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Seismic Evaluation of the Performance of Steel Moment Resisting Frame Subjected to Cyclic Loading in Zone Ⅱ, Ⅲ, Ⅳ and Ⅴ

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Abstract:
All loads, including gravity, wind, and land sliding loads, must be taken into account in the analysis of a structure for an accurate structural design. This research will perform a numerical analysis of a steel moment resistant frame subjected to both concentrated gravity and cyclic stress. We shall study how a gravity load changes the cyclic behavior of a moment-resisting frame. In a moment- resisting frame of a given size, a concentrated load will be applied in the beam's midsection, and lateral cyclic displacement will be generated in accordance with the ATC24 protocol. To assess the results for various seismic parameters, a cyclic diagram for the applied lateral load will be drawn. Using the FEM findings, we will determine how much of an impact gravity load has on the moment-resisting frame in the presence of cyclic displacement. In this work, we compare the results of our analysis across four seismic zones in India.
Keywords: Cyclic loading, Steel Moment Resisting Frame, Lateral Load, Gravity Load, Seismic zones.

1.Introduction:
The current high cost of land is contributing to a worldwide shortage of available land. The population boom and the beginning of the industrial revolution caused people to migrate from rural areas to urban centers, making high-rise buildings necessary for housing and commercial use. It is possible for high- rise buildings to collapse if they are not adequately protected against lateral forces. Certain criteria are used in the design of earthquake-proof buildings. There are many variables to consider, such as the structure's inherent frequency, damping factor, foundation type, the significance of the building, and its ductility. Ductile structures have better moment distribution properties and so require less lateral load in their design. For various building types, the response reduction factor R takes care of this. The structure is a special moment resisting frame, which is optimized for great performance. The forces exerted on it need only be a fraction of what would be required of a standard moment resistant frame.

2.Literature Review:

A. Pavan Kumar Reddy, R. Master Praveen Kumar, et al1., (2017) We have known that earthquakes are a cause of tragedy ever since recorded history began. These days' buildings are increasingly small and prone to shake, making them dangerous during an earthquake. Scientists and engineers have previously figured out how to make buildings more resistant to earthquakes. Seismic factors including base shear, lateral displacements, and lateral drifts are modeled to investigate the effect of unique conditions and different elevations. Soil Type II (medium soils) in Zones IV and V have been included in the learning as intended by IS 1893-2002. The results showed that in both zone4 and zone5, the drift between stories is greatest on story 31, moving clockwise from there.

Narla mohan, A. Mounika vardhan, et al2 (2017) The scope of the current investigation is confined to multi-story commercial buildings made of reinforced concrete (RC) located in zones II, III, IV, and V. The FEM software's E Tabs are used to conduct the analysis. The study's model building is 20 stories tall and each floor is 3 meters tall. Four models are utilized for the analysis, each with a varied bay length while maintaining the same number of bays and bay-width in both the vertical

and horizontal planes. We take several samples with varying SEISMIC ZONE FACTOR values and analyze their impacts. The results of this research show that in more seismically active regions, base shear of structures increases. Zone II has a base shear value of
802.6 KN for a comparable construction, while Zone V has a value of 2889 KN. If the seismic ZONE shifts from II to V, the base shear will increase by more than 350%.

J. Chiranjeevi yadav, I. Ramaprasad Reddy, et al3, (2017) Every designer must solve the challenge of ensuring enough strength and stability against lateral loads, which include wind loads and seismic forces. We investigate the results of zone 2 and zone 5 and compare the effects of lateral load on moments, axial forces, shear force, base shear, maximum storey drift, and tensile forces on the structural system. As may be shown in Table 2, Graph 1, and Table 3, Graph 2, the tale drift x and y are larger in earthquakes than spectra in zone 2 soils, supporting the findings of this study. The tale drift is greater in zone5 compared to zone2 (see graph19, table21, and graph20).

V. Rajesh, K Jaya Prakash, et al4, (2016) The goal of the project titled "WIND AND SEISMIC ANALYSIS AND DESIGN OF MULTISTORIED BUILDING (G+30) BY USING STAAD PRO" is to develop an improved method for the following tasks: creating geometry; defining cross sections for columns and beams; creating specifications and supports; and finally, defining loads. Following that, 'Run Analysis' is used to analyze the model. Then, Analyzing Outcomes (Whether Beam Column Passed or Failed in Loads). After that, the Plan is implemented. From the above, it is clear that the top beams of a building subjected to wind load combination require more reinforcement than a building subjected to seismic load combination (for example, beam no. 1951 required 5 no. of 20 mm and 6 no. of 20 mm bars, whereas for Seismic load combination it required 13 no's of 10 mm and 21 no's of 10 mm).

Tatheer Zahra, Yasmeen Zehra, Noman Ahmed, et al5, (2015) A study was carried out to evaluate the differences between the seismic zones with regards to the construction of a high-rise reinforced concrete skyscraper. The ETABS program was used to simulate a 30-story building and then analyze the differences between the forces applied in low (seismic zone 1), moderate (seismic zone 2a, 2b), and high (seismic zone 3, 4) categories. The building's lateral strength came from the interaction between the shear walls and the moment resistant frame. The research showed that a beam made for a level of seismic risk equivalent to zone 2b (moderate) would not be able to withstand the forces of a zone 3 or 4 earthquake. In high seismic risk areas, the column is inadequate in both its major and minor axes to withstand zone 2b forces.

3.Earthquake:

When two tectonic plates collide, an enormous amount of energy is released at once. Seismic waves are the primary culprit in triggering earthquakes. The fault plane is the area where this sliding takes place. The epicentre is the highest place on Earth where the shaking is felt, while the hypocenter is the lowest. Earthquakes and other abrupt movements, whether caused by nature or by human activity, generate vibrations. The waves will radiate outward from the source in all directions. The vibrations are intense at first, but they progressively weaken the farther you are from the source. A seismograph is the device used to record earthquakes, and the recording itself is called a seismogram. When an earthquake occurs, it releases energy in the form of seismic waves.

4.Cyclic loading:

When subjected to a high enough number of cycles, local stresses in a material might break brittlely even though they are much below the yield limit. Damage due to cyclic loading can be understood by applying the principles of fatigue damage and fracture mechanics. An understanding of how fatigue damage and fracture mechanics relate to crack size is essential for distinguishing between the two. It is generally acknowledged that cracks due to cyclic loading can be classified as:

1. Micro structurally small cracks;
2. Small cracks.
3. Macroscopic cracks.

No standard minimum or maximum crack size applies across the board. A micro structurally tiny crack is typically believed to be less than 100 m in width. We classify as "small" any crack with a width of 100 m to 1 mm. Therefore, any fissure larger than 1 mm is classified as a macroscopic fissure. Problems with cracks as large as 1mm can be analyzed using fatigue damage. The term "crack initiation approach" describes this technique. However, cracks 100 m or greater can be studied using fracture mechanics. The crack growth method is another name for this strategy.

5.Objectives of the studies:

The following objectives are made for the seismic evaluation of a building in this study.

a) To study the behavior of a building under the action of cyclic seismic loads.
b) To Analys and design G+5 steel frame building by using ETABS Software.
c) To compare the various factors different seismic zones in India.
d) To study the displacement, shear force and bending moment of G+6 building for and compare between different seismic zones.
e) To compare various analysis results of building under zone II, III, IV and zone V using ETABS Software. Different values of zone factor are taken and their corresponding effects are interpreted in the results.

6. Problem statement:

In the present study, analysis of G+ 5 stories building in all seismic zones is carried out using ETABS.

Basic parameters considered for the analysis are:

1. Grade of Reinforcing steel : Fe415
2. Dimensions of beam : Auto selection of beams
3. Dimensions of column : Auto selection of columns
4. Thickness of slab : 150mm
5. Height of bottom story : 3m
6. Height of Remaining story : 3m
7. Methodology Used : Cyclic pushover analysis
8. Live load : 5 KN/m2
9. Dead load : 2 KN/m2
10. Density of concrete : 25 KN/m3
11. Seismic Zone : All seismic zones
12. Site type : II
13. Importance factor : 1.5
14. Response reduction factor :5
15. Damping Ratio : 5%
16. Structure class : B
17. Basic wind speed : 44m/s
18. Risk coefficient (K1) : 1.08
19. Terrain size coefficient (K2) : 1.14
20. Topography factor (K3) : 1.36
21. Wind design code : IS 875: 1987 (Part 3)
22. RCC design code : IS 456:2000
23. Steel design code : IS 800: 2007
24. Earth quake design code :IS 1893 : 2002 (Part 1)

7. Modelling in E-Tabs:

The steel building model is developed in ETABS software by considering the above specified problem statement. Initially the grid data and storey data is fixed then the material properties like grade of steel and concrete grades are defined. The shapes and sizes of columns and beans as well as slabs are defined and then properties are assigned to the steel building.

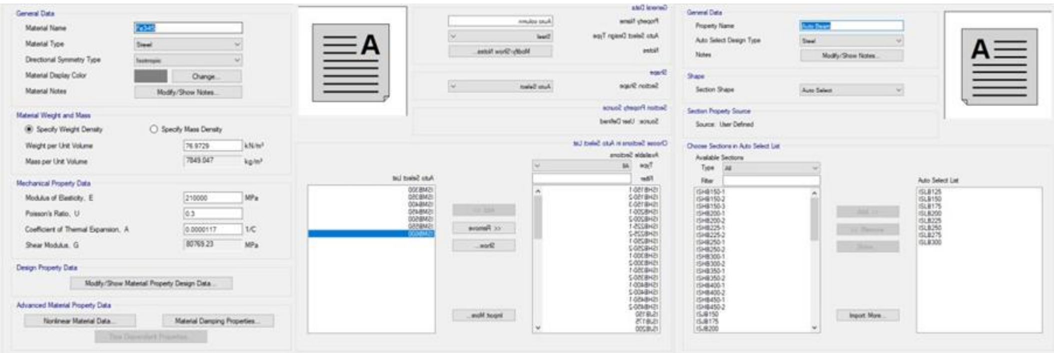

Fig No: 01 Material properties and auto beams and columns

The load cases related to gravity loads and lateral loads are defied as per the IS code specifications and the assignment of the loads are done for the steel building model. The cyclic loading case is created in the load cases and applied the cyclic loading for the model and finally analysis is done for the building model to check the results.

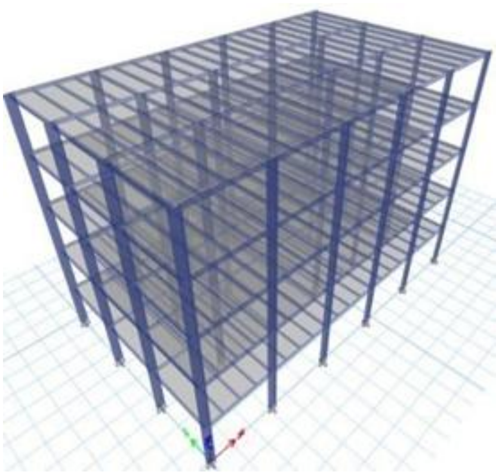

Fig No: 02 3D Building model

8.Results and Analysis:

Cyclic loading in X Direction:

A)Storey drift: The variation of storey drift of story 1 to 5 in different seismic zones is presented in fig.03

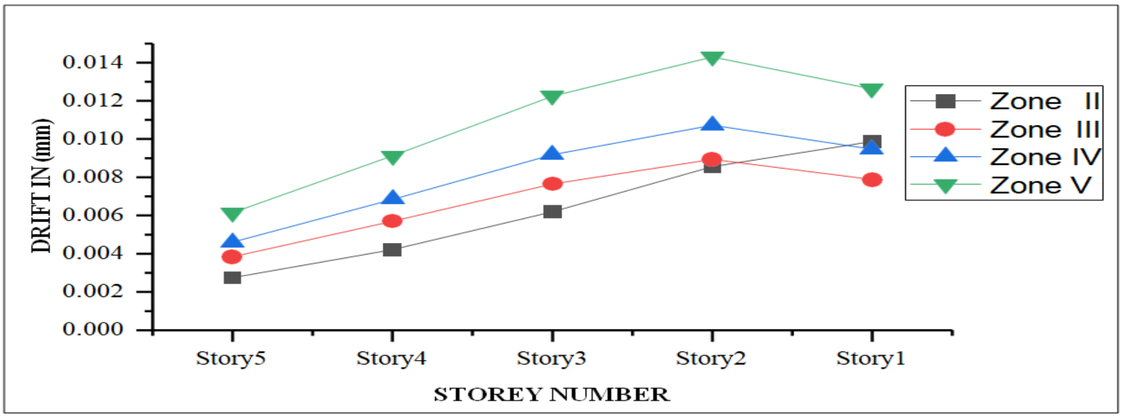

Fig No: 03 Storey Drift

From the figure.03 it can be observed that the building model made in zone V seismic condition is having high as per IS 1893 code standards and the values are increasing for the storey drift fromtop to bottom under the cyclic loading condition in X direction.

B)Base shear: The variation of base shear in different seismic zones of Ⅱ to Ⅴ is presented in fig.04

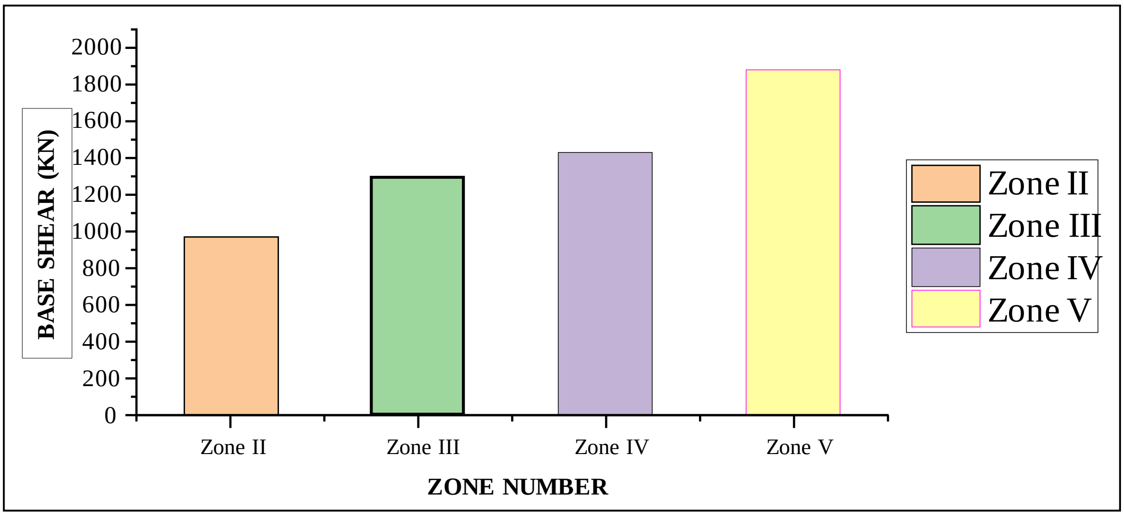

Fig No: 04 Comparison of Base shear

The graphic shows that in seismic zone V, the base shear value of a steel building is higher than in any of the other seismic zones.04 Zone V's base shear value is high under cyclic loading in the X direction because of the high seismic coefficient factor value of 0.36.

C)**Time period:** The variation of Time period in different seismic zones of Ⅱ to Ⅴ is presented in fig.05

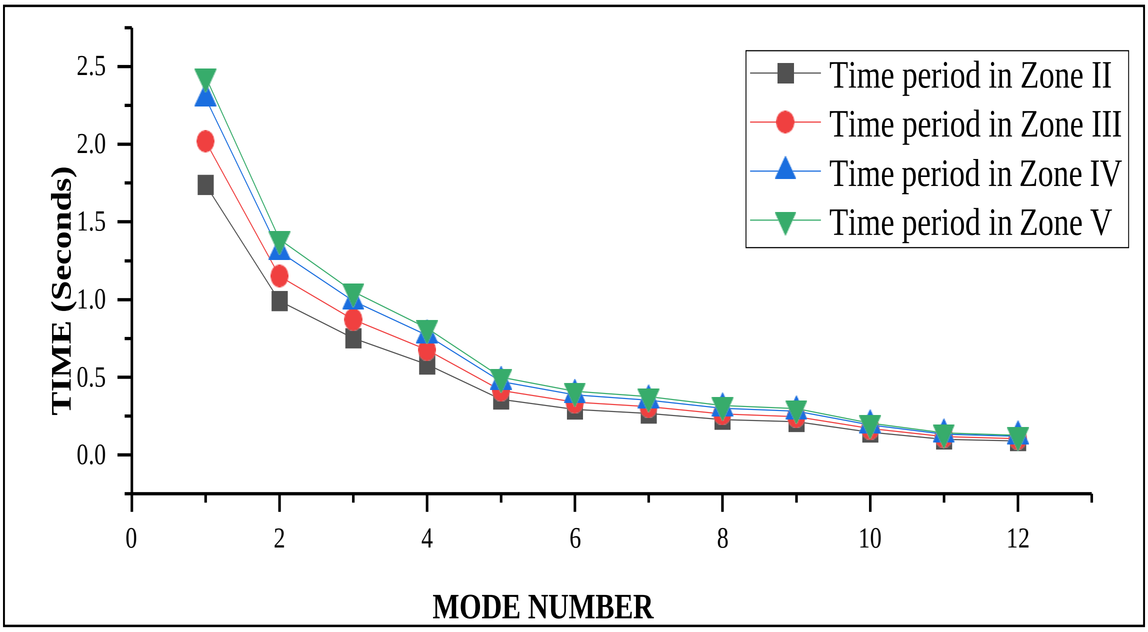

Fig No: 05 Comparison of time period

The time period values are having similar in all seismic zones under the application of cyclic loading X and the intensity of time period decreases from mode 1 to mode 12 under seismic loading action.

D)Frequency: The variation of frequency in different zones of Ⅱ to Ⅴ is presented in fig.06

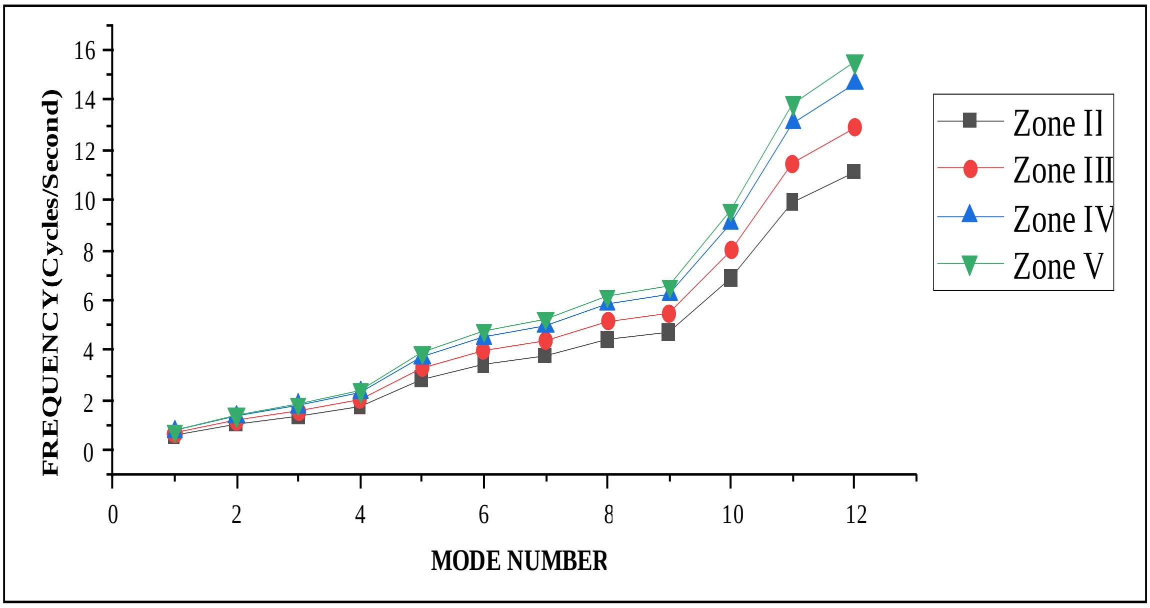

Fig No: o6 Comparison of frequency

The frequency values are having similar in all seismic zones under the application of cyclic loading X and the intensity of time period increases from mode 1 to mode 12 under seismic loading action.

E)Shear Force: The variation of shear values of story 1 to 5 in different seismic zones is presented in fig.07

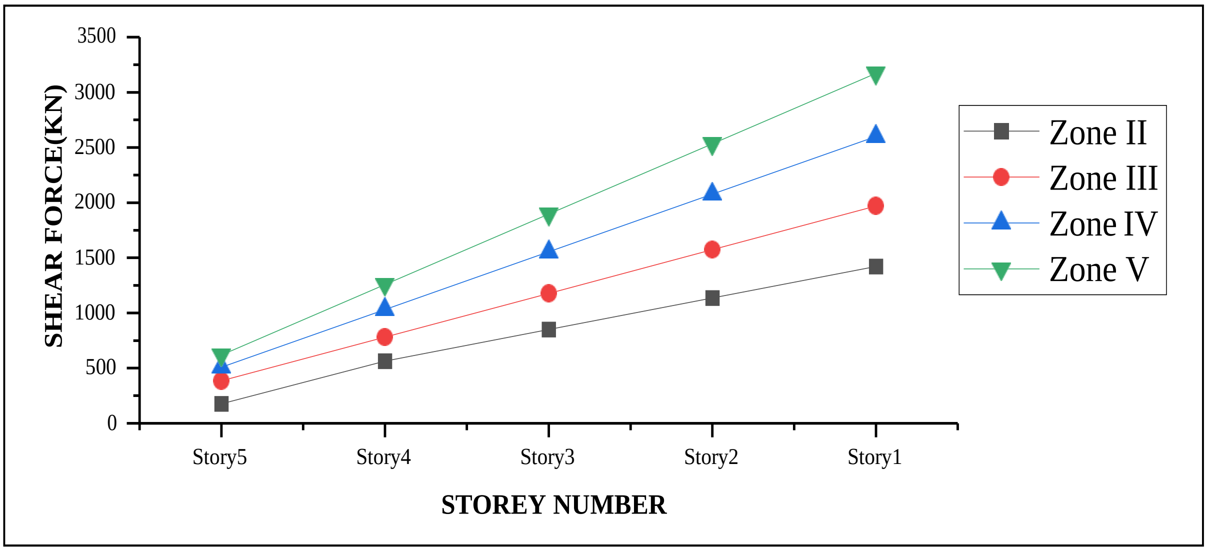

Fig No: 07 Comparison of Shear Force

The figure depicts the shear intensity of the model variation for a steel structure. When seismic loading was applied in 2007, it was found that shear values increased from upper to lower level, with the highest values observed for storey 1 under zone V conditions in cyclic loading along the X axis.

F)Bending Moment: The variation of Bending values of storey 1 to 5 in different seismic zones is presented in fig.08

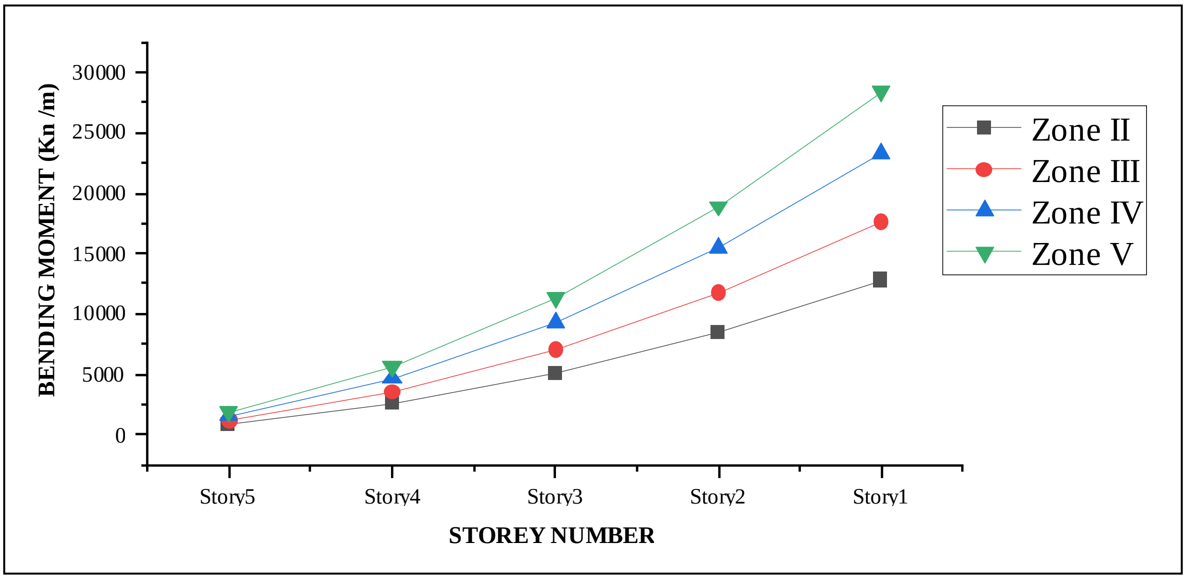

Fig No: 08 Comparison of Bending Moment

Figure.08 shows a variation in the steel building model's bending moments. The graph shows that the highest bending moment occurs in the case of storey 1 with zone V condition under cyclic loading in the X direction, and that the values increase from top to bottom storey when the seismic loading is applied.

G)Torsion Values: The variation of Torsion of storey 1 to 5 in different seismic zones is presented in fig: 09

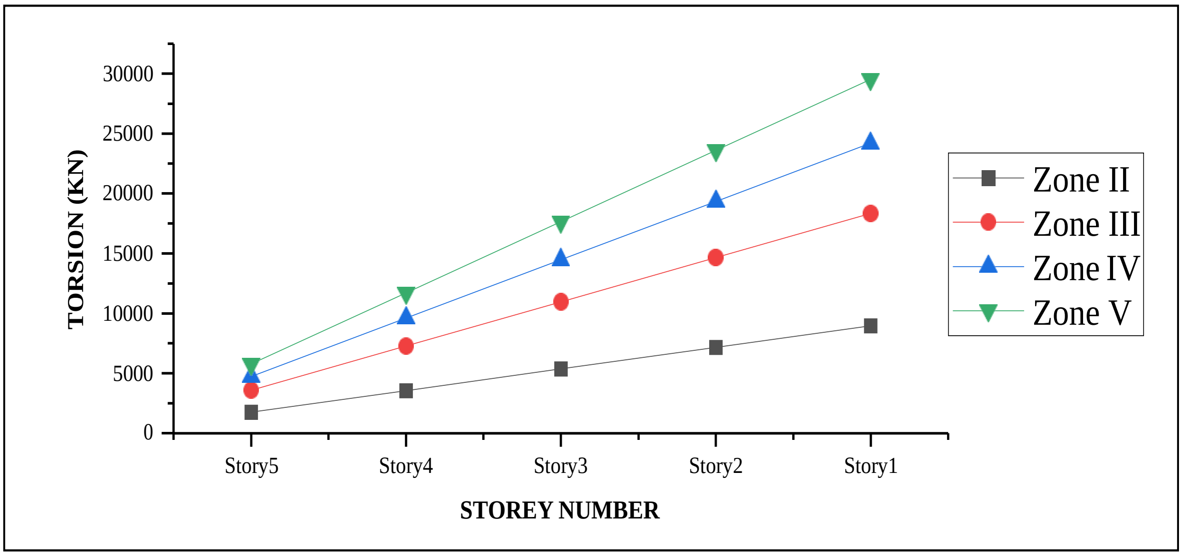

Fig No: 09 Comparison of Torsion

Figure 09 depicts the torsional variation of a model steel structure. Torsion values increase from upper to lower storeys during seismic loading, with maximum values seen in the instance of storey 1 under zone V condition under cyclic loading in the X direction, as shown in the figure.

Cyclic loading in Y Direction:

A)Storey drift: The variation of storey drift of storey 1 to 5 in different seismic zones is presented in fig:10

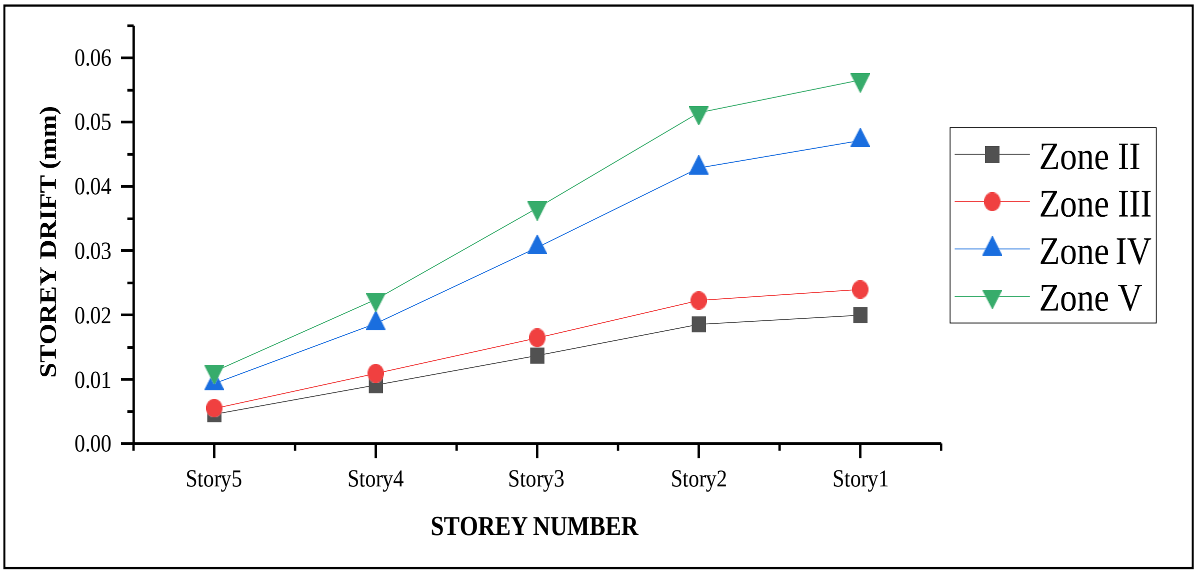

Fig No: 10 Storey Drift

From the figure.10 it can be observed that the building model made in zone V seismic condition is having high results as per IS 1893 code standards and the values are increasing for the storey drift from top to bottom under the cyclic loading condition in Y direction.

B)Base shear: The variation of Base shear in different seismic zones Ⅱ to Ⅴ is presented in fig.11

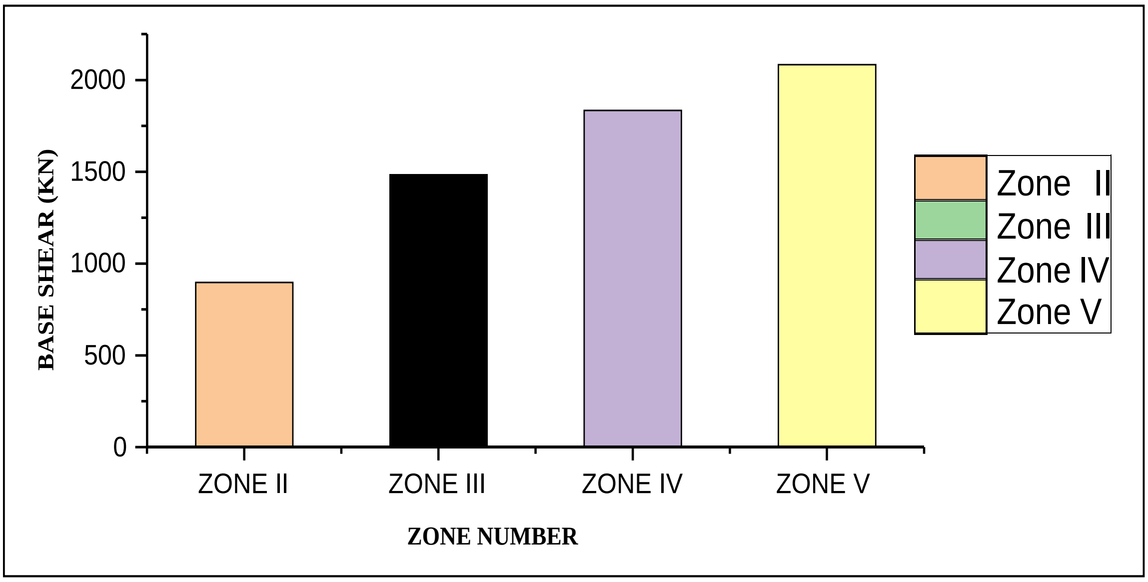

Fig No: 11 Comparison of Base shear

The base shear value of the steel building in increasing in zone V condition when compared with other seismic zones which is shown in figure11. Because of the high seismic coefficient factor value of 0.36 the value of base shear is high in zone V under cyclic loading condition in Y direction.

C)Time period: The variation of Time period in different seismic zones Ⅱ to Ⅴ is presented in fig.12

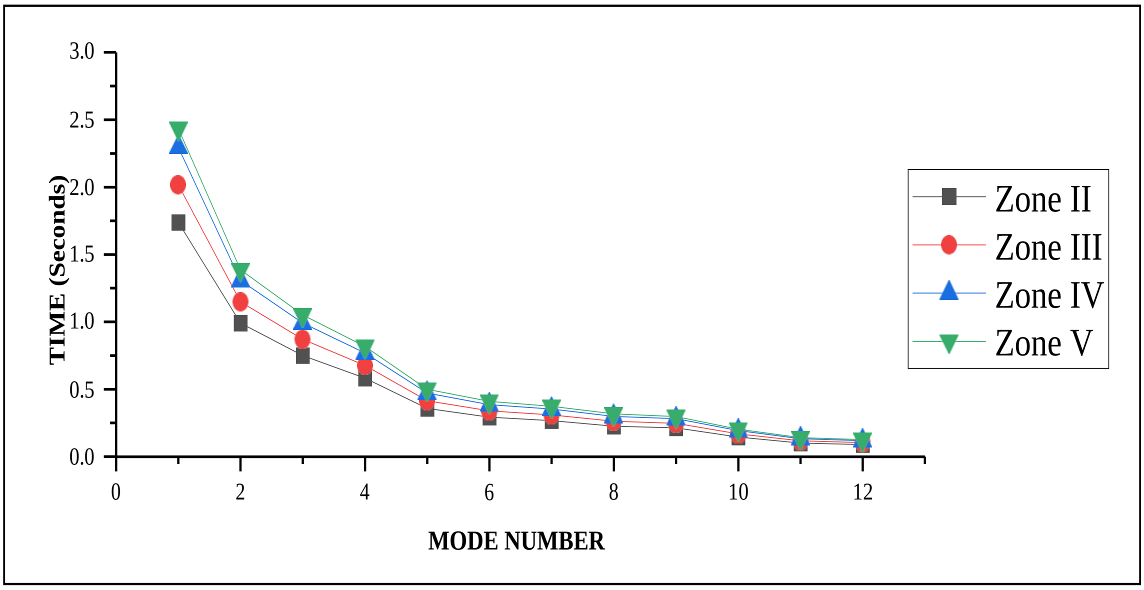

Fig No: 12 Comparison of Time period

The time period values are having similar in all seismic zones under the application of cyclic loading Y and the intensity of time period decreases from mode 1 to mode 12 under seismic loading action.

D)Frequency: The variation of frequency in different seismic zones Ⅱ to Ⅴ is presented in fig.13

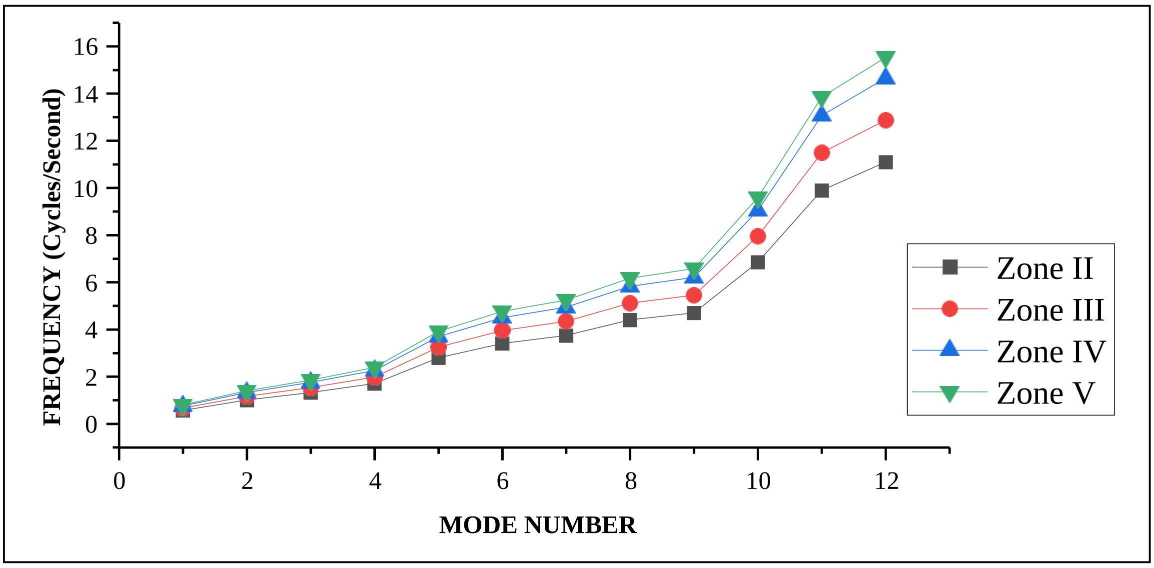

Fig No:13 Comparison of Frequency

The frequency values are having similar in all seismic zones under the application of cyclic loading Y and the intensity of time period increases from mode 1 to mode 12 under seismic loading action.

E)Shear Values: The variation shear value of storey 1to 5 in different seismic zones is presented in fig.14

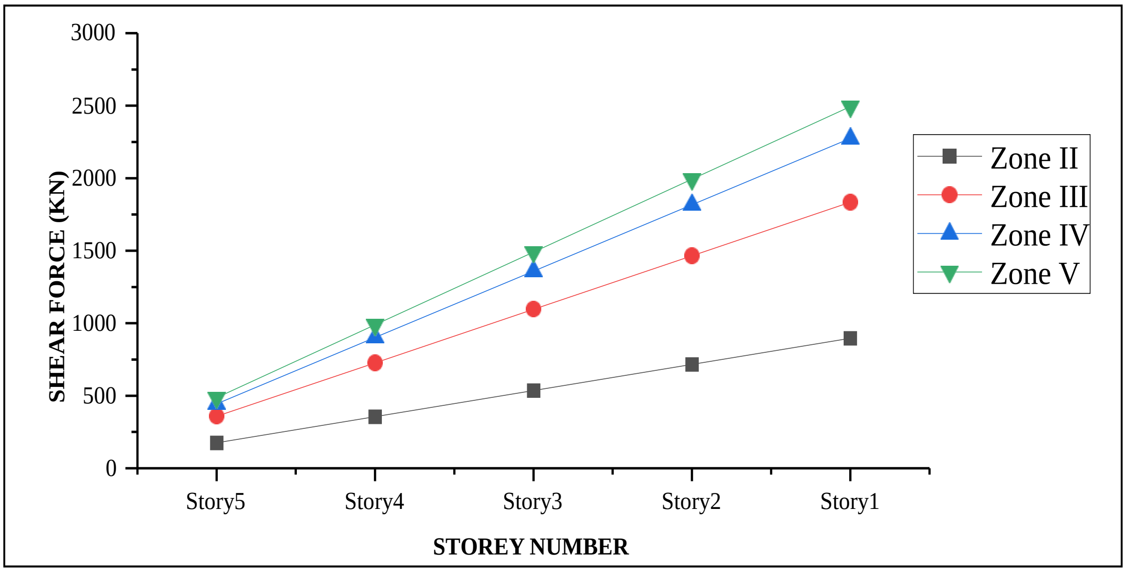

Fig No: 14 Comparison of Shear Force

The shear intensity of the steel building model variation is shown in the figure 14. From the figure it can be observed that when we apply the seismic loading the shear values are increasing from top to bottom storey and maximum values are seen in the case of storey 1 with zone V condition in cyclic loading case in Y direction.

F)Bending Moment: The variation of Bending values of storey 1to 5 in different seismic zones Ⅱ to Ⅴ is presented in fig:15

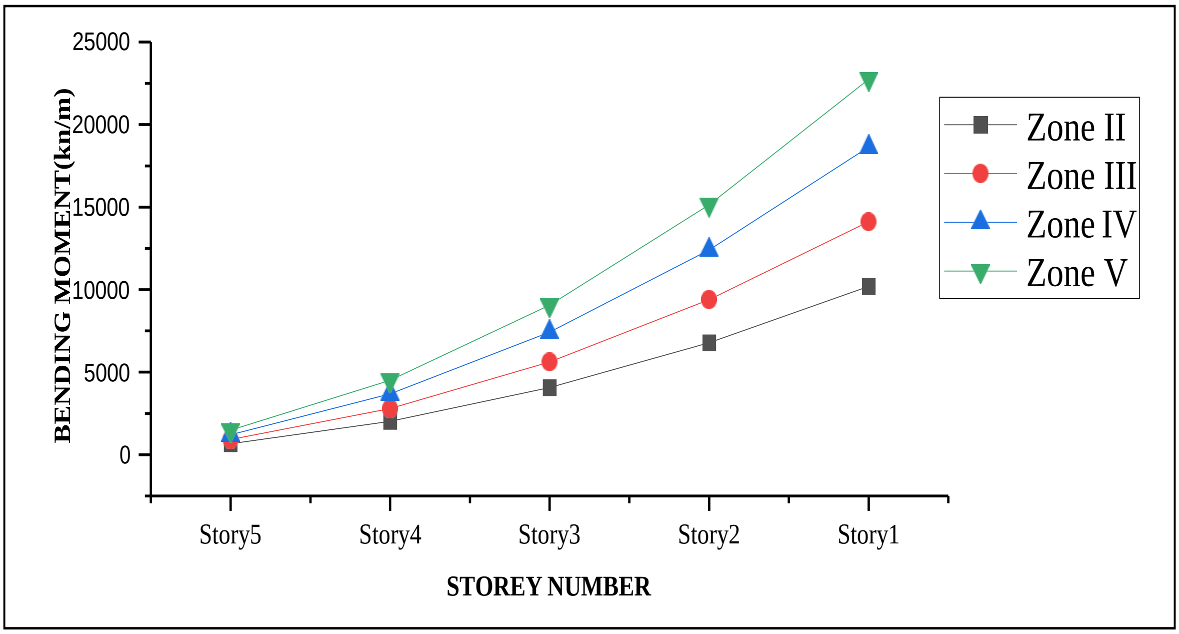

Fig No: 15 Comparison of Bending Moment

The Bending of the steel building model variation is shown in the figure15. From the figure it can be observed that when we apply the seismic loading the bending values are increasing from top to bottom storey and maximum values are seen in the case of storey 1 with zone V condition in cyclic loading case in Y direction.

G)Torsion Values: The variation of torsion of storey 1 to 5 in different seismic zones Ⅱ to Ⅴ is presented in fig. 16

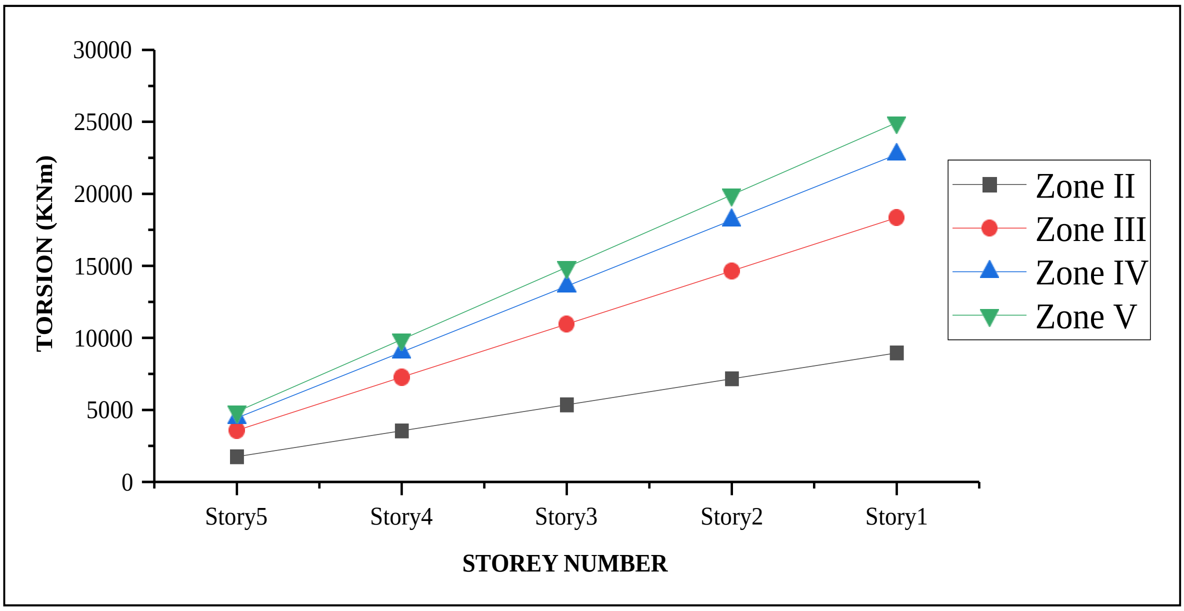

Fig No: 16 Comparison of torsion

The torsion of the steel building model variation is shown in the figure 16. From the figure it can be observed that when we apply the seismic loading the torsion values are increasing from top to bottom storey and maximum values are seen in the case of storey 1 with zone V condition in cyclic loading case in Y direction.

9.Conclusions

The Following conclusions are made from the present study:

1. When comparing the remaining seismic zones, the base shear of the structure increases from 24.60 to 31.80 to 48.26 percent.
2. Increasing the seismic zone from 2 to 5 raises the intensity of the time period by 16%, 24.24%, and 28.57%, respectively.
3. The storey drift is most common at the building's centre. Increases in drift of 28.34 percent, 40.29 percent, and 55.21 percent are recorded for Zones III, IV, and V, respectively.
4. As seismic Zones rise, so does the amount by which building models are displaced.
5. As wind speed and direction rise, building models will be displaced further and further. Extremely large displacements are seen at the top and bottom of the structure.
6. The effect of seismic load on storey drift is greatest at the top and decreases with depth.
7. The percentage rise in torsion intensity from Zone 3 to Zone 4 and Zone 5 to Zone 5 to Zone 4 is 51.1%, 60.57%, and 64.05%, respectively. And when we compared Zone 3, Zone 4, and Zone 5, we found that the intensity of bending increased by 27.80 percent, 45.30 percent, and 55.16 percent, respectively.
8. Zone V has the greatest shear, bending, and torsion values compared to the other seismic zones. With enough cycles, brittle failure can occur under cyclic loading because a fracture can form and spread even though local stresses are well below the yield limit.
9. Damage from cyclic stress can be understood with the use of the principles of fatigue damage and fracture mechanics.

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