing in SB buildings) |  |  |
| SBIV( Inverted steel bracing in SB buildings) |  |  |
| SBD ( diagonal steel bracing in SB buildings) |  |  |

| | | |
|---|---|---|
| SEBSC |  |  |
| SEBSM |  |  |
| SEBX |  |  |
| SEBIV |  |  |
| SEBD |  |  |

The properties of frame members of buildings that are considered for analysis are given in table 5 and table 6.

**Table 5. Specification of building**

| | |
|---|---|
| Seismic zone | V |
| Zone factor | 0.36 |
| Response reduction factor | 5 |
| All general buildings | 1.5 |
| Damping ratio | 5% |
| Structure type | RC frame building |
| Soil type –medium | II |
| Concrete grade | M20 |
| Steel grade | Fe500 |

**Table 6. Step back, set back and plan buildings with sectional properties.**

| Building Configuration | Designation of models | Shear wall mm | Steel bracing | Column size (mm) | Beam size (mm) |
|---|---|---|---|---|---|
| Step-back (SB) | SB | | | 520*520 | 250*500 |
| | SBSC | 200 | | | |
| | SBSM | 200 | | | |
| | SBX | | ISLC300 | | |
| | SBIV | | ISLC300 | | |
| | SBD | | ISLC300 | | |
| Set back (SEB) frames | SEB | | | | |
| | SEBSC | 200 | | | |
| | SEBSM | 200 | | | |
| | SEBX | | ISLC300 | | |
| | SEBIV | | ISLC300 | | |
| | SEBD | | ISLC300 | | |
| Plain land | P | | | | |

## 4: RESULTS AND DISCUSSIONS

For analysis of all considered building seismic load is considered along with accidental eccentricity. For this seismic force was applied in both directions i.e. X- direction and Y-direction. Some important result after analysis of considered buildings are presented below and interpretation of result is done simultaneously. Here data are presented in two section in first section data are presented of three configurations (step back, set back configuration)

### 4.2 Step back Buildings

Study of step-back building having fixed building height having a different type of structural elements like shear wall and bracing system along and across the hill slope [29]. All six models have been analyzed for earthquake loads as per code provisions. The seismic loads applied along and across the slope in hill side building. The result is obtained and analyzed & discussed in the term of seismic parameters such as fundamental time period (FTP), top story displacement, story drift, story shear, and story stiffness.

Design Base shear variations

The base shear is the lateral total force at the base of the structures induced due to the earthquake ground motions. The base shear of the structures depends upon the plan shape of the structures, fundamental time periods and soil types of the sites. It also depends upon the seismic weight of the structures. Maximum story shear of the models having range 2519.4KN to 2047.71 KN along the slope direction whereas 2308.61 KN to 2042.59 KN across the hill slope as shown in figure 2. However, the value of the story shear obtained along and across the hill slope, found maximum near the middle portion of the building height, it is because of the step-back configuration also observed in [29], [30]. The maximum story shear along and across the hill slope shown in fig.2.

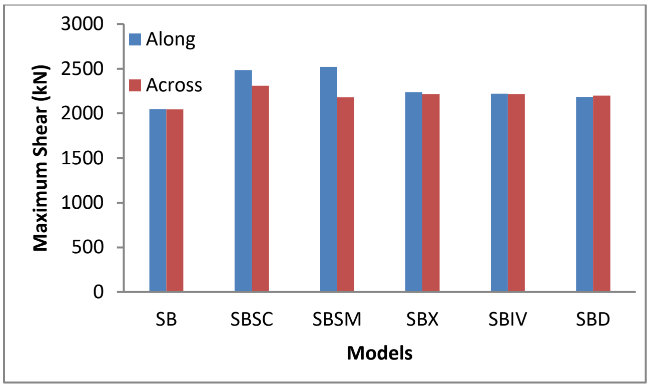



**Figure 2. Base Shear at bottom of each configurations of step back building**

Fundamental Time periods

The seismic behavior of the structure depends upon the fundamental time period of the structure. The base shear of the structure is calculated by using the time period. The time period of the structure depends upon the building height, ductility of the structures, building shape, size of the structure. The fundamental time of the step back buildings are calculated as shown in figure 3. It shows that the natural time period of the unbraced RC SB buildings have relatively higher than the other SB buildings. The SB buildings where shear wall are provided have less value of FTP as compared to the other braced frame structure. It is observed that almost 57% value decreased when the shear wall are provided in SB building at corner side. In Figure 3 we observed that simple SB has a maximum FTP value of 0.514 sec by RSA and minimum FTP by RSA is 0.217 sec for SBSC building.

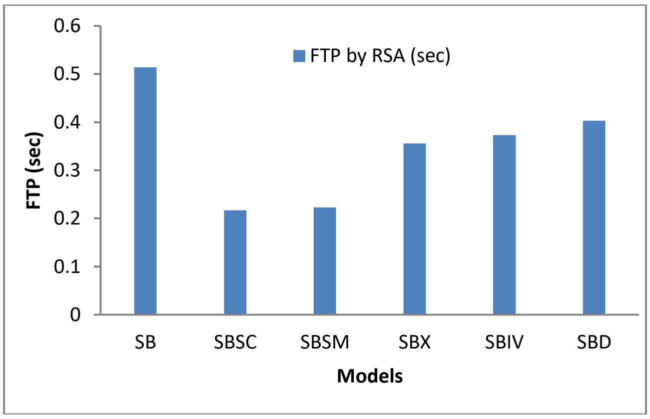



Figure 3. Fundamental time periods for SB buildings with different configurations

Maximum Displacements

The story displacements of the irregular structures subjected by lateral loadings area significant parameter for buildings design [31]. The top story displacements response of the structures helps to understand the damage level of the structures. While designing the structures, the lateral deformation and drift of the structures should be considered carefully, avoiding excessive deformation in the structures. In the irregular structures, the excessive deformations damage the structural and nonstructural members in the buildings. The Fig. 4 show the maximum displacements in the SB shape buildings. In the fig. 3 the maximum displacement 21.713mm across the hill slopes. The reduction of top story displacement of 82.77% in the SBSC and SBSM models along the slope direction to their maximum difference. Top story displacements are reduced by 49.7%, 46.2%, and 37.4%, for SBX, SBIV and SBD respectively along the slope direction. Across the hill side , the top story displacement are reduced by 81.48%, 80.6%, 52.12%, 48.04% and 39.4%, for SBSC SBSM SBX, SBIV and SBD respectively. The shear wall provided in a corner and middle configuration shows minimum top story displacement it is because the shear wall increases the stiffness of the building.

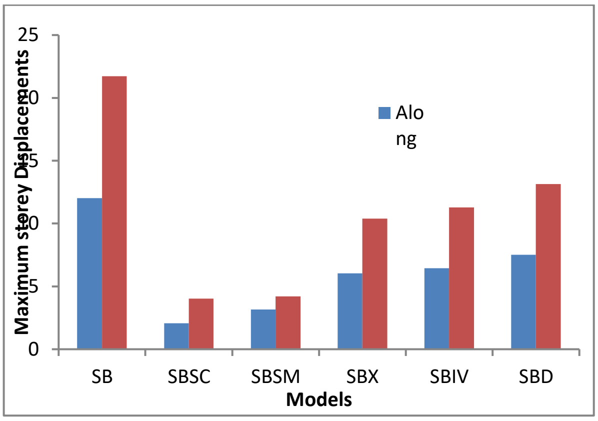



Figure 4 Maximum top story displacements for SB buildings with different configurations

Inter story Drift

Inter-story drift is another important significant parameter for examining the structural behaviors effectively. The inter-story drift (ISD) is the more reliable parameter to observe the structural and nonstructural damage as compared to the displacements [32].

A significant amount of variation in story drift was found both along the slope and across the slope direction. It is found that the maximum story drift is observed in SB configuration as same as in fig. 5. The reduction in story drift ranges from 85.355% to 35.69% along the slope direction. Whereas reduction in story drift range from 87.0 to 47.18% across the slope direction. The maximum reduction in SBSC and minimum in the RCD model. The reduced story drift of SBSC has more as compared to the SBSM configuration.

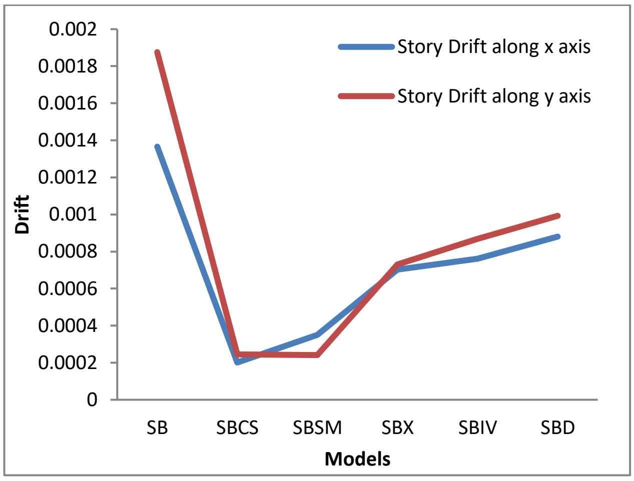



**Figure 5.** Maximum top story drift for SB buildings with different configurations

Story Stiffness

Addition of the steel bracing in the RC buildings, it increases the stiffness of the structures. The steel bracing having the shear force contributions higher, those models have also higher stiffness as shown in the table 1 to 4. Story stiffness of the buildings depends upon the size, shape and length of the columns or bracings. Fig.6 and 7 represents the variation of story stiffness of each model. It is noticed that adding the steel bracings and shear wall in the models to resist the lateral loadings, increases the story stiffness of the buildings. Providing shear wall in the SB buildings almost have high capacity of stiffness and the minimum stiff buildings is SBD. In figure 6 it is clear that similar stiffness behaviors are observed in both the directions. In this study it is noticed that in the SB buildings, the stiffness values are more in the story 4 level.

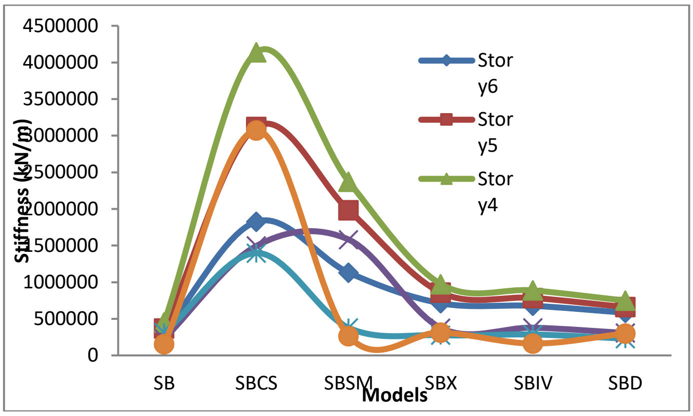



Figure 6. Maximum top story stiffness for SB buildings along x axis

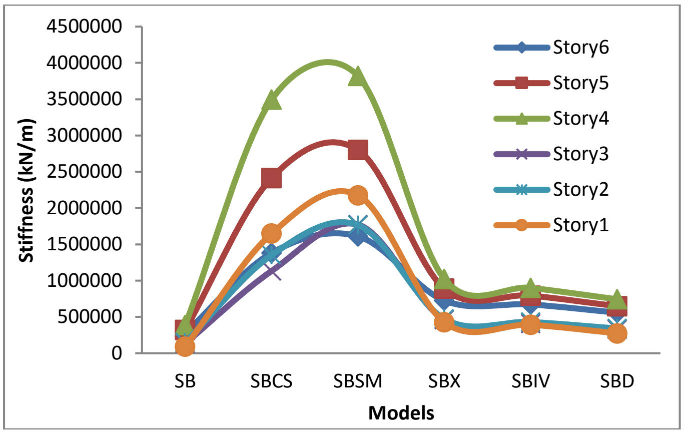



Figure 7. Maximum top story stiffness for SB buildings along y axis

### 4.3 Setback Building

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 various floors of such buildings step back toward the hill slope and at the same time building may have setback. A total of six buildings have been analyzed for seismic force in X as well as in Y directions in this configuration of building. Different seismic parameter are observed in SEB models and compared each other. In same as SB buildings each six models are prepared. Comparative analysis of SEB models are given bellows.

Design Base shear variation

The models having more seismic weight have more base shears as expected. The distribution of story shear is parabolic for the equivalent static case. Figure 8 shows that when the shear wall and bracing are used as a earthquake resisting systems the base shear values also increased. When the same model SEB have introduced the shear wall the base shear value increased around 2500kN forces. Almost 65% shear force is increased when the shear wall are used. Figure 8 also shows that along the x and y direction shear force also similar.

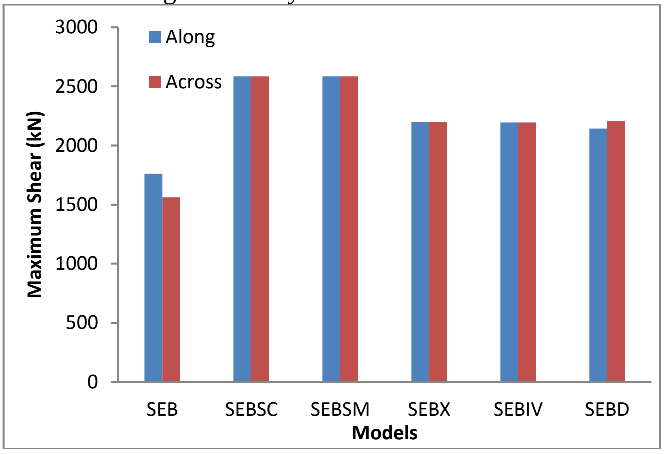



Figure 8. Maximum Shear in SEB buildings with different models

Fundamental time periods

Fig 9 shows the variation of the fundamental time period of the structures on both the x and y-axis. Fig 9 it is clear that where the shear wall are used to resist the lateral load, the fundamental time period at that axis is decreased however the base shear at that axis increases. When the shear wall are provided in both axis in models fundamental time period values are decreased. When the shear wall is used almost 55% FTP value is increased. When the steel bracings used it also decreased the FTP values. The minimum decrease in FTP in the models SEBD models.

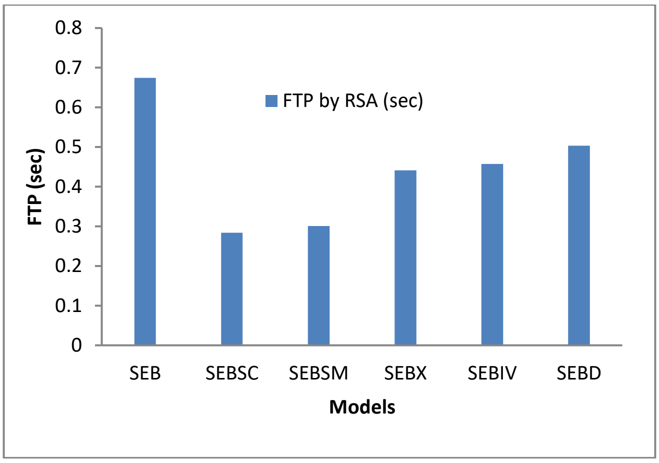



Figure 9. Fundamental time periods for SEB buildings with different configuration

Maximum Displacements

As similar to SB building adding the steel bracing and shear wall in the SEB buildings decrease the maximum displacements. Steel and shear wall reduce the maximum displacements by increasing the stiffness values of the

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buildings. The shear wall and bracings helps to reduce the excessive displacements and reduced the risk of failure of buildings. When the SEB buildings introduced by shear wall at corner side the maximum displacements decreased by 69.6%. The maximum displacements were decreased by 64%, 45.01%, 41.8 and 31.4% in the models SEBSM, SEBX, SEBIV and SEBD respectively as compared by SEB models. As shown in figure 10.

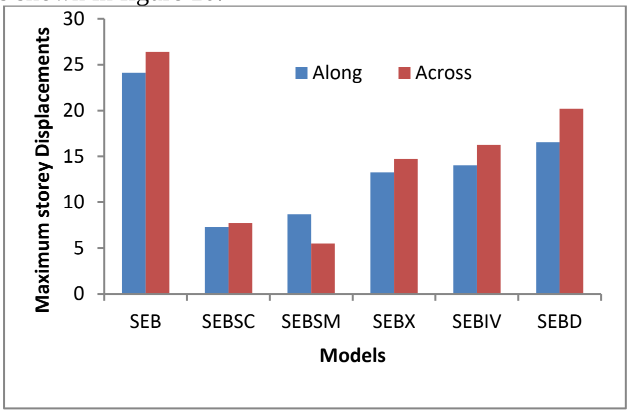


Figure 10. Maximum top story displacements for SEB buildings with different configurations

Inter story Drift

The inter-story response decreased in SEB when the shear walls and steel bracing are used. It is observed that in the SB buildings the maximum ISD of 0.00142, 0.000482, 0.000489, 0.00065, 0.000668 and 0.000767 along the x-axis and 0.00158, 0.000724, 0.000425, 0.00076, 0.000823 and 0.0010 along the y-axis for models SEB, SEBCS, SEBSM, SEBX, SEBIV and SEBD respectively. Overall in SEB Fig 11 shows that adding the shear wall and steel bracing properly in the RC buildings decreased the ISD of the structures effectively. The maximum interstory drifts are observed under the codel provision. The overall results suggested that the adding lateral load resisting system in the SEB buildings decreased the inter story drifts effectively.

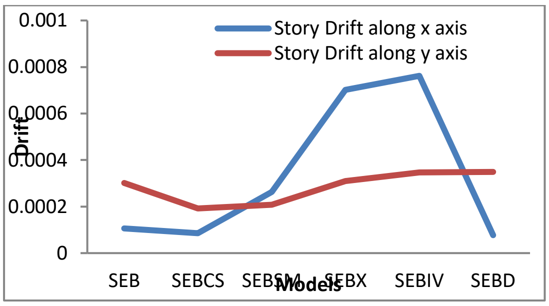


Figure 11. Maximum top story drift for SEB buildings with different configurations

Story stiffness

It is noticed that adding the steel bracings and shear wall in the models to resist the lateral loadings, increases the story stiffness of the buildings. In SEB, the increasing the stiffness of the story in each direction, noticed more uniform. The minimum story stiffness is observed in the model SB and maximum in SBCS, which is retrofitting by shear wall. It is also observed that maximum story stiffness is observed at story 4 for all models as shown in figure 12 and 13. For braced frame structure the maximum story stiffness almost similar.

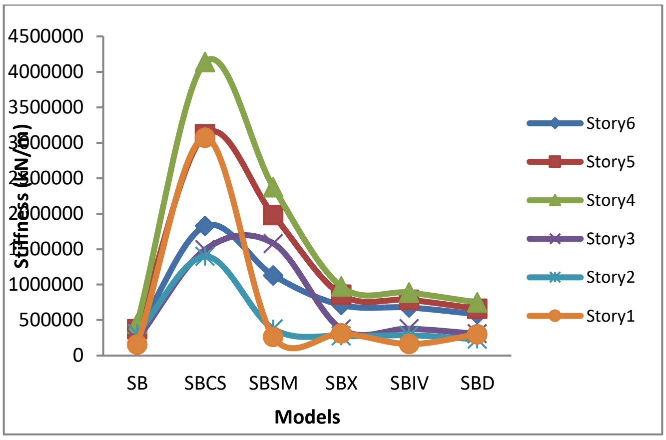


Figure 12.Maximum top story stiffness for SEB buildings along x axis

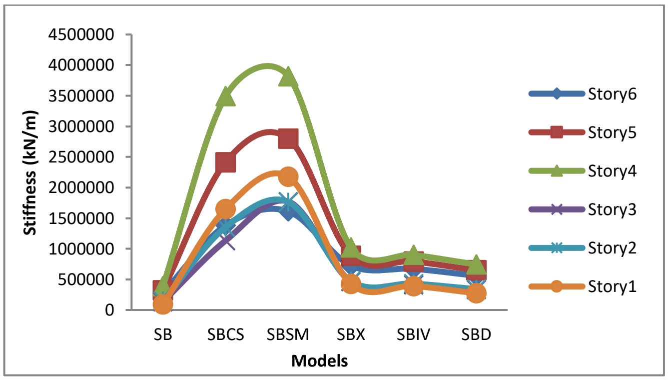


Figure 13. Maximum top story stiffness for SEB buildings along x axis

**4.4 Comparative analysis of models**

To study the comparatively which model shows what type of behaviors in different seismic parameter each models are prepared and compared to each others. In this time plan normal buildings also introduced.

Fundamental time periods

In the figure 14 it shows the fundamental time periods of models P, SEB and SB models. It shows that model p has more seismic fundamental time periods and it is less in SB models. It is because models P have high seismic weight. In the figure 14 it also shows the comparative analysis of SBSC and SEBSC. In this analysis it is also found that setback building have high FTP values. In figure 14 to 19 shows that maximum value are always observed in the SEB type models.

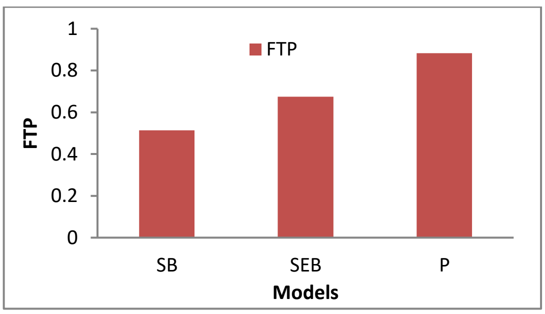

Figure 14. FTP for SB, SEB and P buildings

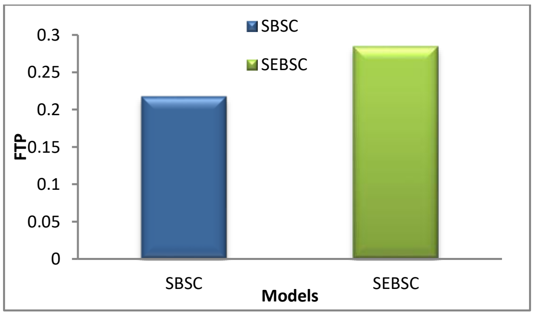


Figure 15. FTP for SBSC, SEBSC

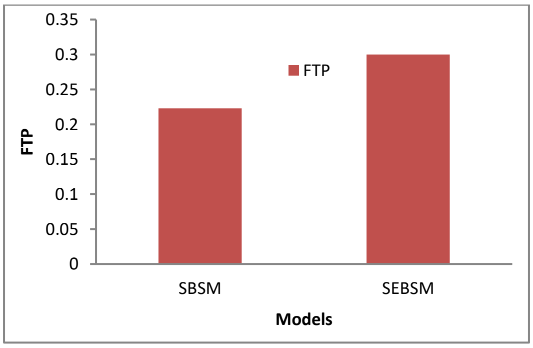


Figure 16. FTP for SBSM and SEBSM

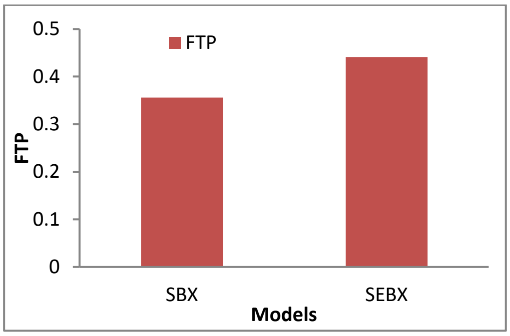


Figure 17. FTP for SBX and SEBX

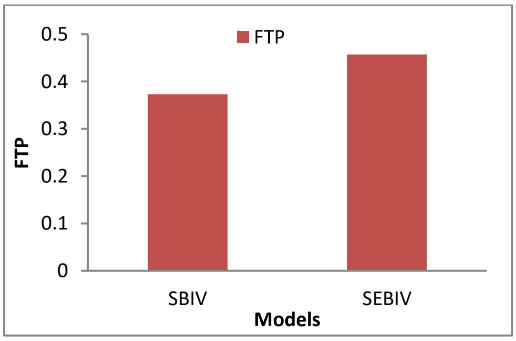


Figure 18. FTP for SBIV and SEBIV

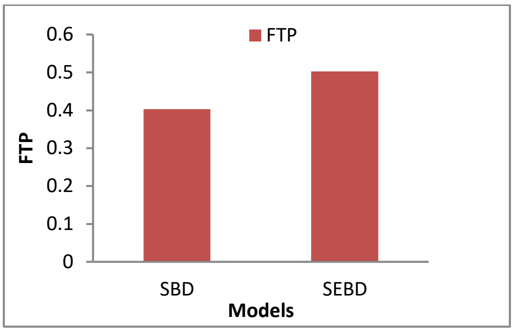


Figure 19. FTP for SBD and SEBD

Base shear and displacements

Figure 20 shows the maximum base shear in the models P, SB and SEB. It shows that base shear values is minimum in SB buildings and also along the x and y axis values are quite different. Figure 21 shows that maximum displacements along both direction in the models P, SB and SEB. In the figure shows that maximum displacements is observed in the P models and minimum displacements was observed in the SEB models. Also in the table 7 to 10 shows the similar results for Base shear and maximum story displacements. In all models maximum displacements was decreased by the models where shear wall are used.

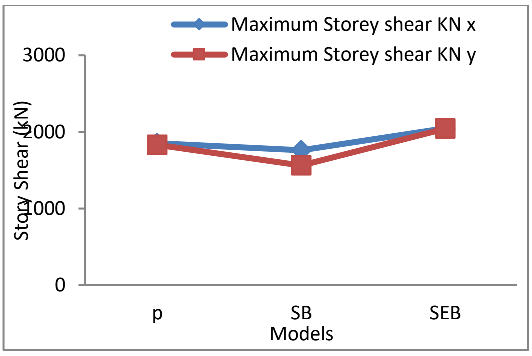


Figure 20. Story shear for SB, P and SEB

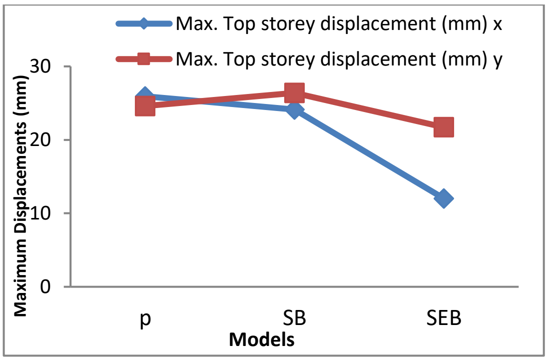


Figure21 Maximum story displacements for SB, P and SEB

Table 7 Story shear and displacements for P, SB and SEB models

| Models | Max. Top storey displacement (mm) | | Maximum Storey shear (kN) | |
|---|---|---|---|---|
| | x | y | x | y |
| p | 25.927 | 24.613 | 1854.076 | 1829.916 |

| | | | | |
|---|---|---|---|---|
| SBSC | 2.07 | 4.026 | 2484.54 | 2308.61 |
| SEBSC | 7.327 | 7.745 | 2586.098 | 2586.098 |

Table 8 Story shear and displacements for P, SBSM and SEBSM models

| Models | Max. Top storey displacement (mm) | | Maximum Storey shear (kN) | |
|---|---|---|---|---|
| | x | y | x | y |
| p | 25.927 | 24.613 | 1854.076 | 1829.916 |
| SBSM | 3.172 | 4.207 | 2519.4 | 2181.4 |
| SEBSM | 8.673 | 5.484 | 2586.098 | 2586.098 |

Table 9 Story shear and displacements for P, SBX and SEBX models

| Models | Max. Top storey displacement (mm) | | Maximum Storey shear (kN) | |
|---|---|---|---|---|
| | x | y | x | y |
| p | 25.927 | 24.613 | 1854.076 | 1829.916 |
| SBX | 6.043 | 10.396 | 2237.12 | 2217.15 |
| SEBX | 13.269 | 14.705 | 2201.481 | 2201.4811 |

Table 10. Story shear and displacements for P, SBIV and SEBIV models

| Models | Max. Top storey displacement (mm) | | Maximum Storey shear (kN) | |
|---|---|---|---|---|
| | x | y | x | y |
| p | 25.927 | 24.613 | 1854.076 | 1829.916 |
| SBIV | 6.454 | 11.283 | 2218.9 | 2215.4 |
| SEBIV | 14.022 | 16.271 | 2195.667 | 2195.6671 |

Story drift and story stiffness

In this section the comparative analysis of each models is performed. The figure 22 shows that the maximum story drift story wise. The data shows that the maximum story drift is observed in the model p. the value of story drift also uniform nature However in the SEB models also shoes the uniform graph. In the figure 23 and 24 also shows that maximum story drift for different models. It is observed that model SEB shows uniform shear force variation. In the model SB, the, maximum inter story drift observed on 4 story height. Figure 25 shows that story stiffness variations in the models P,SB and SEB. It is observed that maximum story stiffness were observed in the model SEB and p models. Figure 22 to figure 27 shows that performance of structure with comparative ways.

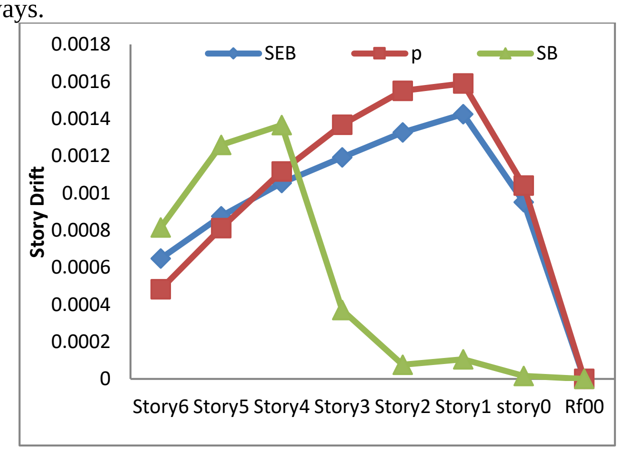


Figure 22 Maximum story drift for SB, P and SEB

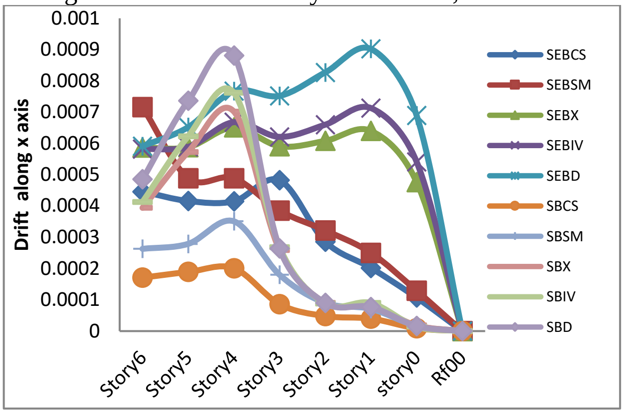


Figure 23. Maximum story drift for braced and shear walled buildings along x

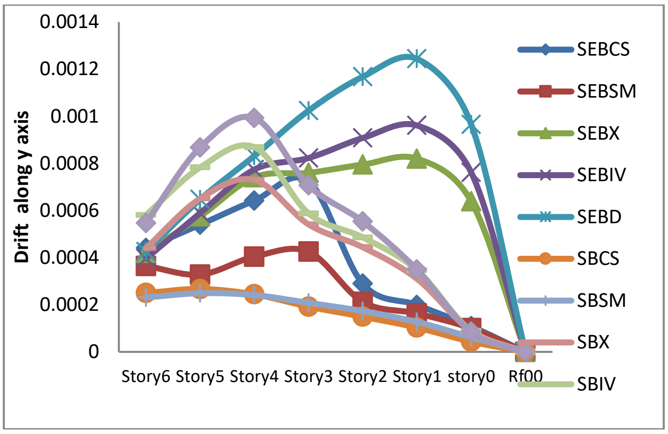


Figure 24 Maximum story drift for braced and shear walled buildings along y

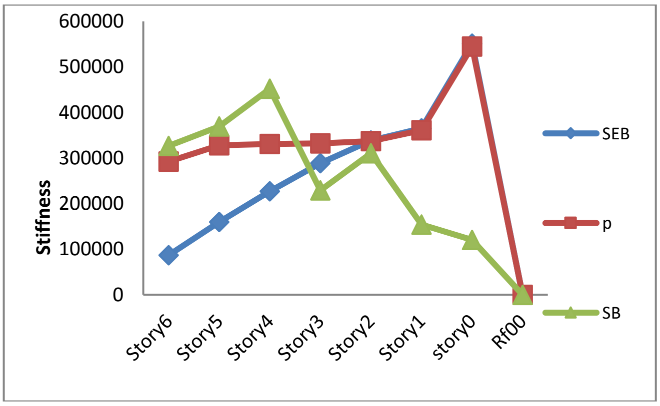


Figure 25 Maximum story stiffness for SB, P and SEB

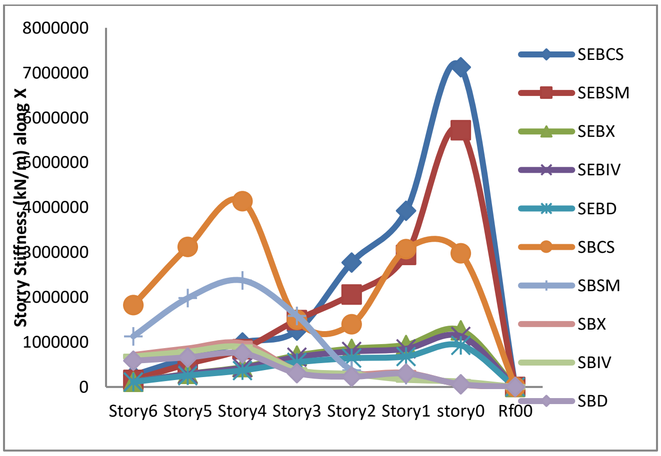


Figure 26. Maximum story stiffness for all braced and shear walled buildings along x

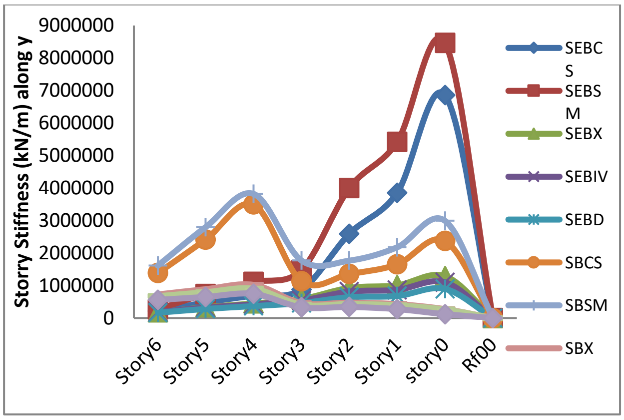


Figure 27. Maximum story stiffness for all braced and shear walled buildings along y

## 5: CONCLUSION

After analyzing all configurations, the study has contributed to our understanding of the seismic behavior of RC building in sloping ground. The combination of set back and step back in SSB building provides lateral stability and the vulnerability to torsional forces compared to step back buildings. Set back building in flat ground will be more rigid than SB building in sloping ground due to higher value of stiffness. Due to provision of set back and step back base shear value is higher for step back building than set back step back building in sloping ground. Fundamental time period during earthquake for step back building is more than other two building. Also storey drift is higher for step back building than SEB buildings.

The study shows that the shear wall placed in the corner side shows better performance. X steel bracing also have good performance value as comparison to the other bracing system. It also suggested that in step-back hill side with high seismic zone side, the design provision of the linear dynamic analysis should be carryout to get an accurate design of the building. As increasing the stiffness of the building the time period decreases. So as the result the shear wall building shows a small time period as compared to the other. In hill side building shows different behavior, the shear wall building the story stiffness shows irregularities along with the height. It was also studied that the rectangular plan of building the maximum top story displacement across the slope direction was found more as comparative to the along the slope direction. The other parameter also the more seismic effect seen across the slope direction. It was also observed that it is better to use the X bracing system. The bracing have less base shear value and also economical.

In analyzing the building that rest on sloping ground in uneven ground, the provision of shear wall increases the base shear and fundamental time period has decreased. Shear wall reduces the storey drift and top storey displacement and overturning moments. Addition of shear wall increases stiffness of buildings. Provision of shear wall improves the seismic behavior of RC building that rest on sloping ground and uneven ground. Therefore, the building with provision of shear wall is considered suitable on the sloping ground and uneven ground.

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