International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 09 Issue: 12 | Dec 2022 www.irjet.net p-ISSN: 2395-0072

SEISMIC ANALYSIS OF STRUCTURE ON SLOPED GROUND CONSTRUCTED WITH ANGLE DIAGRID AND BRACINGS USING ETABS SOFTWARE

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Abstract - *A building that is situated on a hilly slope region differs significantly from buildings that are situated on flat surfaces. Buildings located in hilly areas are significantly more susceptible to seismic activity. When subjected to seismic forces, buildings built on hill slopes develop torsional moments in addition to lateral forces because of the different column lengths that cause mass and stiffness to vary along different floors. This study examines the seismic behaviour of step-back buildings in seismic zones II and III alongside conventional buildings. All of the models were created using finite element software, and the Response Spectrum method was used to analyse the data. In addition, the configurations' story displacement, story drift, and base shear at foundations were compared to the seismic parameters derived from the analysis. The seismic behaviour of buildings on hillsides was also contrasted with that of conventional buildings. Finally, the configurations' suitability and vulnerability to seismic loads were discussed.*

1.INTRODUCTION

Construction on a slope has its unique characteristics and challenges, but it provides admirable advantages once finished. This same views, landscape design, better lighting, isolation, and space will be appreciated by the owner. The above tries to explain why many of the worlds largest most prestigious homes are built on slopes. Even so, it necessitates complicated foundation systems, which add to construction time and cost. It is frequently more expensive than building an entire residence on level terrain. More concrete, depth excavation via specialized excavation or blasting, retaining walls or terraces, and specialized drains and sewage system remedies are needed to ensure that the residence seems to be up to standards and secure to repopulate.

Earthquake analysis is a component of analysis of structures as well as the computation of a building's reaction to seismic events. It is used in the building system, assessment, and retrofitting processes in earthquake regions.

Early seismic designs did not place much emphasis on bridges, but as time has gone on, it has become clear that in seismically active areas, seismic design can be the deciding factor.

Fig -1: Building on Sloping Ground

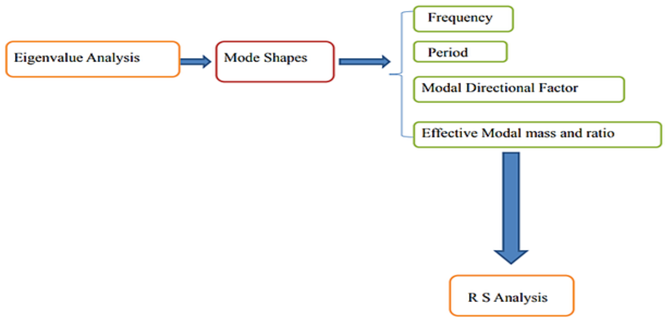


Fig -2: Process of Response Spectrum Analysis

1.1 Bracings

For buildings that are subject to lateral forces from earthquakes, wind, etc., bracing systems are required. They aid in reducing the building's lateral displacement. You can say that bracing system supports the lateral loads while the beams and columns of the frame building support the vertical loads.

1.2 Diagrids

These days, it's popular to design high-rise buildings using diagrid structures. This method was used by many notable towers all over the world, which further contributed to their distinctive shape and design.

A framework made of beams that intersect diagonally is known as a diagrid (diagonal grid). These beams, which can be made of metal, wood, or concrete, were employed in the design of tall buildings as well as roofs.

2.LITERATURE REVIEW

Anjeet Singh Chauhan, Rajiv Banerjee are carried out work on 'Seismic Response of Irregular Building on Sloping Ground' irregularities are one of the key reasons why the construction failed, according to the research they did on it. structural frames with a variety of irregularities, such as torsional irregularity, diaphragm irregularity, mass irregularity, and vertical irregularity. Additionally, dynamic analysis must be performed to ascertain the building's maximum dynamic response in order to properly analyse this kind of structure. Response Spectrum Analysis is a viable option because obtaining the time history records for all the locations would be challenging. Here for study, a G+10 buildings with story height measuring 3.6metres in height and a horizontal angle of inclination of 20degrees, 30degrees, 40degrees, and 45degrees on the sloping ground is analysed by the Response Spectrum method in seismic zone V to make it easier for people to move around during an emergency. Its installation of machines and equipment that creates mass irregularity, as well as the ground up to the top of the story at the, will take place on the top two storeys. According to IS 1893:2016, Etabs software analyses and models Stepback buildings to compare them based on their nonlinear dynamic traits, like modes, Base Shears, Storey deflection, Storey drifts, and Storey shears, it is possible to determine the frame's susceptibility to abnormalities inside the frame on the hillsides.

Prof.Tejaswini junghare , Ravikumar Yadav, Bhushan Rathod, Pawan Ranbawale are carried out work on 'Seismic Analysis on Irregular Structures on hill slopes behave differently from those resting on flat ground when it comes to seismic behaviour, and this requires a 3-D analysis of the structure. The structure's dynamic response to the slope of the hill has been investigated. The majority of studies acknowledge that buildings resting on hilly slopes experience more displacements and base shears compared to those laying flat.

Mr. Anuj Kumar Sharma, Mr. Amit Kumar are carried out work on 'Analysis of G+30 Highrise Buildings by Using Etabs for Various Frame Sections in Zone IV And Zone V' in period of times they studied, earthquakes are known to have caused disasters. Buildings are becoming shorter and much more prone to sway in modern society, which makes them hazardous during an earthquake. In the past, engineers and scientists came up with strategies to increase the earthquake resistance of buildings. The application of lateral force resisting strategies inside the building shape has been found to greatly improve the structure's ability to withstand in earthquake by ETABS 9.7.4, according to a number of real-world investigations. Shear walls and bracing have been used in the work for a variety of conditions, and the maximum height taken into consideration for the study's purposes is 93.5m. The modelling to examine how seismic characteristics, such as base shears, lateral displacement, and lateral drift, may change under given circumstances and at specific heights is complete. The knowledge gained has been applied to Zone 4 and Zone 5 in Soil Type II, as described in IS 1893-2002. (medium soils).

M. Hasan, N. H. M. K. Serker are carried out work on 'Seismic Analysis of RC Buildings Resting on Sloping Ground with Varying Hill Slopes' idealisation of structure geometry and the loading system on the structure determine the analysis of the structure that was studied. The appearance of irregularities in the structure shatters general behaviour. In mountainous places, you can typically find step-back and step-set-back structural frames with some abnormalities. The earthquake reactions of step-back & step-back-set-back frameworks which are maintained upon sloped ground are compared in this study. Using the response spectrum method, the ETABS system analyzes ten step back and ten step back-set back structure frames at slope angles of 0, 5, 10, 15, 20, 25, 30, 35, 40, and 45 degrees. Step back frames may function more well throughout earthquake action than other structure configurations because they create larger levels of base shears, top story displacements, and fundamental time periods than step back-set back frames. Step back-set back frames are therefore preferred.

3.OBJECTIVES

Numerous variables, such as the number of bays, the angle of the hill, the number of floors, etc., affect how a building frame responds to a sloped surface. The study considers two building configurations: the standard building and the step-back building.

1. Creation of 3D models for both flat and sloping buildings.

2. In seismic zones 2 and 3, a comparison between a normal building and a sloped building.

3. A comparison of various bracing types in step-back or sloped buildings in seismic zones 2 and 3.

4. Using response spectrum analysis, calculate the displacement, drifts, and shears of each storey in seismic zones 2 and 3.

5. To identify the most efficient type of bracing for sloped structures in seismic zones 2 and 3.

6. How well 63^0 diagrid performs in the sloped building in comparison to bracing in seismic zones 2 and 3.

4.METHODOLOGY

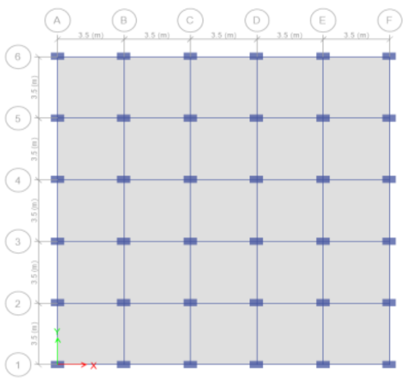
Table -1: Material Properties

Density of RCC	25kN/m^3
Density of Masonry	20kN/m^3
Compressive Strength,f_{ck}	35N/mm^2(Beam) 35N/mm^2(Column)
Steel,f_y	550N/mm^2& 500N/mm^2
Modulus of Elasticity,E_c	5000*(f_{ck})$^{0.5}$

Table -2: Data / Parameters for the Analysis

Each Storey Height	3.1m
Wall Thickness	300mm
Thickness of Slabs	150 mm
Size of Beams	300x600mm
Size of Columns	400x700mm
Building Frame System	Special RC Moment Resisting Frame
Parapet Height	750mm
Supports	Fixed
Building	24mx24m
Spacing in XandY direction	3.50m
Number of Storey	10
Bracing Section	ISMC350
Damping of Structure	5%

4.1 Layout of Buildings



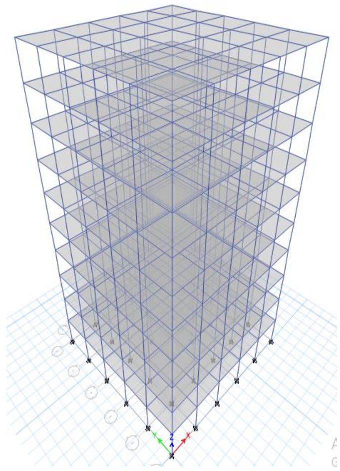
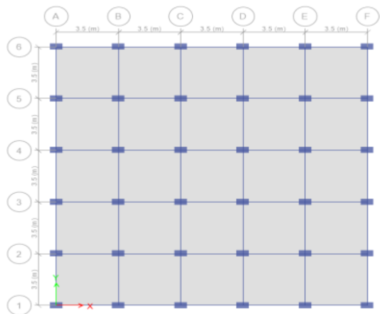


Fig -3: Plan and3D Model of Normal Building



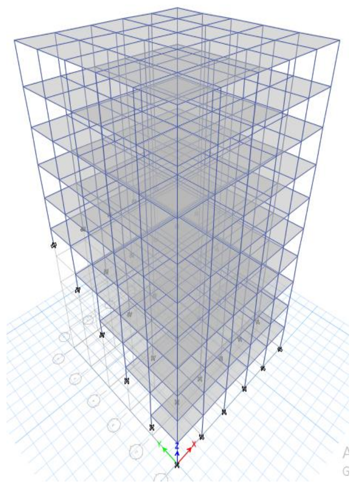
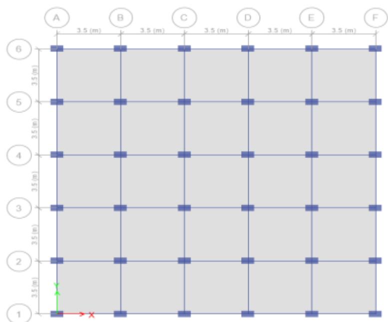


Fig -4: Plan and 3DModel of Sloped Building



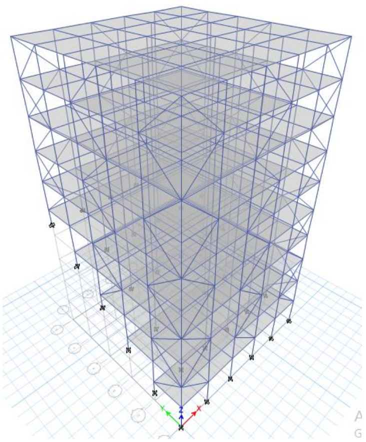
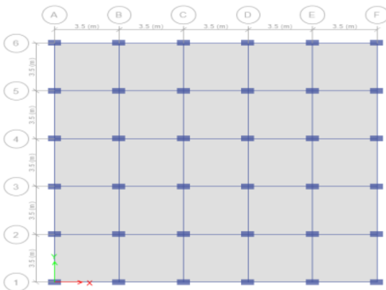


Fig -5: Plan and3D Model of Sloped Building with Diagonal Bracing



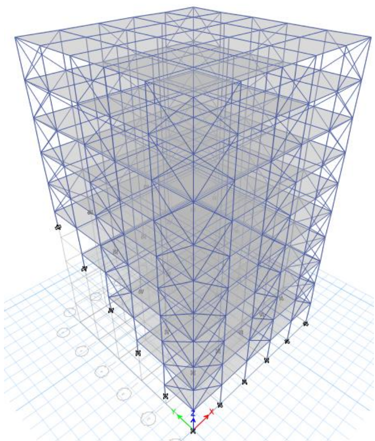
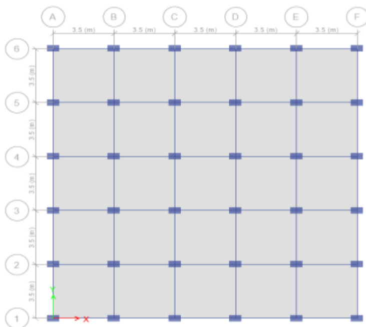


Fig -6: Plan and3D Model of Sloped Building with X Bracing



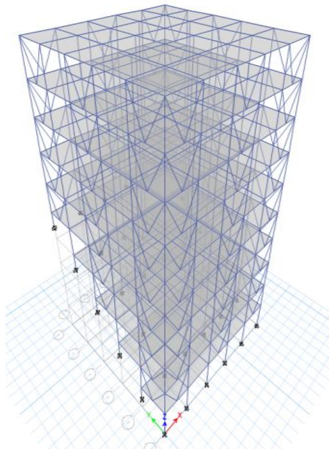
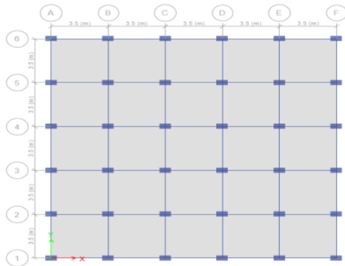


Fig -7: Plan and3D Model of Sloped Building with V Bracing



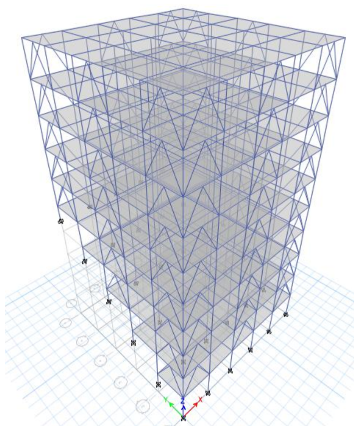
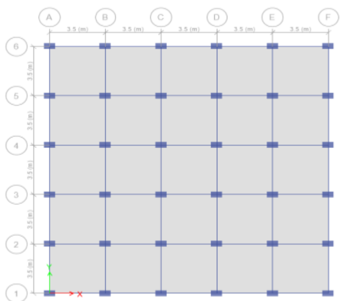


Fig -8: Plan and3D Model of Sloped Building with Inverted V Bracing



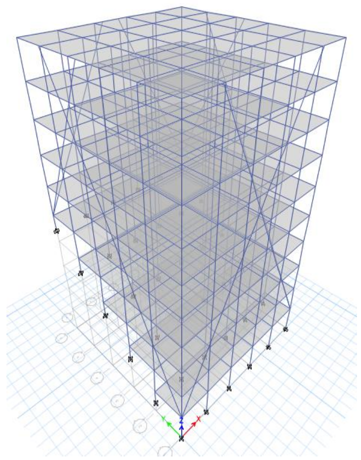


Fig -9: Plan and3D Model of Sloped Building with63⁰ Diagrid Bracing

5. RESULTS AND DISCUSSIONS

5.1 Comparison for Normal Building in Seismic Zones II & III

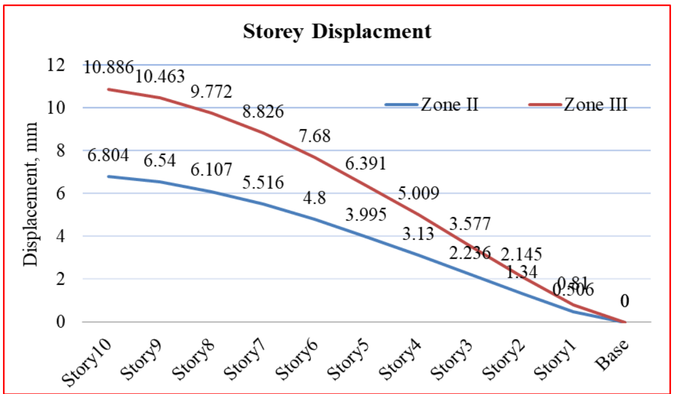


Chart -1: Storey Displacement for EQX Load

The displacement rises as the number of seismic zones increases, as can be seen in chart 1. When the top storey is taken into account, the displacement increases by about 37.50%.

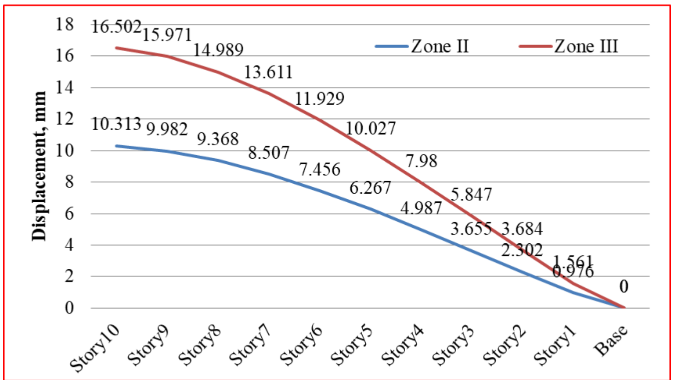


Chart -2: Storey Displacement for EQY Load

The displacement increases as the number of seismic zones increases, as can be seen in chart 2. When the top storey is taken into account, the displacement increases by about 37.50%.

The displacement increased by 37.50% for both the EQX and EQY loads, but the EQY load experienced the greatest displacement in seismic zones II and III.

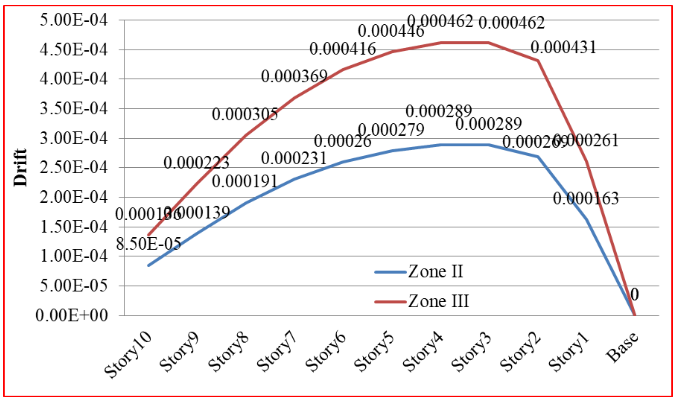


Chart -3: Storey Drift for EQX Load

According to chart 3, the storeys 3 and 4 experience the greatest drift when compared to the other storeys. When compared to seismic zone II, seismic zone III has maximum drift, which has increased by 37.44%.

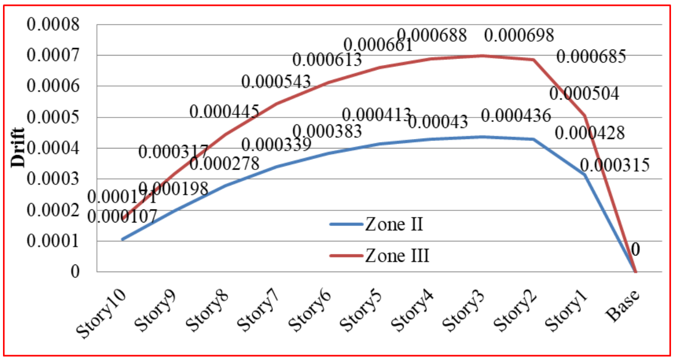


Chart -4: Storey Drift for EQY Load

As can be seen from chart 4, the storey with the greatest amount of drift is storey 3. When compared to seismic zone II, seismic zone III has a 37.53% increase in maximum drift.

Although there was a 37.53% increases in displacement and 37.44% increases in drift for the EQX loads, the EQY load experienced the greatest drift in seismic zones II and III. When compared to the other stories, story 3 is experiencing the most drift.

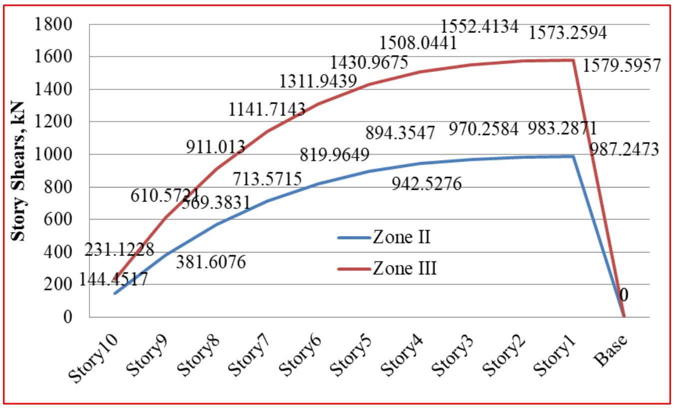


Chart -5: Storey Shears for EQX Load

Chart 5 demonstrates that, when compared to the other storeys, storey 1 experiences the greatest amount of story shear. When compared to seismic zone II, seismic zone III exhibits maximum shear, which has increased by 37.50%.

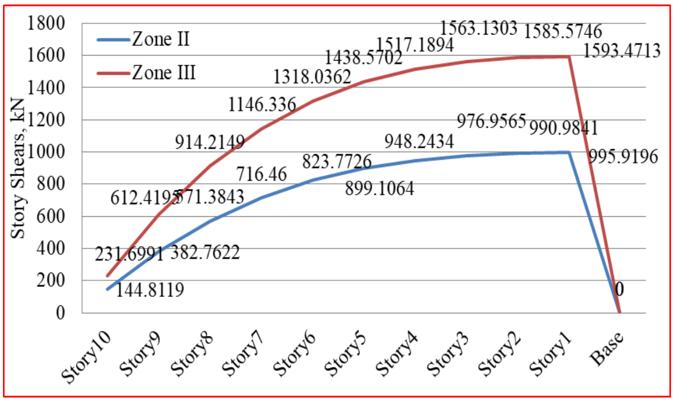


Chart -6: Storey Shears for EQY Load

Chart 6 demonstrates that, when compared to the other storeys, storey 1 experiences the greatest amount of story shear. When compared to seismic zone II, seismic zone III exhibits maximum shear, which has increased by 37.50%.

The shear for EQX and EQY loads increased by the same 37.50%, but EQY load shear was highest for seismic zones II and III. When compared to other stories, story 1 has the most shear

5.2 Comparison for Sloped Building in Seismic Zones II & III

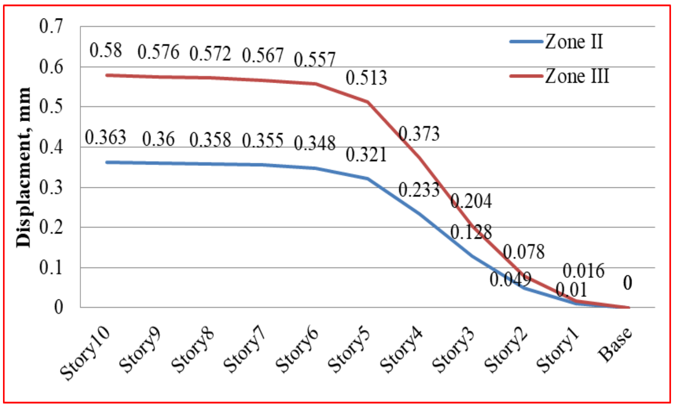


Chart -7: Storey Displacement for EQX Load

Figure 5.8 shows that as the seismic zones expand, there is an increase in displacement. When the top storey is taken into account, the displacement increases by about 37.41%.

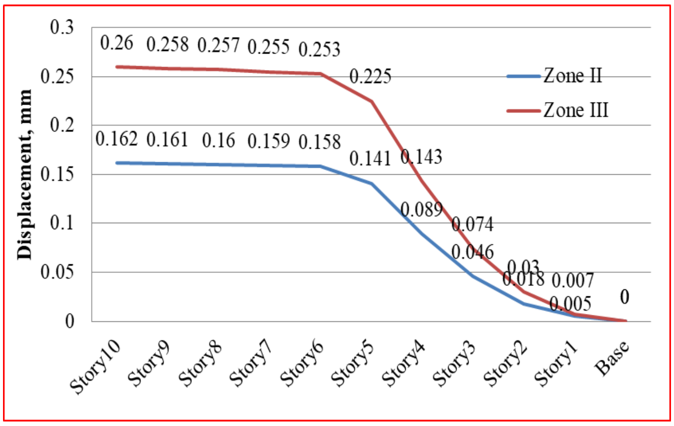


Chart -8: Storey Displacement for EQY Load

The displacement increases as the number of seismic zones increases, as can be seen in chart 8. When the top storey is taken into account, the displacement increases by about 37.70%.

The displacement for EQX load increased by 37.41%, while EQY load increased by 37.70%, but EQX load experienced the greatest displacement in seismic zones II and III. When compared to other stories, the displacement in story 1 is at its highest.

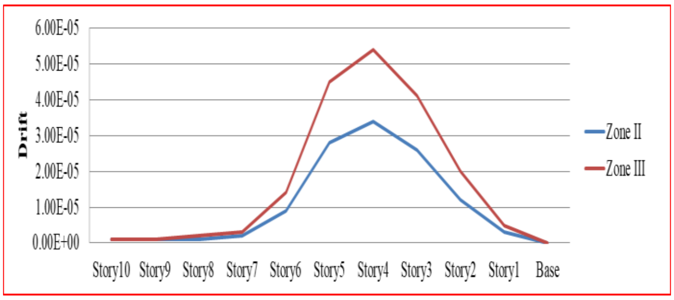


Chart -9: Storey Drift for EQX Load

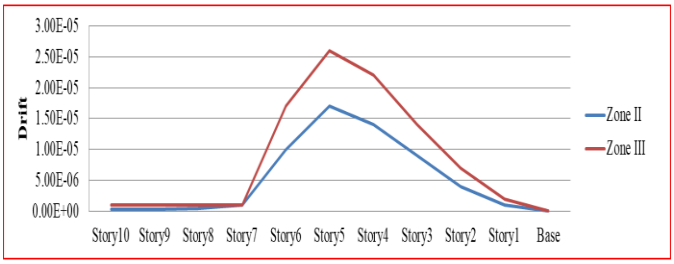


Chart -10: Storey Drift for EQY Load

As can be seen from chart 9, for both seismic zones II and III, the maximum drift is found at story 4. When compared to seismic zone III, the drift has increased by 37%.

From chart 10, it can be seen that for seismic zones II and III, the maximum drift occurs at story 5. When compared to seismic zone III, the drift has increased by 34.61%.

Although there was a 37% increase in the drift for EQX load and a 34.61% increase for EQY load, the EQX load experienced the greatest drift in seismic zones II and III.

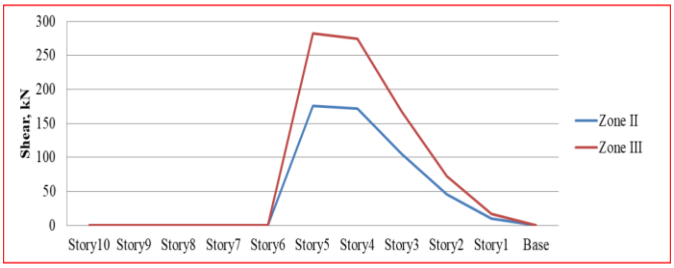


Chart -11: Storey Shears for EQX Load

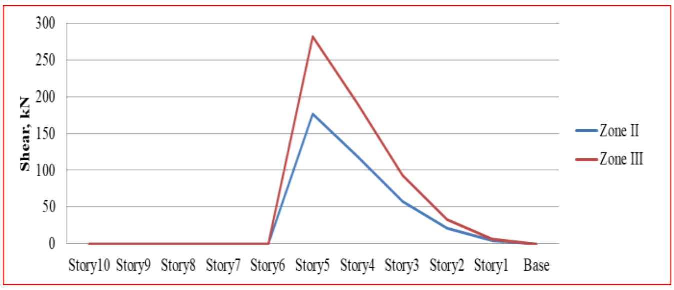


Chart -12: Storey Shears for EQY Load

Chart 11 and 12 show that the maximum shear obtained in story 5 is nearly identical to the values obtained for the EQX and EQY load for both seismic zones II and III. There is a 37.50% increase when comparing seismic zone II to seismic zone III.

5.3 Comparison for Sloped Building in Seismic Zones II & III with Diagonal Bracing

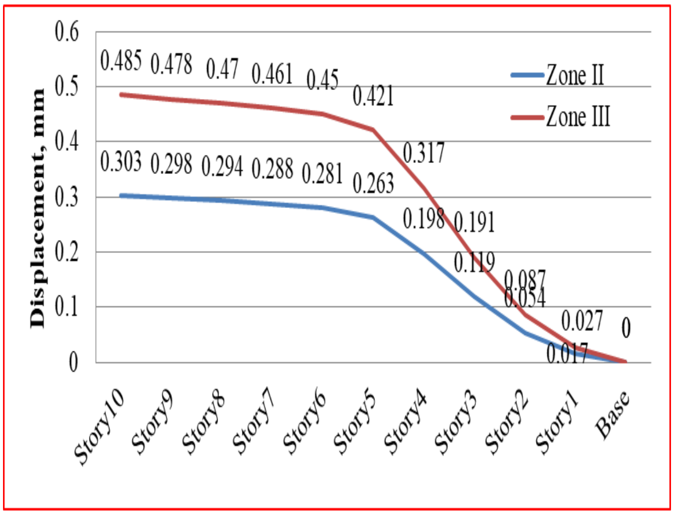


Chart -13: Storey Displacement for EQX Load

Chart 13 illustrates how the displacement increases along with the seismic zone. Displacement has increased by 37.52% from seismic zone II to seismic zone III.

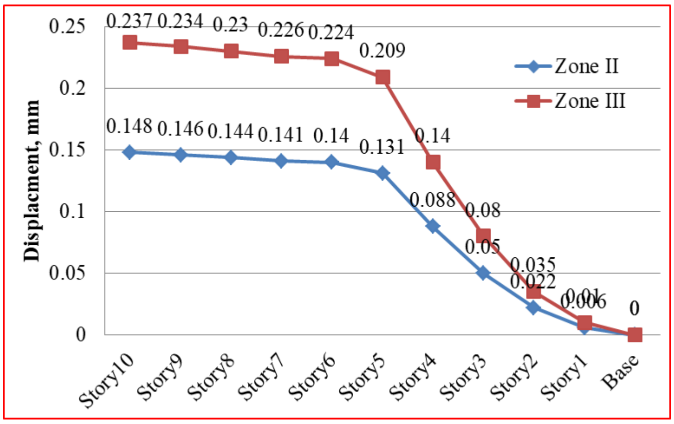


Chart -14: Storey Displacement for EQY Load

Chart 14 illustrates how the displacement increases along with the seismic zone. Displacement is increased by 37.55% from seismic zone II to seismic zone III.

Chart 13 and 14 above show that the top story received the EQX load's maximum displacement.

International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 09 Issue: 12 | Dec 2022 www.irjet.net p-ISSN: 2395-0072

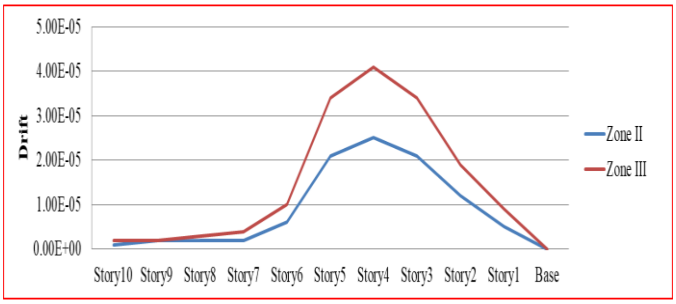


Chart -15: Storey Drift for EQX Load

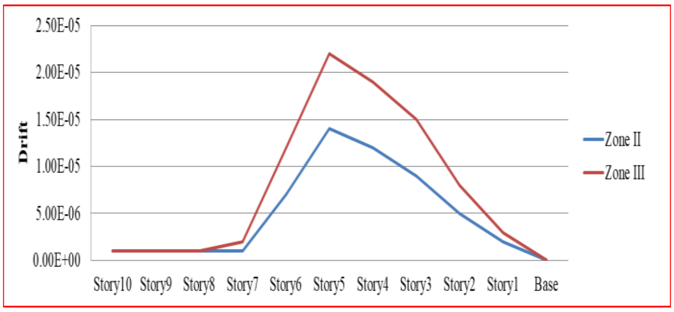


Chart -16: Storey Drift for EQY Load

Chart 15 and 16 show that the drift rises as the number of seismic zones rises, reaching its maximum in stories 4 and 5 respectively, for the EQX load and the EQY load.

However, when compared to the EQY load, the EQX load exhibits the greatest drift. The EQX load increases by 39% and the EQY load by 36.36% when seismic zone II and zone III are compared.

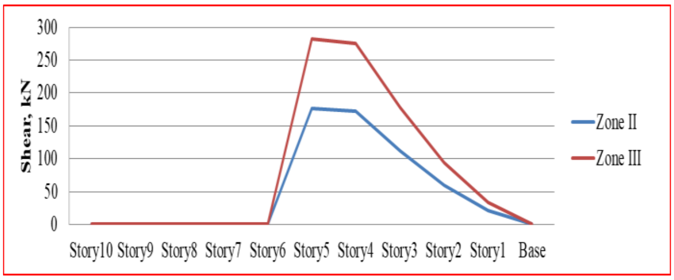


Chart -17: Storey Shears for EQX Load

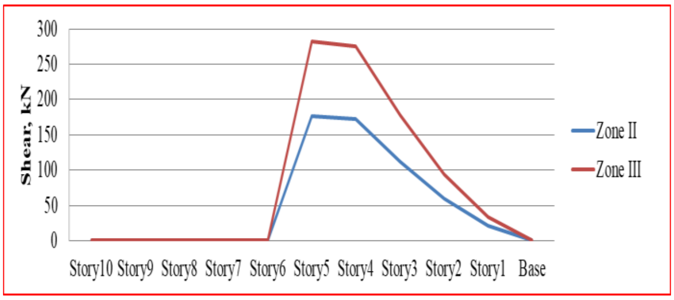


Chart -18: Storey Shears for EQY Load

Chart 17 and 18 show that the drift increases as the seismic zones expand and that the maximum shear for both the EQX and EQY load occurs in story 5. Additionally, the values obtained with a 37.50% increase in percentage from seismic zone II to zone III are nearly identical.

5.4 Comparison for Sloped Building in Seismic Zones II & III with X Bracing

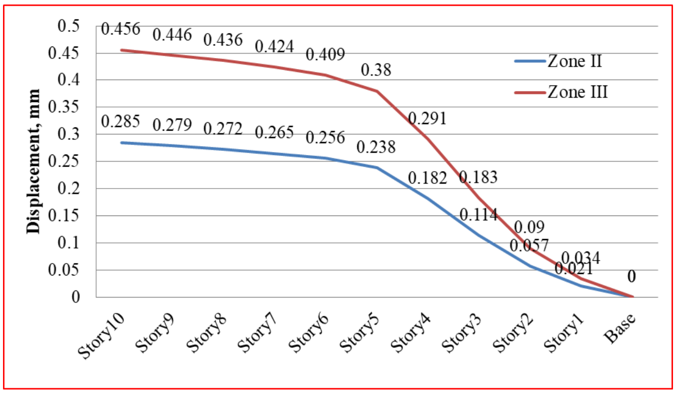


Chart -19: Storey Displacement for EQX Load

As can be seen from chart 19, there is a displacement increase of 37.50% when compared to seismic zones II and III.

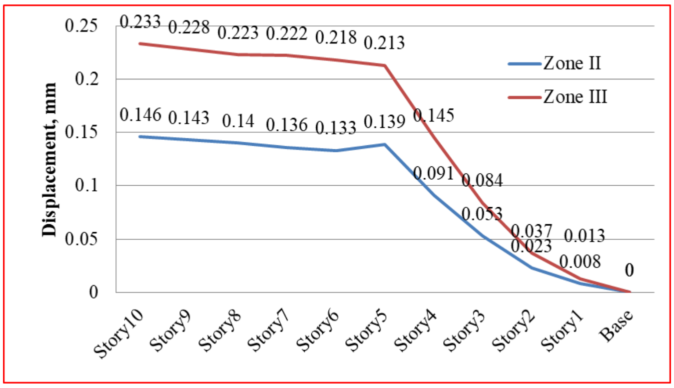


Chart -20: Storey Displacement for EQY Load

As can be seen from chart 20, there is a 37.33% increase in displacement from seismic zone II to seismic zone III.

Chart 19 and 20 show the maximum displacement obtained for the EQX load when compared to the EQY load.

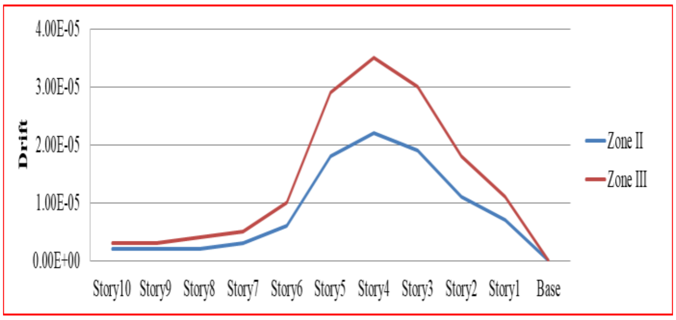


Chart -21: Storey Drift for EQX Load

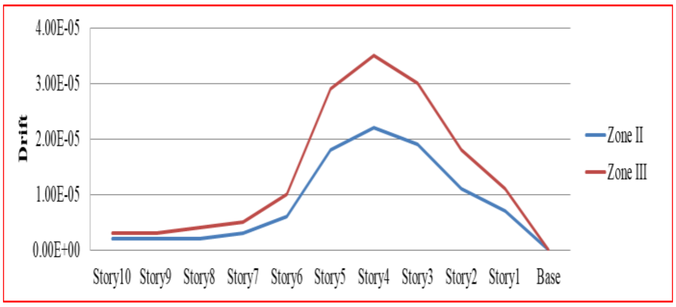


Chart -22: Storey Drift for EQY Load

Chart 21 and 22 show that there is a 37.14% increase in drift for EQX load for story 4 where the maximum drift occurred and a 35% increase in drift for EQY load for story 5 where the maximum drift occurred when compared to seismic zone II to seismic zone III, respectively. EQX load experienced the highest drift.

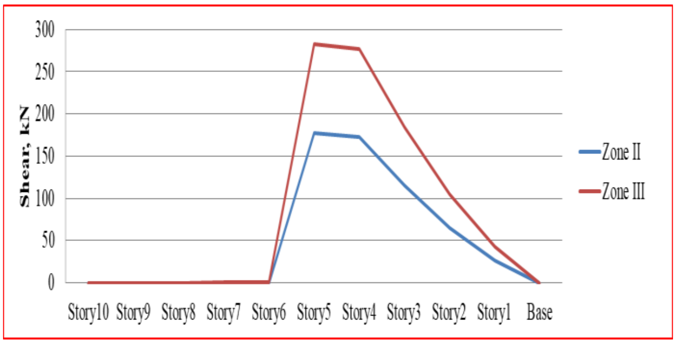


Chart -23: Storey Shears for EQX Load

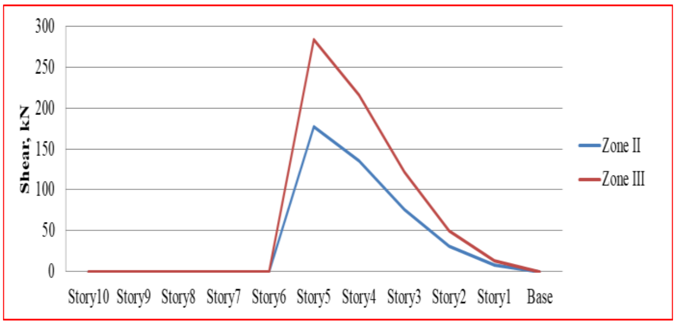


Chart -24: Storey Shears for EQY Load

Chart 23 and 24 show that the values obtained for the EQX and EQY loads in story 5 are nearly identical. The shear also grows as the seismic zone does. When compared to seismic zones II and III, the shear increased by 37.50%.

5.5 Comparison for Sloped Building in Seismic Zones II & III with V Bracing

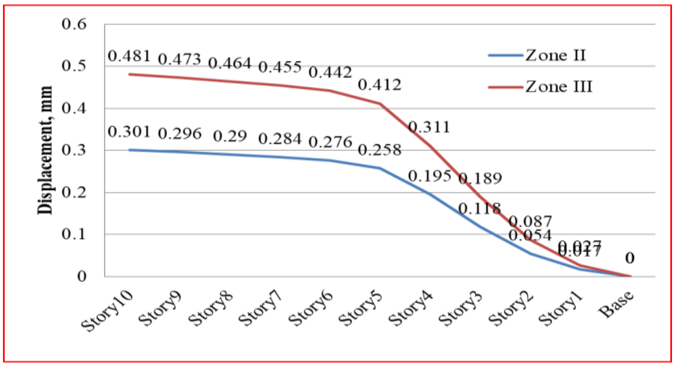


Chart -25: Storey Displacement for EQX Load

According to chart 25, the displacement for the top story has increased by 37.42% in comparison to seismic zones II and III.

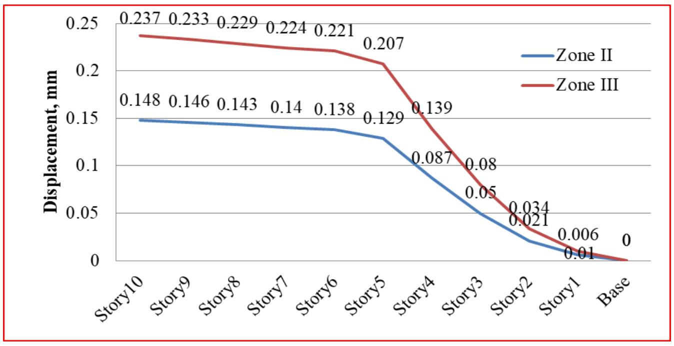


Chart -26: Storey Displacement for EQY Load

Chart 26 shows that, for the top story, there is a displacement increase from seismic zone II to seismic zone III of37.55%.

Chart 25 and 26 show the maximum displacement obtained for the EQX load when compared to the EQY load.

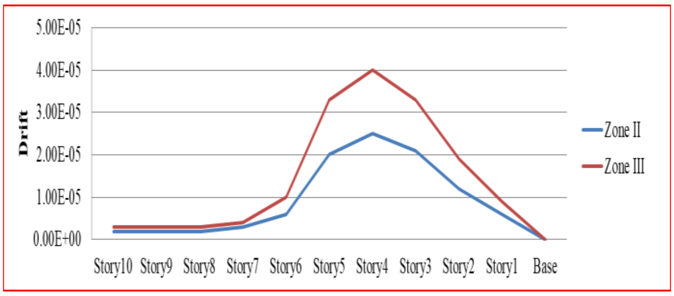


Chart -27: Storey Drift for EQX Load

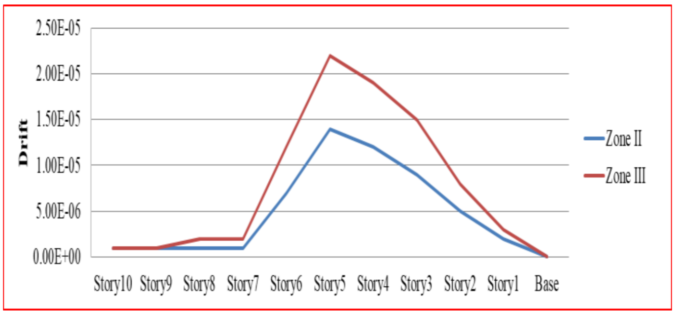


Chart -28: Storey Drift for EQY Load

Chart 27 and 28 show that, for the EQX load for story 4, where the maximum drift occurred, there is a 37.50% increase in the drift when compared to seismic zone II to seismic zone III, and for the EQY load for story 5, where the maximum drift occurred, there is a 36.36% increase in the drift when compared to seismic zone II to seismic zone III. The EQX load experienced the highest drift.

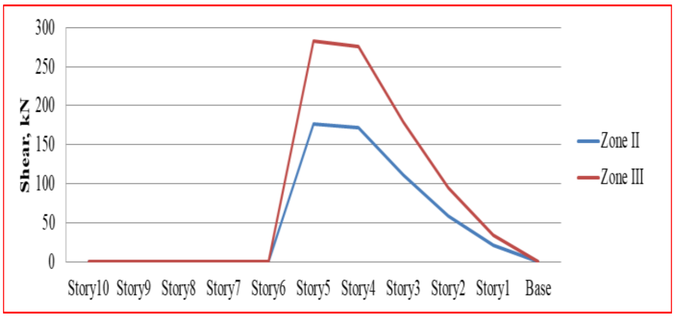


Chart -29: Storey Shears for EQX Load

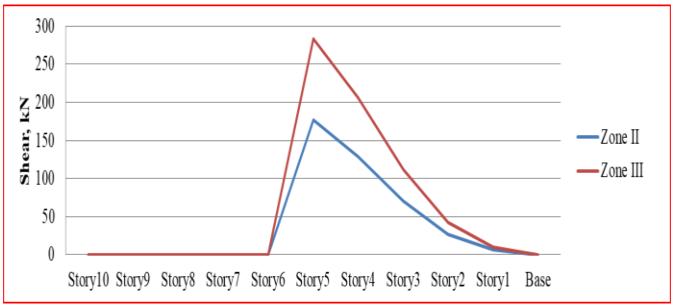


Chart -30: Storey Shears for EQY Load

It can be seen from chart 29 and 30 that the values obtained for the EQX and EQY loads in Story 5 are almost identical. The shear also grows as the seismic zone does. When compared to seismic zones II and III, the shear increased by 37.50%.

5.6 Comparison for Sloped Building in Seismic Zones II & III with Inverted V Bracing

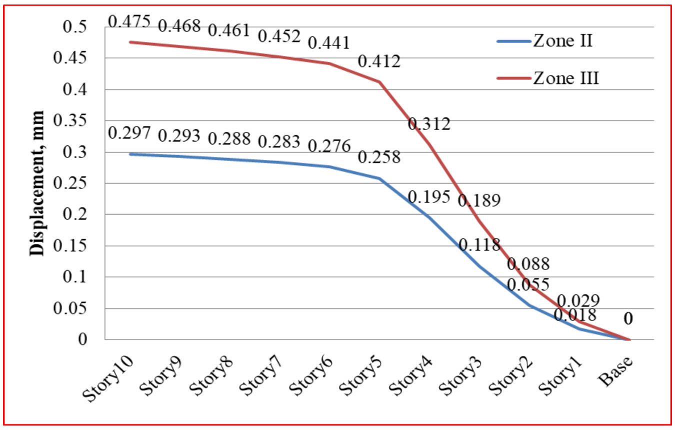


Chart -31: Storey Displacement for EQX Load

According to chart 31, the displacement for the top story has increased by 37.47% when compared to the seismic zones II and III.

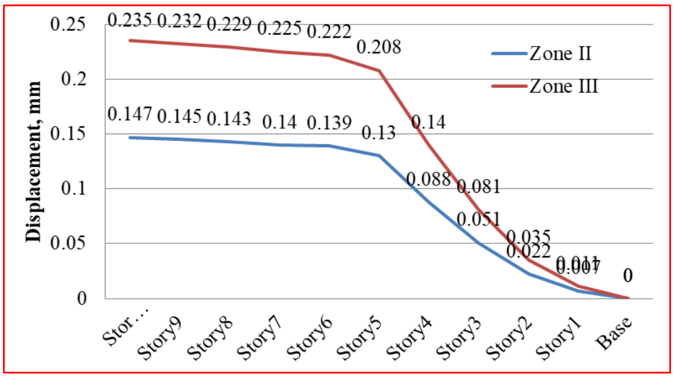


Chart -32: Storey Displacement for EQY Load

Chart 32 shows that, for the top story, there is a 37.44% increase in displacement from seismic zone II to seismic zone III.

Chart 31 and 32 show the maximum displacement obtained for the EQX load when compared to the EQY load.

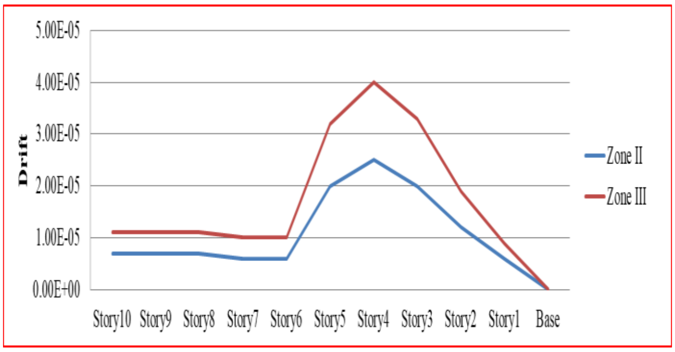


Chart -33: Storey Drift for EQX Load

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Volume: 09 Issue: 12 | Dec 2022 www.irjet.net p-ISSN: 2395-0072

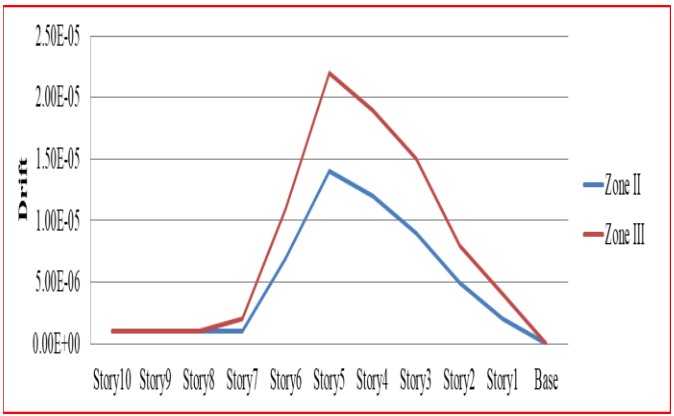

Chart -34: Storey Drift for EQY Load

Chart 33 and 34 show that there is a 37.50% increase in drift for EQX load for story 4 where the maximum drift occurred and a 36.36% increase in drift for EQY load for story 5 where the maximum drift occurred when compared to seismic zone II to seismic zone III, respectively. EQX load experienced the highest drift.

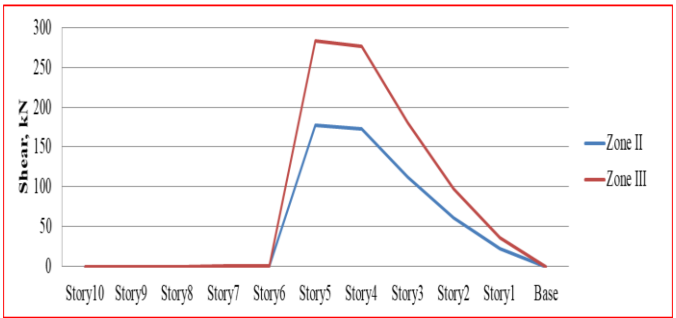

Chart -35: Storey Shears for EQX Load

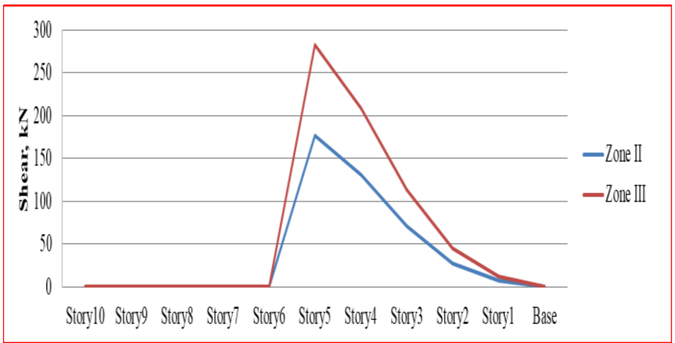

Chart -36: Storey Shears for EQY Load

Chart 35 and 36 show that the values obtained for the EQX and EQY loads in story 5 are nearly identical. The shear also grows as the seismic zone does. When compared to seismic zones II and III, the shear increased by 37.50%.

5.7 Comparison for Sloped Building in Seismic Zones II & III with 63° Diagrid

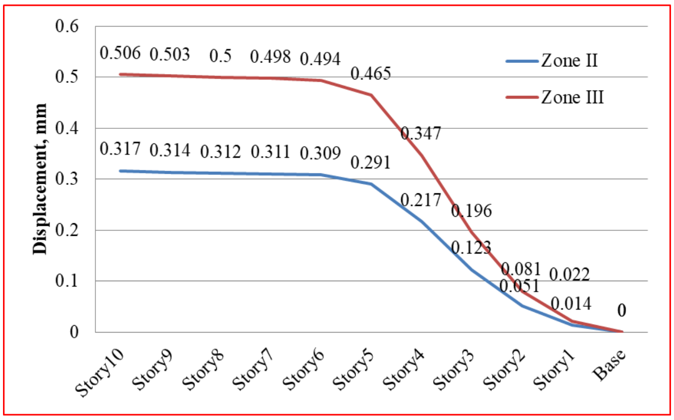

Chart -37: Storey Displacement for EQX Load

Chart 37 shows that the displacement for the top story has increased by 37.35 percent when compared to seismic zones II and III.

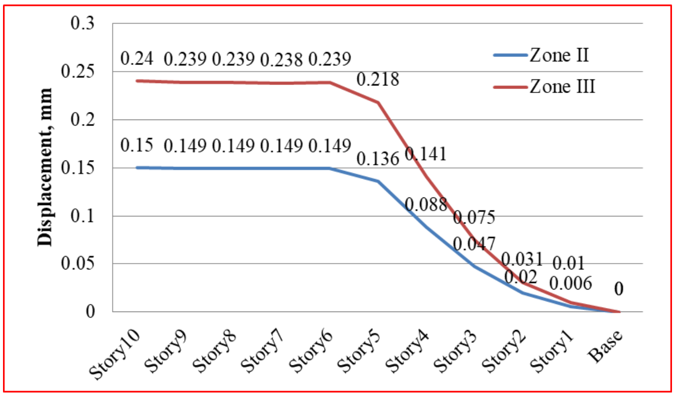

Chart -38: Storey Displacement for EQY Load

Chart 38 shows that, for the top story, there is a displacement increase of 37.50% from seismic zone II to seismic zone III.

Chart 37 and 38 show the maximum displacement obtained for the EQX load when compared to the EQY load.

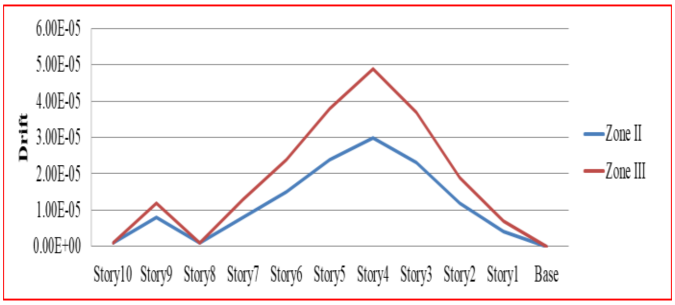

Chart -39: Storey Drift for EQX Load

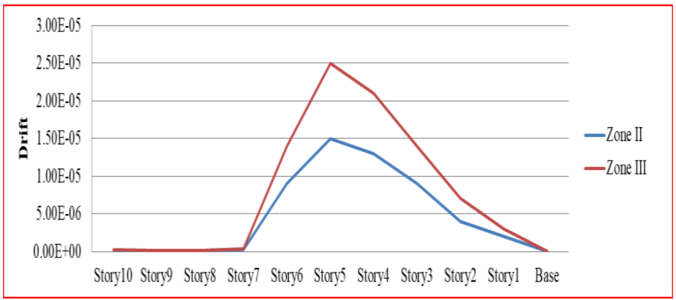

Chart -40: Storey Drift for EQY Load

Chart 39 and 40, it can be seen that the drift increased by 38.776 percent for the EQX load for story 4, where the maximum drift occurred, and by 40% for the EQY load for story 5, where the maximum drift occurred, when compared to seismic zones II and III, respectively. The EQX load experienced the highest drift.

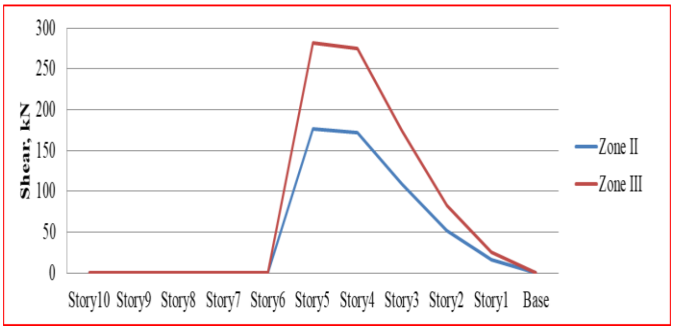

Chart -41: Storey Shears for EQX Load

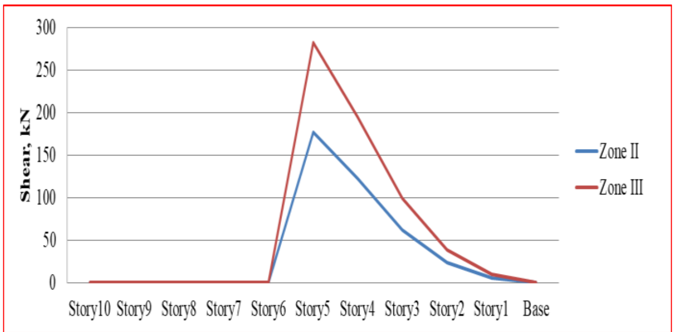

Chart -42: Storey Shears for EQY Load

Chart 41 and 42 show that the values obtained for the EQX and EQY loads in story 5 are almost identical. The shear also grows as the seismic zone does. When compared to seismic zones II and III, the shear increased by 37.50%.

5.8 Comparison for Normal Building and Sloped Building in Seismic Zone II

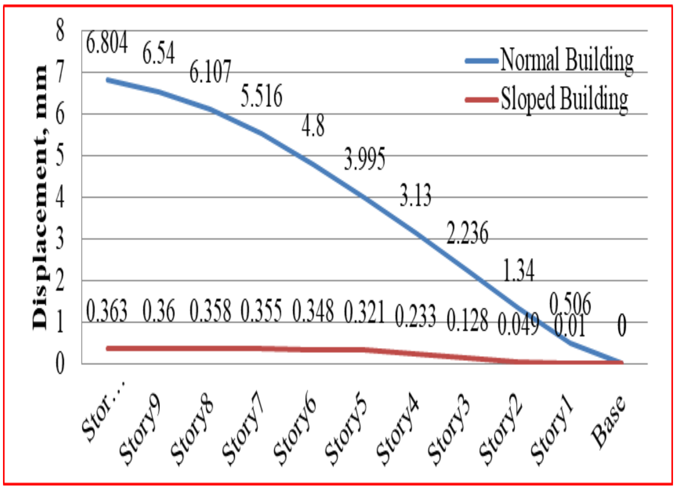

Chart -43: Storey Displacement

When a building is built in a sloped or hilly area, the displacement of the stories is reduced by 94.66%, as can be seen in chart 43.

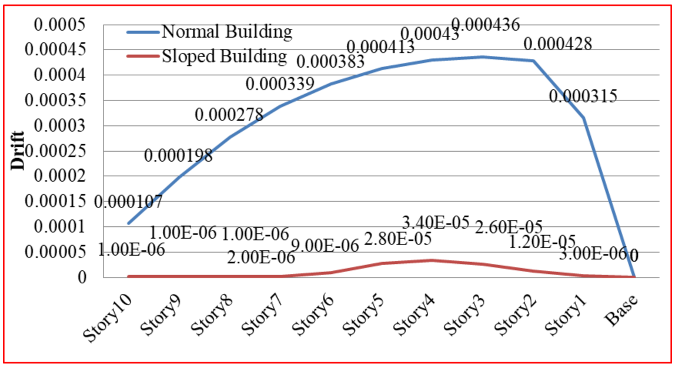

Chart -44: Storey Drift

When a building is built in a hilly or sloped area, compared to a normal building, the story drift is reduced by 92.20%, as can be seen in chart 44.

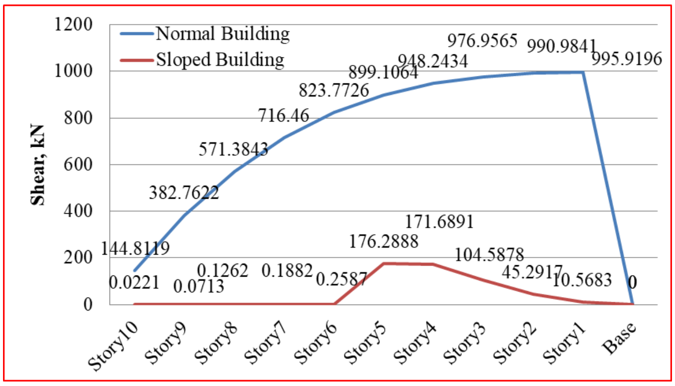

Chart -44: Storey Shear

When a building is built in a hilly or sloped area, as opposed to a flat area, there is an 82.30% reduction in the story shear, as shown in chart 44.

5.9 Comparison for Normal Building and Sloped Building in Seismic Zone III

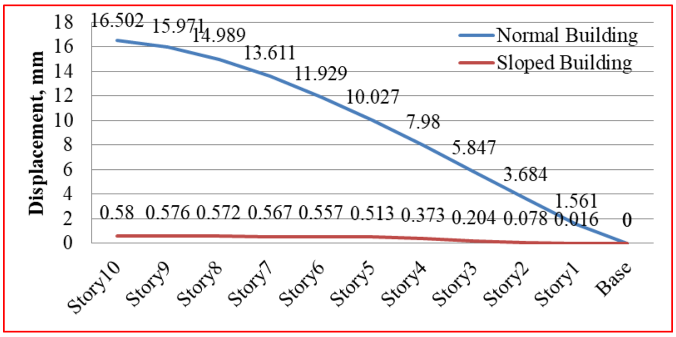

Chart -45: Storey Displacement

When a building is built in a sloped or hilly area, the displacement of the stories is reduced by 96.48%, as can be seen in Figure 5.47.

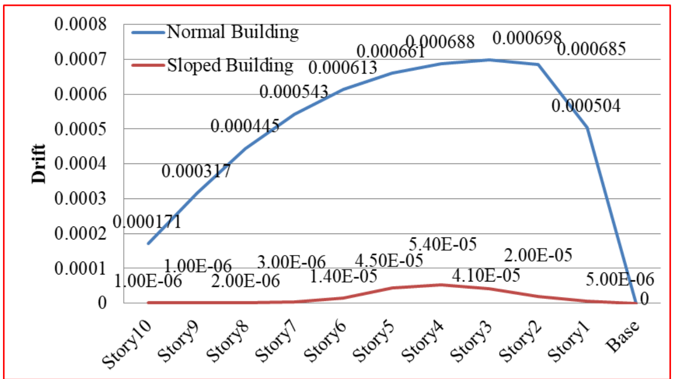

Chart -46: Storey Drift

When a building is built in a hilly or sloped area, compared to a normal building, the story drift is reduced by 92.28%, as can be seen in chart 46.

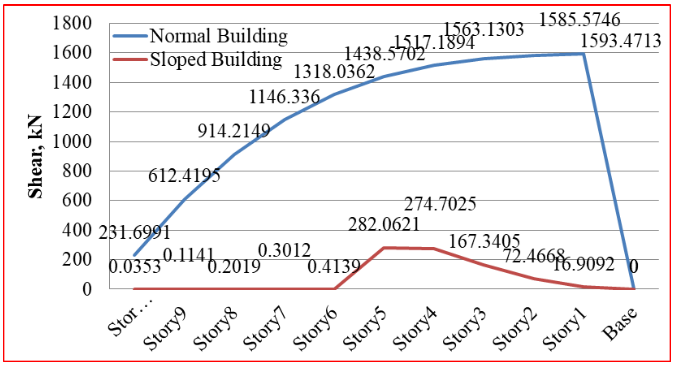

Chart -47: Storey Shear

When a building is built in a hilly or sloped area, compared to a normal building, the story shear is reduced by 82.30%, as can be seen in chart 47.

5.10 Comparison for Sloped Building with Bracings and Diagrid in Seismic Zone II

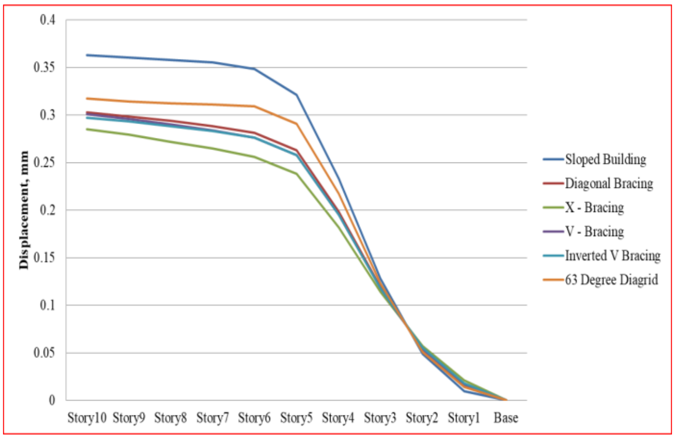

Chart -48: Storey Displacement

As shown in chart 48, there is a reduction in displacement when bracings and diagrid are used. The greatest reduction was obtained when we provided X-bracing in comparison to others by 21.48%.

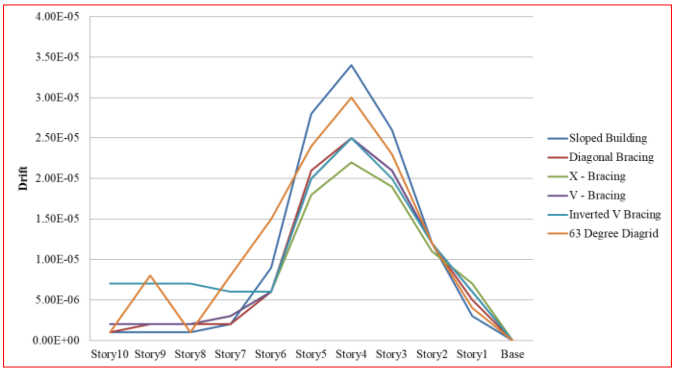

Chart -49: Storey Drift

As shown in chart 49, there is a reduction in drift when bracings and diagrid are used. The maximum reduction obtained when we offer X-bracing in comparison to others was 35.29%. There is an 11.76% decrease when the 630 diagrid is provided.

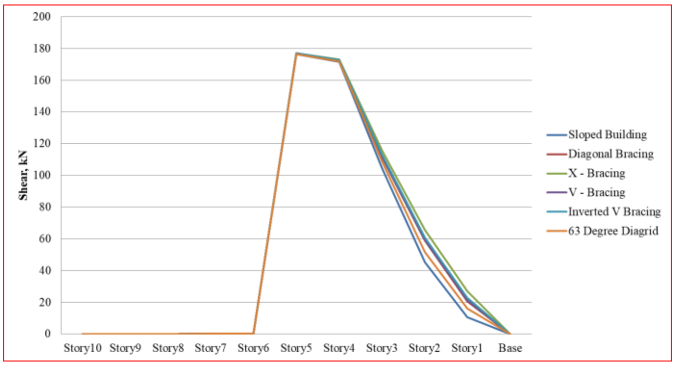

Chart -50: Storey Shear

Chart 50 shows that the shear values for the various types of bracings and the diagrid are almost identical or nearly identical, indicating that there is little variation in the shear.

5.11 Comparison for Sloped Building with Bracings and Diagrid in Seismic Zone III

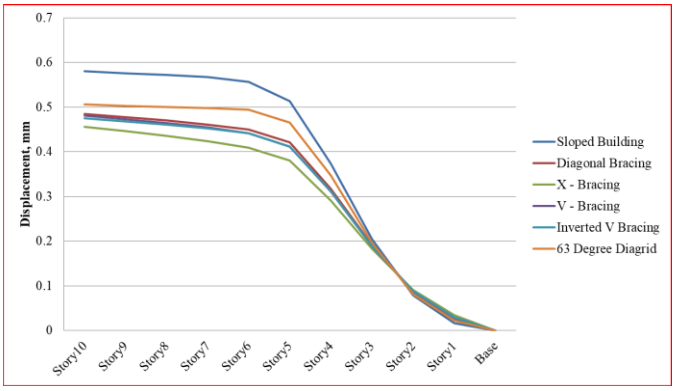

Chart -51: Storey Displacement

As shown in chart 51, there is a reduction in displacement when bracings and diagrid are used. The greatest reduction was obtained when we provided X-bracing in comparison to others by 21.37%. The 63^0 diagrid results in a 12.75% reduction.

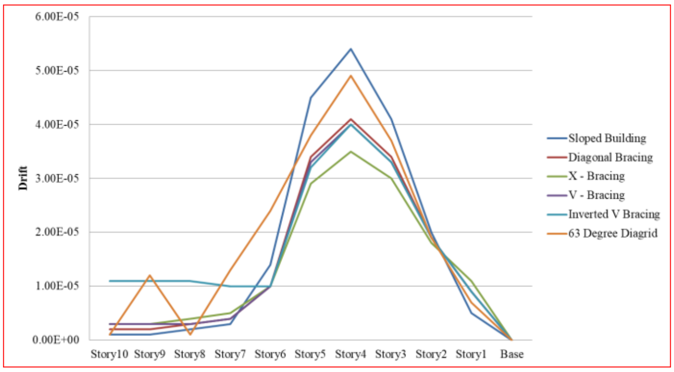

Chart -52: Storey Drift

As shown in chart 52, there is a reduction in drift when bracings and diagrid are used. The maximum reduction obtained when we offer X-bracing in comparison to others was 35.18%. There is a 9.26% decrease when the 63^0 diagrid is provided.

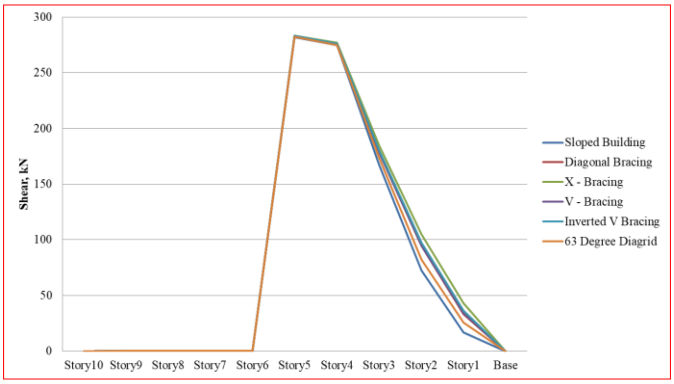

Chart -53: Storey Shear

Chart 53 demonstrates that there is little variation in the shear, with nearly identical values being obtained for the diagrid as well as for the various types of bracings.

6. CONCLUSION

This is difficult to pinpoint in what requirements and prepare will be the most efficient since there would seem to not be any widespread ability to address all issue please. A few systems are best adapted when such things are considered, but they have downsides over another. The main findings based on the investigation presented in Chapter 5.

1. Housing on sloped land across the edge of a hill can improve air circulation inside a residence.
2. Even before particularly in comparison to housing developments on flat terrain encircled by other structures, new houses on mountainsides are much more energy intensive.
3. Mountain side assets frequently have breath taking views. A greater altitude provides spectacular views of ones surroundings, even if they are of the beautiful mountains or the peaceful ocean.
4. Constructing on sloping land necessitates the addendum of more storey level in order to maximise room and eventually expand vertical position instead of laterally.
5. A design considerations used in the research meet the limits allowed by Indian Standards.
6. As the seismic zones expand, so do the design parameters.

7. When bracings and diagrid are installed in sloped buildings, displacement and drift are reduced by 10% to 35% in each seismic zone.

8. For each seismically active region, there is no discernible change with in story shears, which are nearly identical to the values we obtained.

9. The greatest reduction we obtained for X-bracing in comparison to other bracings and diagrid.

10. Whenever the diagrid was applied to sloped buildings, it did not result in a significant reduction when tried to compare to a X-bracing.

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