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Seismic Performance of Multi-Storey Building with Flat-Slab in High Seismic Zone on Sloping Ground

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Abstract

The lack of level land in slope territory has driven the construction of building on slope Slant. Due to the slope of the land, structures in hilly terrain have unique structural configurations that use varying foundation levels. The asymmetry and irregularity of the building's vertical and horizontal directions provides a noticeable dynamic feature in the shape of the structure on the slope.

On sloping terrain, set-back, step-back, and step-back set-back buildings are the most common building configurations to be seen. In current research work, step-back set-back building are used alongside flat-slab buildings with drop-panel and perimetric beams on sloping land with different gradients. The drop panels are provided to prevent punching shear failure and perimetric beams are provided to reduce the displacement. The different models of G+9 storey building that are considered in the present study are as follows; model M1-structure resting on 0° slope, 2) Model M2-structure resting on 15° slope, 3) Model M3-structure resting on 30° slope in seismic zone V. The building models and characteristics as such storey shear, storey displacement, storey drift, storey stiffness and torsional irregularity are examined while doing the static, dynamic, and time history analysis. In the present study, the storey displacement is found maximum for model M1 and with the increase in slope the storey displacement gets reduced. The storey drift ratio is found more in model M1 and with the increase in slope, the drift decrease. The storey shear is more prevalent in model M1 when compared to other two models. Also there is an irregular variation in storey shear for models M2 and M3. During the design inspection, the short-column effect is observed in columns with restricted height owing to the slope of the ground. The torsional irregularity in all the building models is found to be within safe permissible limits as per IS-1893 2016. The tabular findings and a graphical comparison of the results are provided.

Keywords: Irregular construction • Step-back setback • Stiffness • Torsional irregularity • Slope

Introduction

The scarcity of flat ground in Sloped country has led to construction of building on slopes. Due to the slope of the land, structures in hilly terrain have unique structural designs that use varying foundation levels. The asymmetry and irregularity of the building's in vertical and horizontal directions provide a noticeable dynamic feature in the shape of the structure on slope.

Slant incline buildings have column heights that vary within of a comparable storey, which creates significant variation in the stiffness of columns in that storey. The stiffer short columns of the extreme side along with being prone to damage draw higher lateral stresses. This blend of mass and stiffness in terms of both the vertical and horizontal planes results in the unequal Centre of Mass and Centre of Stiffness in each storey. Most of these constructions are subjected to torsion, which is to say, lateral stresses have a twisting effect. The structure's overall behavior during a seismic earthquake depends on many factors including stiffness, lateral strength, and design of the structure. A common structural design is used in the structures on a sloping ground. Following this, the floor in the building steps back from the slope, resulting in uneven column heights on one level. The unevenness in stiffness in both directions creates a lack of uniformity.

Other than stiffness irregularity, buildings in slope slant with the symmetric arrangement when subjected to seismic tremor in a cross-slant direction are exposed to torsion because the centers of stiffness and mass do not coincide at each floor level. This torsion is more complicated than the structure on the level ground. Building in hill slope with the symmetric arrangement, when exposed to seismic forces along the slope direction are not exposed to torsion, however, the shorter columns on the uphill side of a story draw more lateral forces, that are usually greater and may lead to shear failure.

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Methodology

Flat-slabs

Given that it is a two-way reinforced concrete slab, the flat-slab rests directly on supporting concrete columns. Furthermore, since beams and girders are often not provided in flat-floor slabs, the supporting concrete columns directly carry the load imposed by the flat-slab slab. Drop-panels and capitals are occasionally used in flat slab structures to further improve the performance and look of the columns by wrapping them around them and placing them at the highest point of the columns (Figure 1).

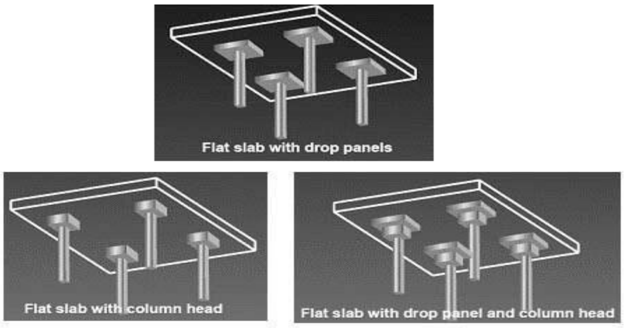

Figure 1. Preoperative computed tomography scan showing large hydatid cysts of the liver and massive splenomegaly.

The punching shear failure which is common in the flat-slab structures can be prevented by the following three methods:

- By incorporating a drop-panel with column-capitals into a flat-slab design.
- By including a drop-panel in a flat-slab that does not include column-capitals.
- By incorporating a column-capital into a flat-slab without the need of a drop-panel.

Advantages of column-heads in the flat-slab structure

- By providing column-heads in flat-slab structures, it increases shear strength.
- By providing Column-heads, it reduces the span (clear or effective) between the two floors, which results in reducing the moment in the flat-slab floor.

Advantages of drop-panels in the flat-slab structure

- A flat-slab floor may benefit from drop panels since they increase the shear strength of the flat-slab floor.
- The addition of drop panels increases the negative moment capacity of the flat slab floor.
- Drop panels help to decrease deflection by stiffening the flat slabs, which helps to reduce deflection.

Behavior of flat-slab structure in seismic zones: The Flat slab systems are being extensively used for multistory structures owing to their many advantages, including greater clear height, easy construction, cheap cost, and a building's height being low. Although, being favored and having many benefits, the enactment of flat-slab structures under seismic tremors is hesitant.

Flat-slab buildings being very pliable go through large deflection, under lateral load induced by the earthquake. The ductility of the flat-slab structures is lessened due the brittle mode of failure which is caused by the punching shear and is too often found in these structures. The unexpected building collapses were observed in the flat-slab buildings in previous earthquakes due to punching shear failure.

Birajdar et al. studied the seismic response of three different configurations of buildings situated on sloping ground and found that stepback setback buildings were more suitable on sloping ground [1,2].

Derived the fragility curves and flat slab buildings with masonry infill walls exhibit fragility curves. The curve results were then compared to the curve results for moment resistant frames after the study was completed. The study assumed that flat-slab buildings suffer tremors in a proportionate amount compared to moment resistant frames. However, there are obvious differences. It was found that the differentiations were acceptable, in terms of the structure's response characteristics. Focused on the alterations that were done within flat-slab system i.e., by providing perimetric beams in the building and/or RC walls [3]. The behavior of flat-slab system can be improved by using extra construction elements. It can improve the bearing capacity of the flat-slab system and the same time can induce strength and stiffness, therefore, improving the seismic conduct of the flat-slab system. Halkude et al. performed Response Spectrum Analysis (RSA) on two types of building frames namely step back frames and stepback and setback building frames on sloping ground [4]. They found that step back and set back building frames were more suitable on sloping ground in comparison with step back frames. Suresh G performed dynamic analysis on the step-back, step-back set-back building with and without bracing sitting on the inclining ground of 270 degrees with horizontal ground was examined next to a structure with ground level ranging from 8 to 10 storeys [5]. A significant amount of base shear and time period was found in the non-braced structures when collated with the step-back and set-back frames. As step back buildings are constructed without bracing, there is a rise in top storey displacement. In addition, the time to accomplish this construction is longer, and thus they determined that step back buildings should not be used on sloping terrain. Kalsulkar et al. carried out response spectrum method of analysis on the step back frames and step back–set back frames on the sloping ground with varying number of bays [6].

They found that step back setback frames were less vulnerable than step back frames and greater number of bays was better under seismic conditions.

Ghosh et al. investigated the deficiency of soft storeyed structure in both linear static and linear dynamic method [7]. They recommended the use of shear walls in the soft storey to mitigate its failure by increasing its stiffness and controlling its displacement and drift excellently. Ghosh et al. studied the seismic vulnerability of soft-storeyed structures with plan irregularity, and to mitigate the structural failure, a solution was proposed by them [8]. Arjun et al. studied the behaviour of G+3 storied sloped frame building having step back–set back configuration for sinusoidal ground motion with different slope angles by performing response spectrum analysis [9]. They observed that short column was affected more during the earthquake. Thombre et al. made comparison between sloping ground, with different slope and plain ground buildings in response spectrum method as per IS 1893–2000 [10]. They found that, on sloping ground, the displacement of building showed the same behavior as of regular building but displacement's value reduced with the increment of slopes due to curtailment of column.

Details of building and modeling of structure: A commercial step-back set-back building resting on plain and sloping ground has been analyzed. The building is symmetric in plan and elevation up to the third storey on plain ground, but setback is located in the fourth and fifth floors. The building becomes highly unsymmetrical, when it is considered on 45° sloping ground of a hill.

Seismic design data are as follows: Zone (v), Zone factor (Z): 0.36, soil type: Hard soil, damping ratio: 5%, frame type: Special Moment-Resisting Frame (SMRF), Response reduction factor (R): 5, and importance factor (I):1.

Material properties are as follows: Unit weight of concrete: 25 kN/m^3, Unit weight of light-weight brick wall: 11 kN/m^3, characteristic strength of concrete: 20 MPa (for beams and slabs), 40 MPa (for columns) characteristic strength of steel: 500 MPa.

Details of structural elements are as follows: Beam: 300 x 750 mm, column: 800 x 800 mm, slab thickness: a) with drop panel 250 mm b) Normal slab 150 mm, Wall height: 3.2 m, wall thickness: 200 mm parapet height: 1 m, parapet wall thickness: 200 mm.

The types of load considered during the design are dead loads of beams, columns, slab, wall weight (WL), live load of 3 at floors and 1.5 kN/m^2 at roof, floor finish of 2.5 kN/m^2 mass source (1DL+1SDL+.25LL).

The model under consideration in this research is made up of beams, columns, and shell components (Flat-slab) shell elements with four nodes are used to model the floor. Each node has six degrees of freedom, which are three rotations along mutually perpendicular axes and three translations along mutually perpendicular axes. It is necessary to employ a stiff junction to link all of the structural components together. The imposed loads are distributed evenly over the floor surface. Even though no modeling of the infill walls is done, their load is directly applied to the beams in order to get correct results.

The (G+9) plan is used in the current research as a model. It has 7 bays of 8 m in the y-direction and 8 bays of 8 m in the y-direction. The average storey height is 3.2 meters. The models are created and analyzed in integrated building design software E-TABS software version 17.0.1.

Models analyzed

The model is made up of a G+9 structure having step-back set-back configuration. Three different models have been proposed on sloped ground with angle varying between 0°, 15°, and 30°. Every building is equipped with a flat-slab floor system in which column drop panel has been provided.

Considering the slope of the terrain and the building with flat-slab+drop panels, there are three distinct case scenarios to take into consideration.

Model 1 (M1): Step-back setback building model resting on 0° slope with flat-slab having drop panel (Figure 2).

Model 2 (M2): Step-back setback building model resting on 15° slope with flat-slab having drop panel (Figure 3).

Model 3 (M3): Step-back setback building model resting on 30° slope with flat-slab having drop panel (Figure 4).

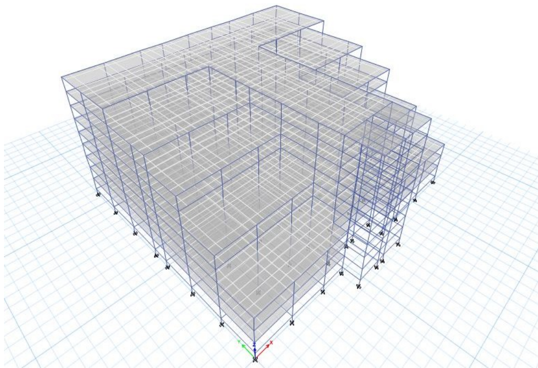

Figure 2. Model M1: Building resting on 0° slope (3D view).

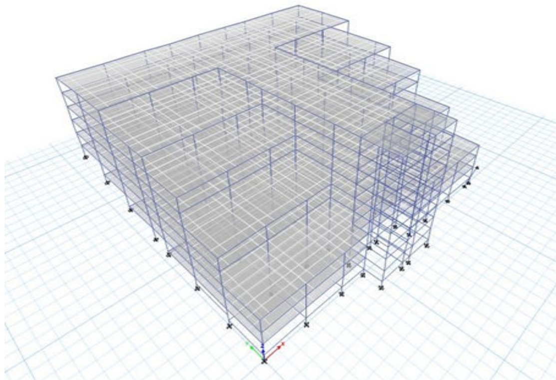

Figure 3. Model M2: Building resting on 15° slope (3D view).

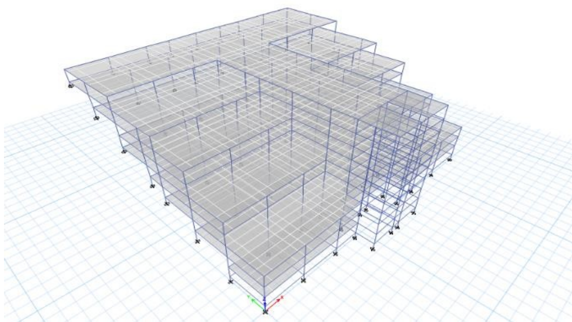

Figure 4. Model M3: Building resting on 30° slope (3D view).

Analysis methods: In this paper, all the models are analyzed both in linear static method which is known as Equivalent Static Force Method (ESFM) and linear dynamic method which is Response Spectrum Method (RSM) and Time History Method (THM). ESFM analysis and RSM analysis are done and results are compared to study the seismic behavior of the structures.

In modal analyses, mode shapes are generally obtained in normalized form, and thus, the results of response spectrum method need to be properly scaled. In the present study, the scaling has been done by equating the base shear obtained from ESFM to that obtained from RSM. Time history analysis is done using real earthquake data of Imperial Valley earthquake.

Results and Discussion

The bare frame models having step-back set-back configurations on 0°, 15°, and 30° slope ground are compared to study the basic difference between these structures. Also, the effect due to the variation in slope is studied. The results of the above-mentioned study for all building models are expressed as base shear, storey displacement, storey drift, storey stiffness, and storey shear, torsional irregularity.

Results from modal analysis

The modal time period of each of the building models is shown in Figure 5. Compared to the models M2 and M3, which are resting on 15° and 30° slopes, the natural time period is discovered in higher in the model M1, which is resting on 0° slope. As a result, the natural time period of the models reduces as the slope increases. With an increase in model time period, the natural frequency of the models decreases in proportion to the time period. The modal mass participation ratio of 90 percent for all models while maintaining the number of modes at twelve (12). Time period for all models decreases somewhat up to the third mode, but beyond the third mode, time period decreases and becomes nearly constant.

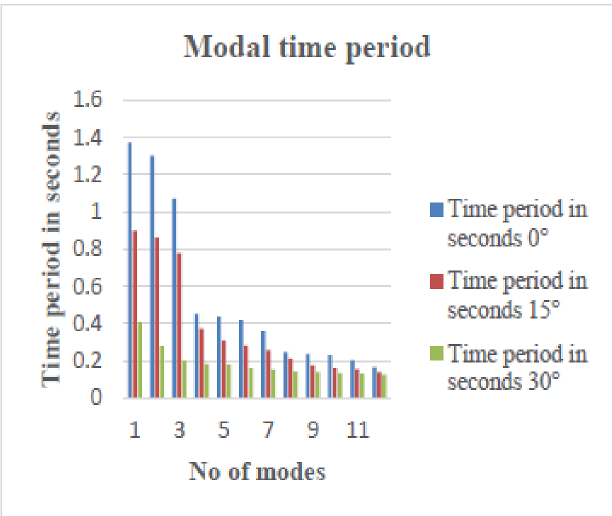

Figure 5. Modal time period for all building models.

Note: ( ) Time period in seconds 0°, ( ) Time period in seconds 15°, ( ) Time period in seconds 30°.

Results from linear static and linear dynamic analysis

Storey displacement: Storey displacement, also known as lateral displacement of the storey relative to the base, is a kind of structural displacement that occurs between two storeys. It is the displacement in the lateral direction caused by seismic load acting in the lateral direction on a structure.

Figures 6 and 7, shows the results of the storey displacement for all of the set-back step-back models in the direction of the applied forces. Since storey displacement is directly proportional to the height of the building, as the height of the building rises, so does the displacement of the stories inside the structure on the same level. The storey displacement is determined to be greatest at the top of all building models and to be least at the bottom of all building models for all building models.

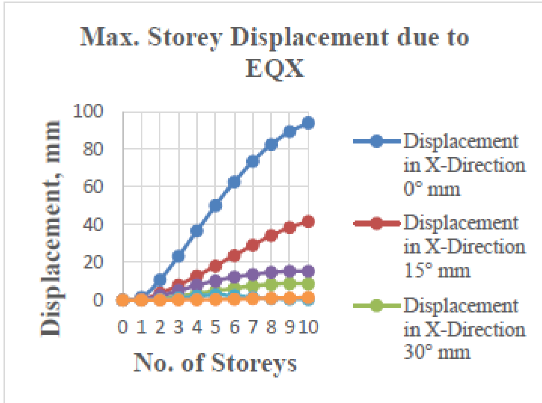

Figure 6. Max storey displacement for all three models due to EQX.

Note: ( ) Displacement in X-Direction 0° mm, ( ) Displacement in X-Direction 15° mm, ( ) Displacement in X-Direction 30° mm.

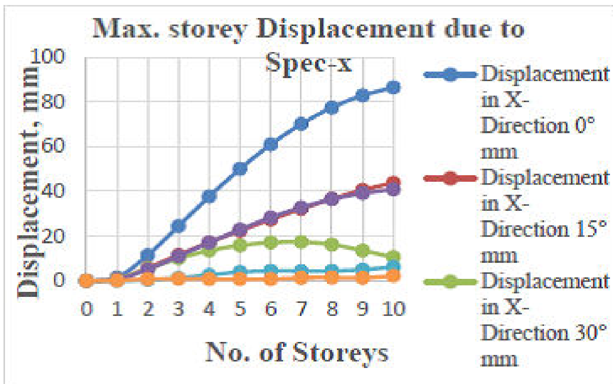

Figure 7. Storey displacement for all models in X and Y direction due to SPEC-X.

Note: ( ) Displacement in X-Direction 0° mm, ( ) Displacement in X-Direction 15° mm, ( ) Displacement in X-Direction 30° mm.

The storey displacement is more in direction of force. With all models, bidirectional displacement (X and Y) was seen for unidirectional force (X-direction), with the x-direction being detected more often than the y-direction in all cases. The storey displacement from both the linear static and linear dynamic analysis is found to be maximum for the model M1 resting on 0° slope. As the slope increases the storey displacement decreases and is found least for the building model M3 resting on 30° slope from both the analysis. For storey

10, there is approximately 56% decrease in the storey displacement for model M2 and 91% for model M3 corresponding to the model M1 due to linear static analysis and from linear dynamic analysis, For storey 10, there is an approximately 49 percent reduction in storey displacement for model M2 and an 87 percent decrease in storey displacement for model M3 as compared to the case of model M1. This happens because as the slope increases, it increases the fixity for the building at different heights and as the fixity is increased, the stiffness of the building increases resulting in decrease in storey displacement of the building models.

Storey drift ratio: Specifically, storey drift is the lateral displacement of a floor in relation to either the level above or below it. The storey drift ratio is calculated by dividing the storey drift by the height of the storey.

The storey drift ratio from both the linear static and dynamic analysis is shown in Figures 8 and 9. The storey drift is more in x-direction due to eqx than in y-direction. The storey drift is found more in the model M1 resting on 0° slope as compared to other two models model M2 and M3 resting on 15° and 30° slope respectively. Therefore, with the increase in slope, the drift gets reduced and is mainly because the mass participation is less resulting in less storey drift.

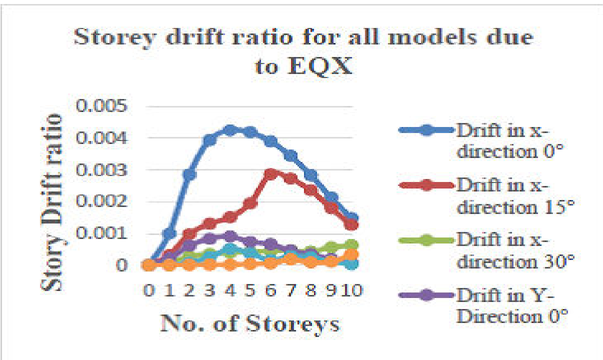

Figure 8. Max storey drift ratio for all three models due to EQX.

Note: ( ) Drift in X-Direction 0°, ( ) Drift in X-Direction 15°, ( ) Drift in X-Direction 30°, ( ) Drift in Y-Direction 0°.

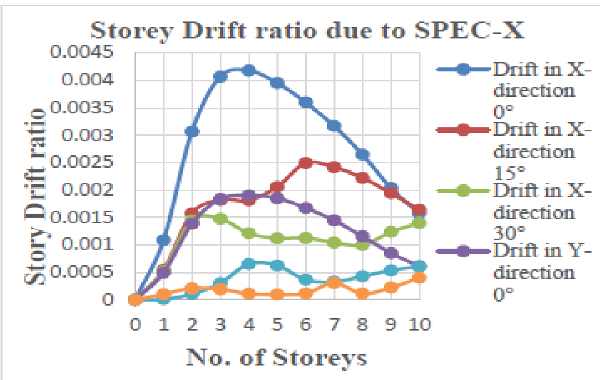

Figure 9. Storey drift ratio for all models in X and Y direction due to SPEC-X.

Note: ( ) Drift in X-Direction 0°, ( ) Drift in X-Direction 15°, ( ) Drift in X-Direction 30°, ( ) Drift in Y-Direction 0°.

From both the linear static and linear dynamic analysis, for the model M1 resting on 0° slope, the storey drift is found to be least at the bottom and is found maximum at storey 4, after storey 4, drift again decreases. For the model M2 resting on 15° slope, the storey drift is maximum at 6th storey and after 6th it decreases again and for model M3 resting on 30° slope, the storey drift is maximum at the terrace level. The same is the case with linear dynamic analysis but storey drift ratio values are lesser as compared to linear static analysis.

Storey shear: The lateral force owing to external forces such as earthquakes and wind forces acting on each level and is computed for each storey separately. The storey shear from both the linear static and dynamic analysis is shown in Figures 10 and 11. From both the linear static and linear dynamic analysis, the story shear in the direction of force is found to be more for the model M1 resting on 0° slope, as compared to other two models. Therefore, as the slope increases, the storey shear values gets reduced and least values are observed for model M3 resting on 30° slope. From both the analysis, considering model M1, the storey shear is maximum at the storey 1 and is least at the terrace level but for other two models i.e. for 15° and 30° model, the storey shear is found maximum at storey 6^{th} and at storey 10^{th} i.e., where the slope of the models ends and below these stories, the storey shear gets reduced and that is mainly due short height of columns. The storey shear values from linear dynamic analysis are slightly lesser when compared to static analysis. For maximum value of storey shear across the slope, there is 26% decrease in storey shear for model M2 and 86% decreases for model M3 corresponding to the model M1 from static analysis and from dynamic analysis, Model M2 has a 31 percent reduction in storey shear across the slope, while model M3 has an 86 percent decrease in storey shear across the slope, compared to model M1.

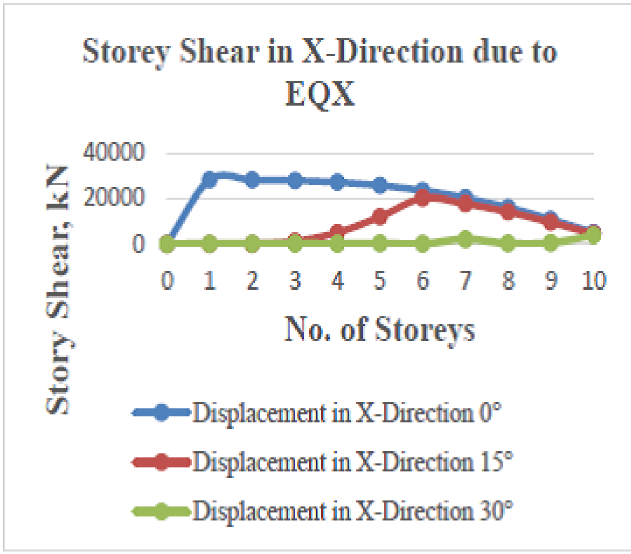

Figure 10. Storey Shear in X-Direction due to EQX.

Note: ( ) Displacement in X-Direction 0°, ( ) Displacement in X-Direction 15°, ( ) Displacement in X-Direction 30°.

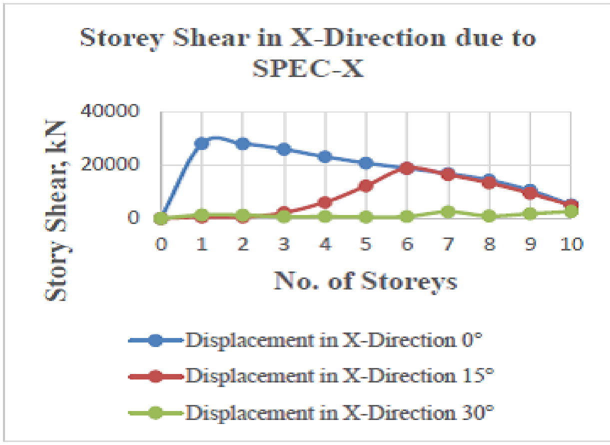

Figure 11. Storey Shear in X-Direction due to SPEC-X.

Note: ( ) Displacement in X-Direction 0°, ( ) Displacement in X-Direction 15°, ( ) Displacement in X-Direction 30°.

Storey stiffness: The storey stiffness of a storey is usually described as the ratio of the storey shear and the storey drift. The storey stiffness from both the linear static and dynamic analysis is shown in Figures 12 and 13. From both the linear static and linear dynamic analysis, the story stiffness in the direction of force is found to be more for the model M1 resting on 0° slope, as compared to other two models and for models M2 and M3 resting on 15° and 30° slope, storey stiffness values are lesser as compared to the building model M1 resting on 0° slope, this is mainly due the increase in slope and short column effect. From linear static analysis, For maximum value of storey stiffness across the slope, there is 88% decrease in storey stiffness for model M2 and 85% decreases for model M3 corresponding to the model M1. And from linear dynamic analysis, For maximum value of storey stiffness across the slope, there is 8% decrease in storey stiffness for model M2 and 5% decreases for model M3 corresponding to the model M1.

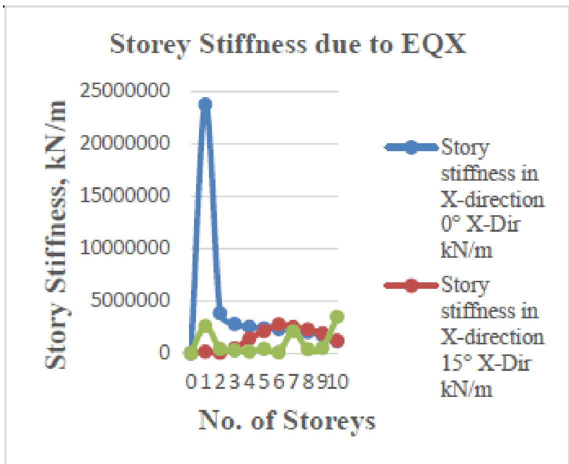

Figure 12. Storey stiffness for all models in X-direction due to EQX.

Note: ( ) Story stiffness in X-Direction 0° X-Dir kN/m, ( ) Story stiffness in X-Direction 15° X-Dir kN/m.

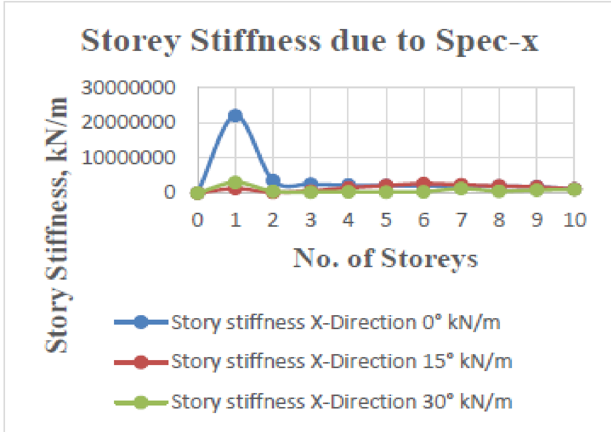

Figure 13. Storey Stiffness for all models in X-direction due to SPEC-X.

Note: ( ) Story stiffness X-Direction 0° kN/m, ( ) Story stiffness X-Direction 15° kN/m, ( ) Story stiffness X-Direction 30° kN/m.

Base shear: Base shear results are shown in Figures 14 and 15. The linear static analysis shows that the base shear is maximum in the model M1 resting on 0° slope as compared to the two models and is least for the model M3 resting on 30°slope. Therefore, with the increases in slope base shear gets reduced. This is mainly due to less participation of mass. Base shear data obtained *via* response spectrum analysis are in both the x and y directions are matched with the base shear obtained from linear static analysis. Base shear in the case of response spectrum analysis increases with the increases in the slope, this happens because base shear, which is dependent on the mass and stiffness of the structure, is a component of spectral acceleration and time period. Because of increasing spectral acceleration and reduced time period with the increase in the slope, the base shear of the structural models increases when the slope is raised. Because of response spectrum analysis, the equivalent is visible in the y-heading.

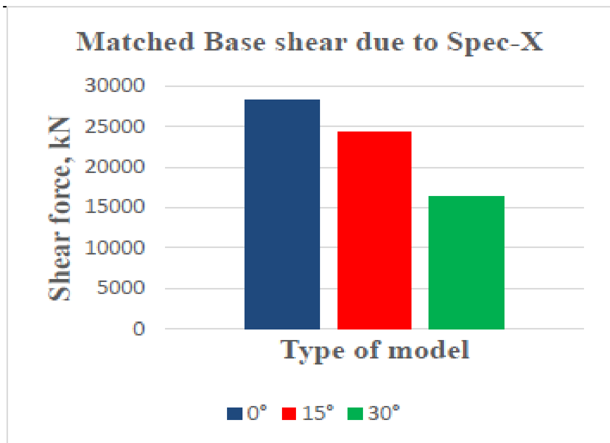

Figure 14. Matched Base shear from response spectrum analysis in x-direction.

Note: ( ) 0°, ( ) 15°, ( ) 30°.

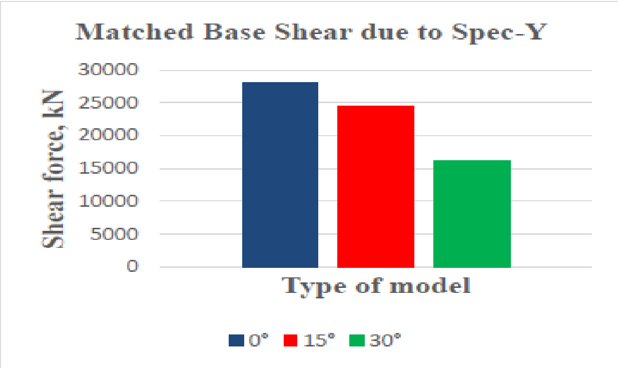

Figure 15. Matched Base shear from response spectrum analysis in y-direction.

Note: ( ) 0°, ( ) 15°, ( ) 30°.

Results from time history analysis: Time history analysis is done using real earthquake data of Imperial Valley earthquake. Time history results are shown in Figures 16-18.

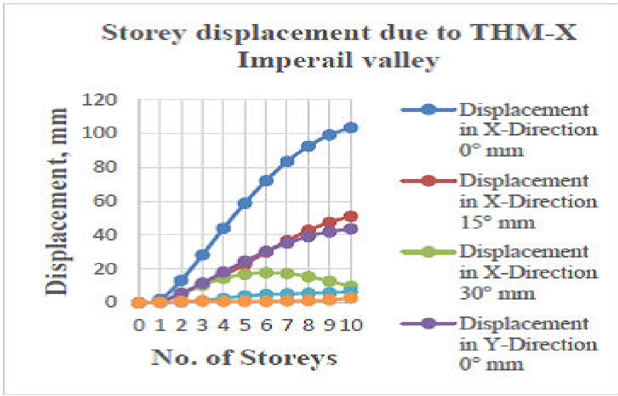

Figure 16. Storey displacement due to THMX-Imperial valley.

Note: ( ) Displacement in X-Direction 0° mm, ( ) Displacement in X-Direction 15° mm, ( ) Displacement in X-Direction 30° mm, ( ) Displacement in Y-Direction 0° mm.

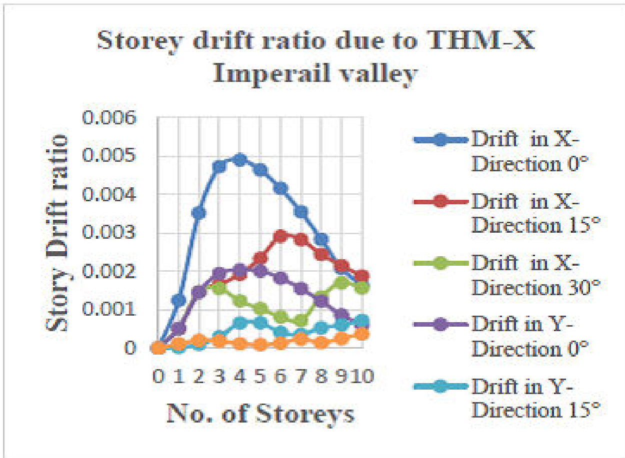

Figure 17. Storey drift ratio due to THMX-Imperial valley.

Note: ( ) Drift in X-Direction 0°, ( ) Drift in X-Direction 15°, ( ) Drift in X-Direction 30°, ( ) Drift in Y-Direction 0°, ( ) Drift in Y-Direction 15°.

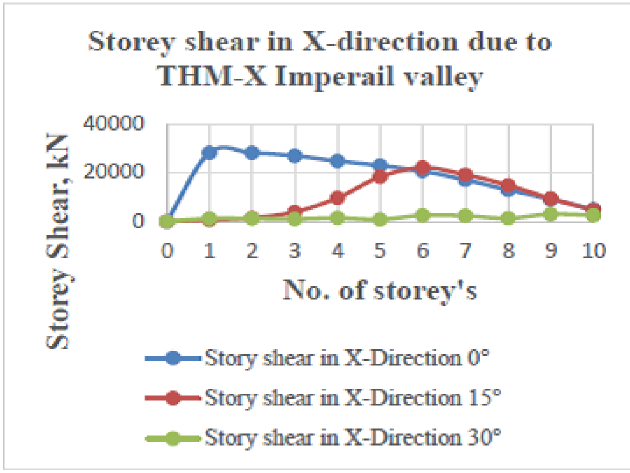

Figure 18. Storey Shear in X-direction due to THM-X Imperial Valley.

Note: ( ) Story shear in X-Direction 0°, ( ) Story shear in X-Direction 15°, ( ) Story shear in X-Direction 30°.

The displacement in the direction of the force (X-direction) was found to be the greatest for model M1, and the displacement values for models M2 and M3 decrease as the slope angle increases. As the maximum value of storey displacement across the slope is reached, the storey displacement for model M2 drops by 50% and the storey displacement for model M3 decreases by 90% when compared to the model M1.

The drift in the direction of force(X-direction) was found maximum for model M1 when compared to models M2 and M3.The model M1 showed maximum drift at 3rd storey and after 3rd storey drift got reduced again. The model M2 showed maximum drift at 5th storey and model M3 showed irregular pattern and drift was maximum at 8th storey for model M3. In minor direction(Y-direction), less drift values were obtained.

The storey shear in the direction of force(X-direction) was found more for the model M1 resting on 0° slope as compared to other two models. Therefore, as the slope increases, the storey shear values gets reduced and least values were observed for model M3 resting on 30° slopes. For model M1, the storey shear is maximum at the ground floor and is least at the terrace level but for other two models M2 and M3, the storey shear is found maximum at storey six and at top storey i.e., where the slope of the models ends and below these stories, the storey shear gets reduced and that is mainly due short height of columns. For maximum value of storey shear across the slope, there is 21% decrease.

Torsional irregularity: According to IS-1893 2016, the torsional irregular buildings are those in which;

- Max horizontal displacement of one end of any floor in the direction of lateral force>1.5x times min horizontal displacement at far end of same floor. If it is in the Range of 1.5-2.0- Building configuration shall be revised.
- Natural period is corresponding to fundamental torsional mode of oscillation> than those 1st 2 translational modes along each principal directions.

- Range 1.5-2.0- Building configuration shall be revised to ensure natural period less than 1st two translational modes.
- 1.5-2.0 then 3D-Dynamic-analysis method shall be adopted.
- >2.0- Building configuration shall be revised.

In the present study, for all the building models, the max. Horizontal displacement at one end of top floor in the direction of lateral forces is found to be less than 1.5 times the min. horizontal displacement at the far end of the same floor and also the natural time period corresponding to fundamental torsional mode of oscillation is found to be less than torsional modes along each principal directions, therefore, it can be concluded that all the building do not exhibit torsional irregularity and are found with safe limits as per IS-1893 2016.

Conclusion

The findings are obtained by conducting linear static, linear dynamic, and linear time history analysis on factors such as base shear, storey displacement, strorey drift ratio, storey shear, and storey stiffness and torsional irregularity for model M1 resting on 0° slope, model M2 resting on 15° slope and model M3 resting on 30° slope.

- From the modal analysis, it is found that the modal time period is higher in model M1 when compared to the models M2 and M3. Therefore, with the increases in the slope, the modal time period decreases. Also, from the modal analysis, the modal mass participation ratio of 90 percent is achieved for all models while maintaining the number of modes at twelve (12).
- From linear static analysis, the base shear is greatest for the model M1 sitting on the 0° slope, and as the slope increases, the base shear decreases.
- The greatest storey displacement is observed for the model M1 at the top storey and decreases as the slope rises in all three analysis conducted.
- It is observed the storey drift ratio is more in the model M1 resting on 0° slope, and as the slope increases, the drift decreases, owing to less mass involvement and it shows irregular variation of drift ratio.
- The storey shear is more prevalent in model M1 and is greatest at the bottom storey when compared to other two models Also there is an irregular variation.
- The storey stiffness for model M1 was found to be more and greater at the bottom level and less at the top, while the storey stiffness for models M2 and M3 exhibited an uneven pattern.
- During the design inspection, the short-column effect is observed in columns with restricted height owing to the slope of the ground, and these columns that exhibited the short-column effect may be built as pedestal columns.
- The maximum shear force and bending moment in short columns for model M2 is for found for column having height 0.7194 m and is 1616.5971 kN and 1305.1121 kN-m respectively.
- The maximum shear force and bending moment in short columns for model M3 is for found for column having height 0.8723 m and is 1105.2201 kN and 908.5425 kN-m respectively.
- The torsional irregularity of all the building models has been checked and is found within safe permissible limits as per IS-1893 2016.

Future Scope of the Study

- Wind analysis can be performed on the step-back set-back buildings.
- The seismic analysis can be done using a mass tuned damper to reduce storey- acceleration, storey-displacement and shear of the buildings, if mentioned seismic parameters are not within permissible limit.
- The short-columns can be designed as pedestal columns to prevent short-column effect.
- The modifications can be done to the structure by providing additional structural elements i.e., using bracings, shear wall to improve the bearing capacity of the structure.

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