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Research Article

Performance Assessment of Commercial Building for Symmetric and Asymmetric Plan Configurations in Different Seismic Zones of Bangladesh Using ETABS

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Abstract

Bangladesh is among the nations most vulnerable to earthquakes worldwide. Being a developing country, it has been a challenging issue to ensure commercial prosperity along with safety against seismic hazards. Structural engineers also face difficulties in accurately designing buildings with maximum economy and efficiency. ETABS, a leading global engineering software with BNBC 2020 guidelines plays a vital role in these cases. In this study, analysis of a B+G+6 storied building for Symmetric & Asymmetric Plan configuration has been performed using ETABS software. Both kinds of structures have experienced a range of loads for example- dead loads, live loads, partition loads, wind loads, and seismic loads, as well as load combinations that have been pursued following BNBC 2020 requirements. The objective of this work is to evaluate the seismic impact resulting from varying seismic coefficients for four seismic zones in Bangladesh, given identical symmetric and asymmetric plan arrangements. Four required metrics were evaluated between the structural performances of symmetric and asymmetric structures: storey drift, overturning moment, storey shear, and storey stiffness. The structural software provided the analytical results and parameter computations. The comparison's result demonstrates that the asymmetric structure exhibits greater storey rigidity and less storey drift over the longer axis.

Keywords

Symmetric & Asymmetric Plan, Commercial Building, Storey Drift, Overturning Moment, Storey Shear, Storey Stiffness, ETABS, BNBC 2020

1. Introduction

The seismic vulnerability of structures is a critical consideration in the design and construction of buildings, particularly in regions prone to seismic activity. Bangladesh, situated in a seismically active zone, faces unique challenges in ensuring the safety and resilience of its built environment. This research focuses on a comprehensive performance assessment of commercial buildings of both symmetric and asymmetric plan configurations across various seismic zones in Bangladesh. The behavior of structures will be compared responses in the form of storey drift, overturning moment, storey shear and stiffness for both plans [1].

Numerous elements, such as ground motion characteristics,

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material attributes, and structural geometry, affect a building's seismic performance. The uniform distribution of mass and stiffness found in symmetric structures has historically led to their favorability due to their apparent simplicity and balance. On the other hand, asymmetric structures depart from this homogeneity by displaying differences in stiffness, mass, or both along various axes. These differences may result from preferences for specific architectural designs, limitations on available space, or utilitarian needs.

Extended Three-Dimensional Analysis of Building Systems (ETABS), a popular engineering program, is an important tool for this research since it integrates all relevant forces- static, dynamic, linear, and non-direct into one integrated system. This tool is also used to calculate forces, bending moments, deformation, and deflection for a complicated underlying framework [2].

1.1. Symmetric & Asymmetric Plan

A symmetric plan in structural engineering refers to a building layout where the arrangement of structural components, spaces, and loads exhibits a mirror-like balance or proportionality about one or more axes. In a symmetrically designed building, the geometry and distribution of elements on one side are essentially identical or nearly identical to the other side. Symmetry is commonly observed in buildings with a central axis, resulting in a balanced and aesthetically pleasing design. Symmetric plans often simplify the analysis and design process, as the load distribution is more predictable.

On the other hand, an asymmetric plan in structural engineering refers to a building layout where the distribution of structural elements, spaces, and loads lacks mirror-like balance or proportionality about any axis. Asymmetry introduces intentional irregularities in the building's layout, which can impact its structural response to lateral loads, including seismic forces that can make the structure susceptible to damage [3]. Thus, it requires additional engineering considerations to address potential torsional effects and uneven load distributions, especially in regions prone to seismic activity.

1.2. Seismic Zones of Bangladesh

According to the Bangladesh National Building Code (BNBC)-2020, Bangladesh is divided into four seismic risk zones considering the severity of an earthquake. They are-

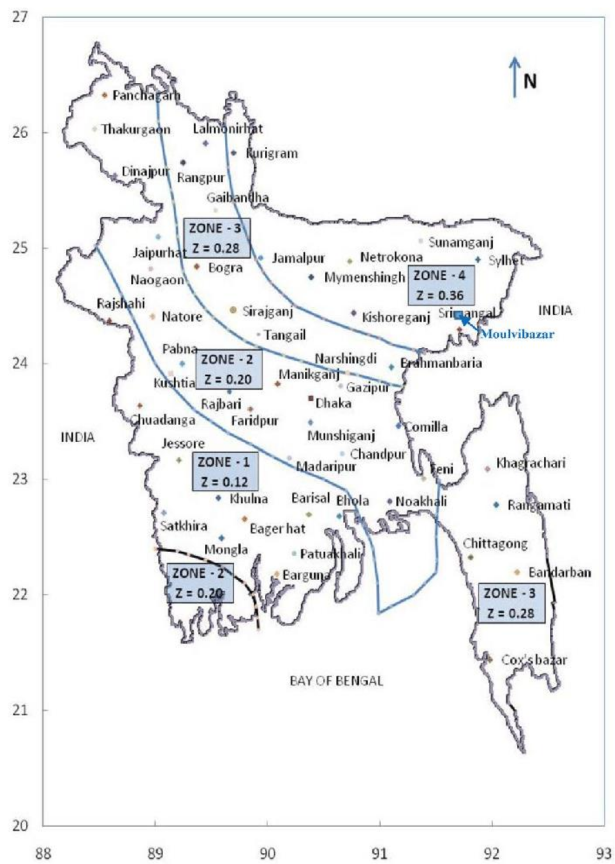

Figure 1. Seismic Zones (Four) in Bangladesh (www.researchgate.net, 2024).

Zone-I (seismic intensity: low), Zone-II (seismic intensity: moderate), Zone-III (seismic intensity: severe), and Zone-IV (seismic intensity: very severe). They have different seismic coefficients shown in the (Figure 1) map.

1.3. Statement of the Study

This paper offers comparative research on the performance of a B+G+6 story commercial building with both symmetric and asymmetric plan configurations. ETABS 2019 version was used for modelling and analysis of the structures. Load patterns and load combinations for this analysis were considered as per BNBC 2020, Indian IS 875:2015, and IS 1893:2016. For four desired parameters-storey drift, overturning moment, storey shear and stiffness, comparative analysis was done for different seismic zones of Bangladesh. Also, this study's evaluation of the deviation between software and manual calculation is another concern.

1.4. Objectives of the Study

1. To assess the multistory commercial building's seismic susceptibility with regard to storey drift, overturning moment, storey shear, and stiffness in Bangladesh's various seismic zones.
2. To compare the performance of symmetric and asymmetric buildings considering software and manual calculation.

1.5. Literature Review

The research was performed on comparative analysis of asymmetrical and symmetrical (T, L & H shape) structures for seismic load. T-shaped buildings showed the susceptible result to seismic load, whereas L-shaped and H-shaped buildings showed similar displacement. Overall symmetrical buildings performed better than asymmetrical which justifies our findings also in particular cases [4]. The research was conducted on a comparative study on the lateral displacement of a multi-storey building under lateral load actions using the base shear method and ETABS. There was a little discrepancy between the base shear method and ETABS software. However, though the base shear approach could be utilized when there is no irregularity, ETABS result was superior for the overall condition. It justifies our research as the manual seismic load calculation process showed a small difference to ETABS [5]. A G+10 structure was analyzed in three dimensions for various seismic zones in India. Various storey responses such as lateral load, storey drift, storey displacement & storey stiffness were determined by ETABS for different seismic zones. Whereas in this manuscript, comparative research was conducted for different seismic zones in Bangladesh [6]. Another research was conducted on the (G+9) story building by the response spectrum method for seismic analysis. The response spectrum function was used to determine the maximum storey displacement, maximum storey drift, storey stiffness and storey shear. Also, these storey data were used to compare structures in this research [7-9]. A case study was also performed on seismic analysis, design, and retrofit method which used various nonlinear force-deformation curves and response spectrum for analysis. Also, the retrofit method was studied for various existing vulnerable structures [10]. As per BNBC 2020, a striking occurrence of three intended parameters- story displacement, story drift, and overturning moment- has been examined and contrasted across four seismic zones in Bangladesh for various plan configurations. Based on an analysis of the maximum percentage increase in maximum storey displacement, maximum storey drift, and maximum overturning moment of rectangular and H-shaped buildings compared to L-shaped buildings, it was determined that L-shaped buildings have the best overall economic design qualities [11]. Regular shape plan configuration is advised in an ETABS analysis of the auxiliary conduct of a 12-story reinforced concrete frame structure with various shapes (rectangular shape, H, U, L, and plus shape). This is because irregular shape plan configurations experience more deformation than configurations [12]. Lateral load analysis, especially seismic analysis can be done using various methods and can be compared with manual calculation following specific building codes. In a study on seismic analysis of multistoried buildings, the seismic coefficient method was adopted using the software ETABS and further analysis was recommended using the response spectrum and time history [13].

2. Methodology

2.1. Structural Model

For this study, a B+G+6 storied commercial building was chosen. Both symmetric (Figure 2) and asymmetric (Figure 3) floor plan for the commercial building was prepared by using AutoCAD. With symmetric designs, stability and balance were carefully considered, producing visually pleasing and robustly functional results. On the other hand, asymmetric structures were investigated, defying accepted conventions and embracing dynamic geometry. Each structure was created by meticulous planning and drafting with the proper integration of engineering principles. For both symmetric and asymmetric plans same number of columns and beams were used to emphasize enhanced acceptance through uniformity and optimized structural design. Internal loading arrangement has made the difference between symmetric and asymmetric structures. The dimensions for both structures were also kept same 148’6” in length and 75’6” in width.

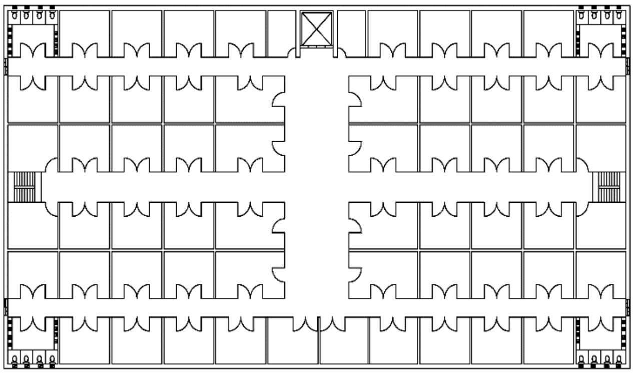

Figure 2. *Symmetric Plan View.*

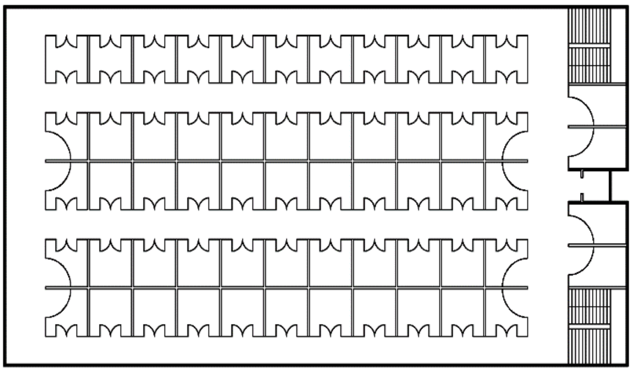

Figure 3. *Asymmetric Plan View.*

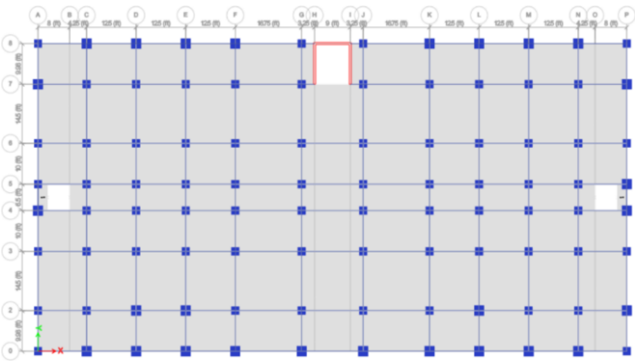

Figure 4. *Symmetric Plan View (ETABS).*

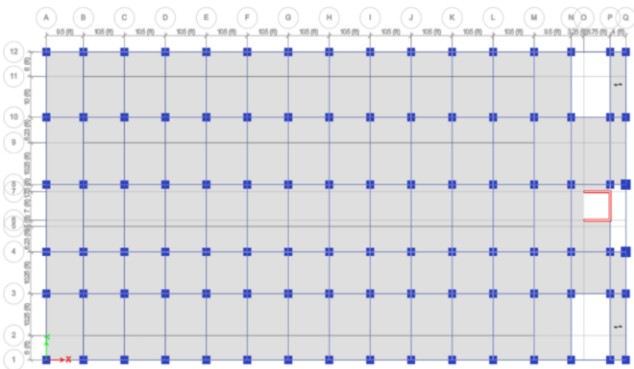

Figure 5. *Asymmetric Plan View (ETABS).*

Then both plans were taken for modelling in ETABS. Figure 4 shows the view of a typical floor of the symmetrical plan of the structure. Figure 5 shows the view of a typical floor of the asymmetrical plan of the structure. Suitable material and section properties (Tables 1, 2, 3) were chosen and different load patterns and load combinations (Tables 4, 5, 6) were applied as per BNBC 2020 for further analysis.

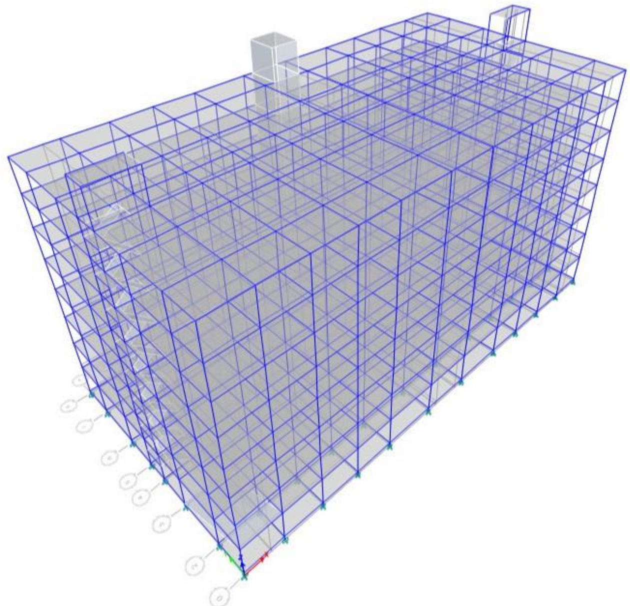

Figure 6. *Symmetric Plan 3D View.*

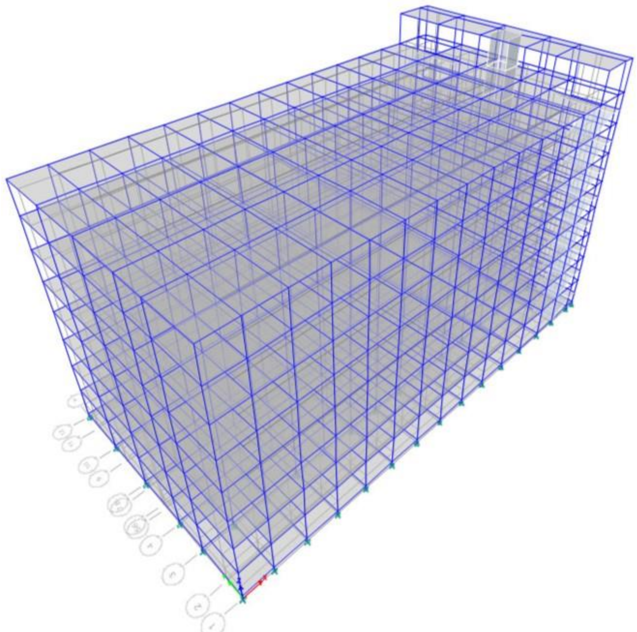

Figure 7. *Asymmetric Plan 3D View.*

The 3D model was generated automatically. Figure 6 shows the diagram of the symmetrical structure in 3D view. Figure 7 shows the diagram of the asymmetrical structure in 3D view. Then, using ETABS analysis, we examined the structure as well as the data on deflection, drift, storey shear, overturning moment, storey drift, etc. for various seismic risk zones. These facts served as the basis for the comparison.

2.2. Tables

Table 1. *Material Properties.*

Name	Type	Unit Weight, lb/ft^2	Modulus of Elasticity, lb/in^2	Grade
Concrete 4000psi	Concrete	150	3604996.53	f'c=4000psi
Rebar 60,000psi	Rebar	490	29000000	f'c=60000psi

Table 2. *Frame Section Properties.*

Name	Material	Section Shape
Beam 2'x 1.5'	Concrete 4000psi	Concrete Rectangular
Column 2'x 2'	Concrete 4000psi	Concrete Rectangular
Column 2.5'x 2.5'	Concrete 4000psi	Concrete Rectangular
Stair Beam 1'x 1'	Concrete 4000psi	Concrete Rectangular

Table 3. *Shell Section Properties.*

Name	Type	Element Type	Material	Thickness, in
Shear Wall Lift 8"	Wall	Shell-thin	Concrete 4000psi	8
Slab 8"	Slab	Membrane	Concrete 4000psi	8
Underground Slab 10"	Slab	Membrane	Concrete 4000psi	10
Waist Slab 8"	Slab	Membrane	Concrete 4000psi	8

Table 4. *Seismic Properties.*

Zone	Zone Coefficient	Wind Speed (m/s)
Zone-I (Rajshahi)	0.12	49.2
Zone-II (Dhaka)	0.20	65.7
Zone-III (Chittagong)	0.28	80.0
Zone-IV (Kurigram)	0.36	65.6

Table 5. *Load Pattern.*

Load	Type	Self-weight Multiplier	Auto Load
Dead	Dead	1	Self-weight

Load	Type	Self-weight Multiplier	Auto Load
Live	Live	0	---
Floor Finish	Super Dead	0	---
Parapet Wall	Super Dead	0	---
Partition Load	Dead	0	---
Eq X	Seismic	0	IS 1893:2016
Eq Y	Seismic	0	IS 1893:2016
Wind Load X	Wind	0	Indian IS 875:2015
Wind Load Y	Wind	0	Indian IS 875:2015

Table 6. Load Combinations.

Sl. No.	Load Combination	Sl. No.	Load Combination
1	1.4DL	17	1.2DL +LL +0.3Ex - Ey
2	1.2DL+1.6LL	18	1.2DL +LL -0.3Ex + Ey
3	1.2 DL+LL	19	1.2DL +LL -0.3Ex - Ey
4	1.2DL +0.8 Wx	20	0.9 DL + Wx
5	1.2DL +0.8 Wy	21	0.9 DL + Wy
6	1.2DL -0.8 Wx	22	0.9 DL - Wx
7	1.2DL -0.8 Wy	23	0.9 DL - Wy
8	1.2 DL +LL + 1.6 Wx	24	0.823 DL + Ex + 0.3 Ey
9	1.2 DL +LL + 1.6 Wy	25	0.823 DL + Ex - 0.3 Ey
10	1.2 DL +LL - 1.6 Wx	26	0.823 DL - Ex + 0.3 Ey
11	1.2 DL +LL - 1.6 Wy	27	0.823 DL - Ex - 0.3 Ey
12	1.2DL +LL + Ex + 0.3 Ey	28	0.823 DL +0.3Ex + Ey
13	1.2DL +LL + Ex - 0.3 Ey	29	0.823 DL +0.3Ex - Ey
14	1.2DL +LL - Ex + 0.3 Ey	30	0.823 DL -0.3Ex + Ey
15	1.2DL +LL - Ex - 0.3 Ey	31	0.823 DL -0.3Ex - Ey
16	1.2DL +LL +0.3Ex + Ey		* DL = DL' + FF + PW

3. Result

3.1. Seismic Zone-I (z=0.12)

3.1.1. Maximum Storey Drift Due to Seismic Load

The variation in storey drift to storey along X-axis (longer direction) is displayed in Figure 8 and Table 9. It is visible from the figure that, drift drift is higher for symmetric cases along X-axis (longer direction).

Again, the variation in storey drift to storey along Y-axis (shorter direction) is displayed in Figure 9 and Table 10. It is portrayed from the figure that, drift is higher for asymmetric cases along Y-axis (shorter direction).

Drift is observed to be increased from the 2nd to 3rd floor and then decreased gradually for the other stories.

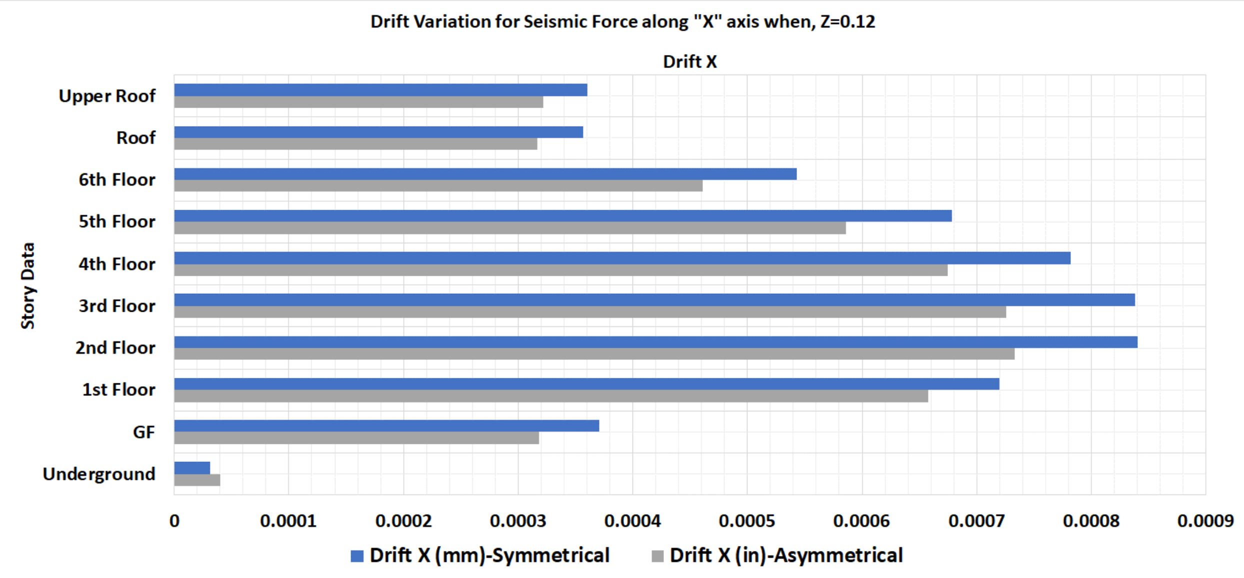

Figure 8. *Variation in Storey Drift for E_x.*

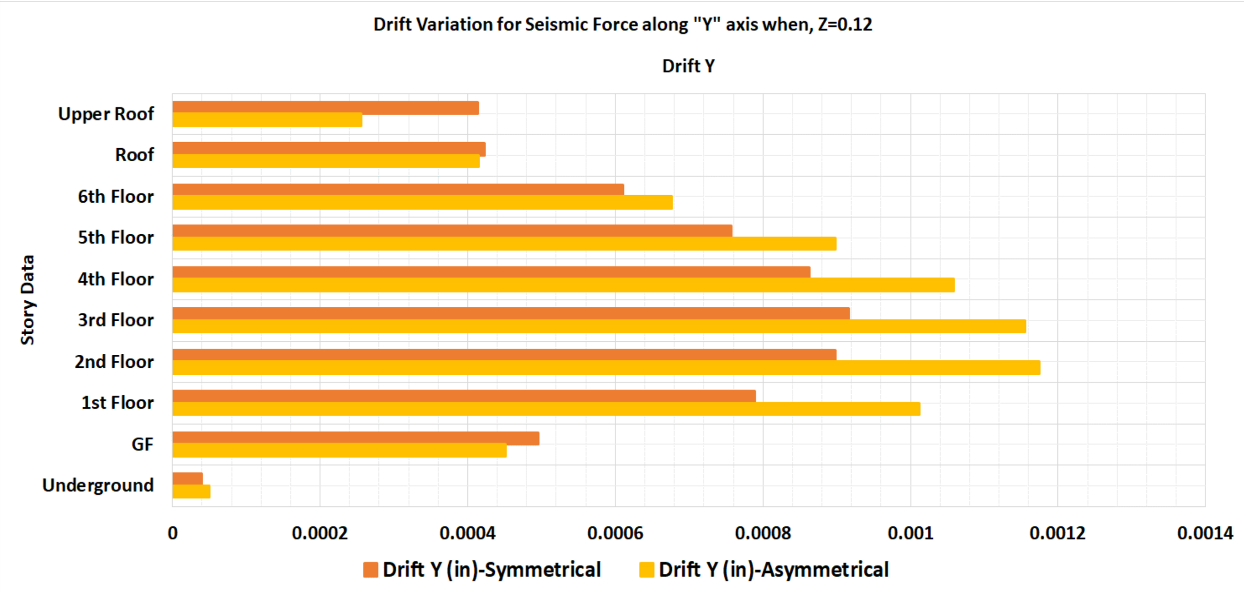

Figure 9. *Variation in Storey Drift for E_y.*

3.1.2. Overturning Moment Due to Seismic Load

The variation in overturning moment with respect to storey along X-axis is displayed in Figure 10 and Table 17. It is visible from the figure that, overturning moment for both symmetrical and asymmetrical plans is non-linear. The value is higher for asymmetric plan in this case.

Again, the variation in overturning moment with respect to storey along Y-axis is displayed in Figure 11 and Table 17. It is portrayed from the figure that, the moment for both symmetrical and asymmetrical plans is non-linear and the value is lesser for the asymmetric case.

The overturning moment is observed to be increased till the middle of the building height and then decreased giving parabolic shape to the graph.

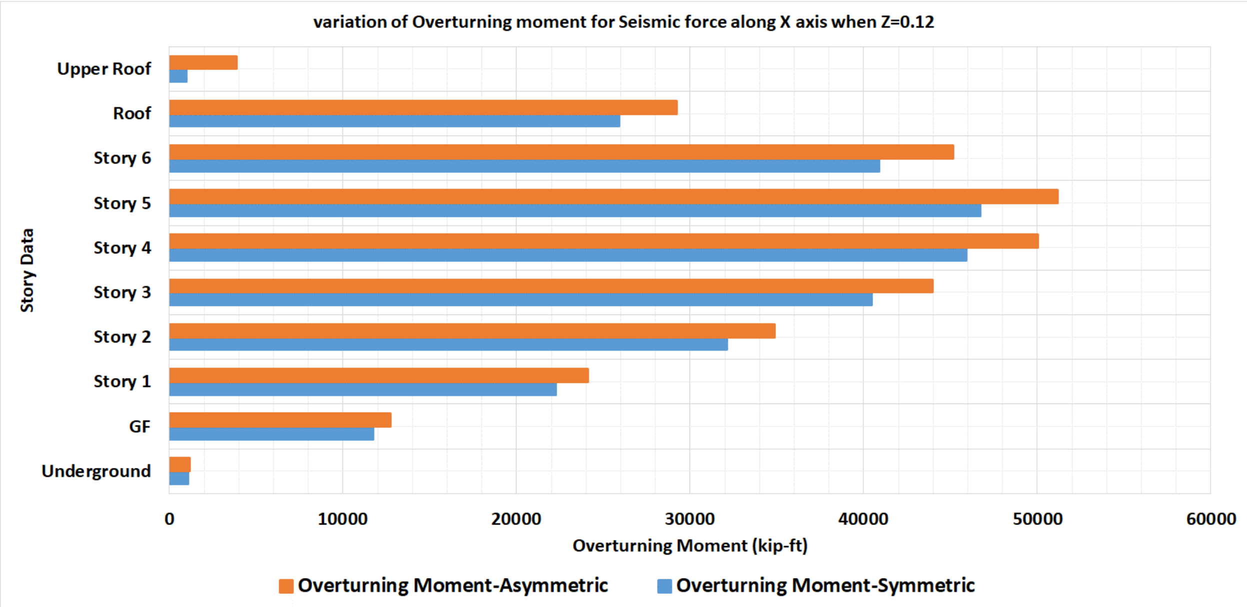

Figure 10. *Variation in Overturning Moment with respect to E_x.*

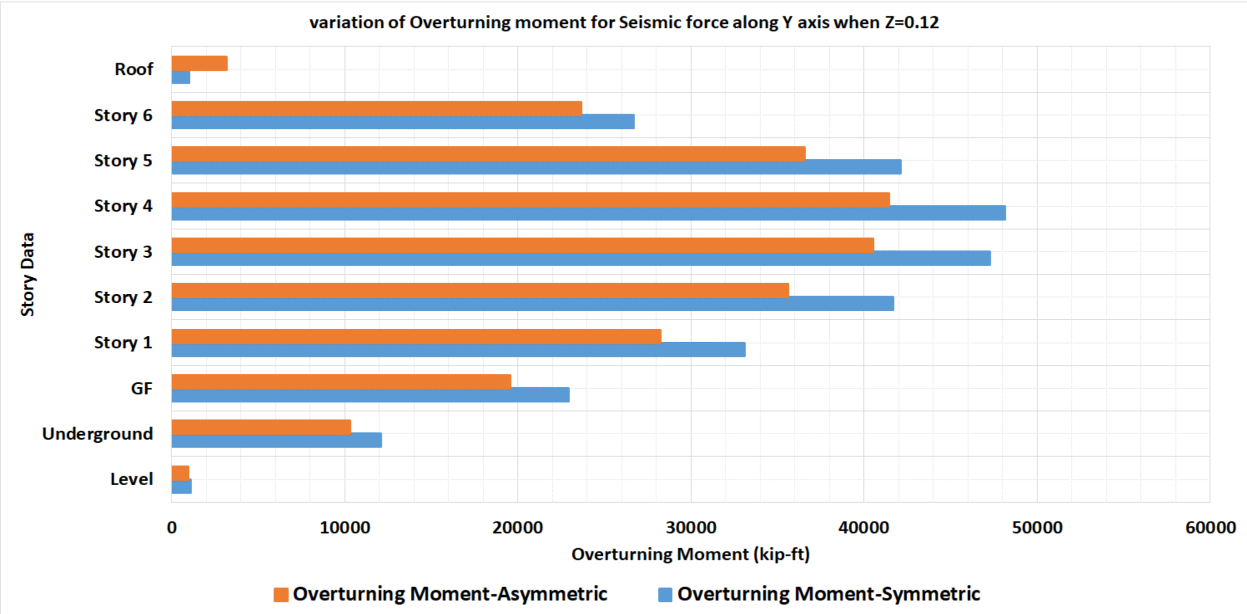

Figure 11. *Variation in Overturning Moment with respect to E_y.*

3.1.3. Storey Shear Due to Seismic Load

The variation in storey shear with respect to storey along X-axis is displayed in Figure 12 and Table 9. It is visible from the figure that, storey shear for both symmetrical and asymmetrical plans is non-linear. The value is higher for asymmetric plan in this case.

Again, the variation in storey shear with respect to storey along Y-axis is displayed in Figure 13 and Table 10. It is portrayed from the figure that, the shear for both symmetrical and asymmetrical plans is non-linear and the value is lesser for the asymmetric case.

The shear for both cases gradually decreased with the increase in the height of the building.

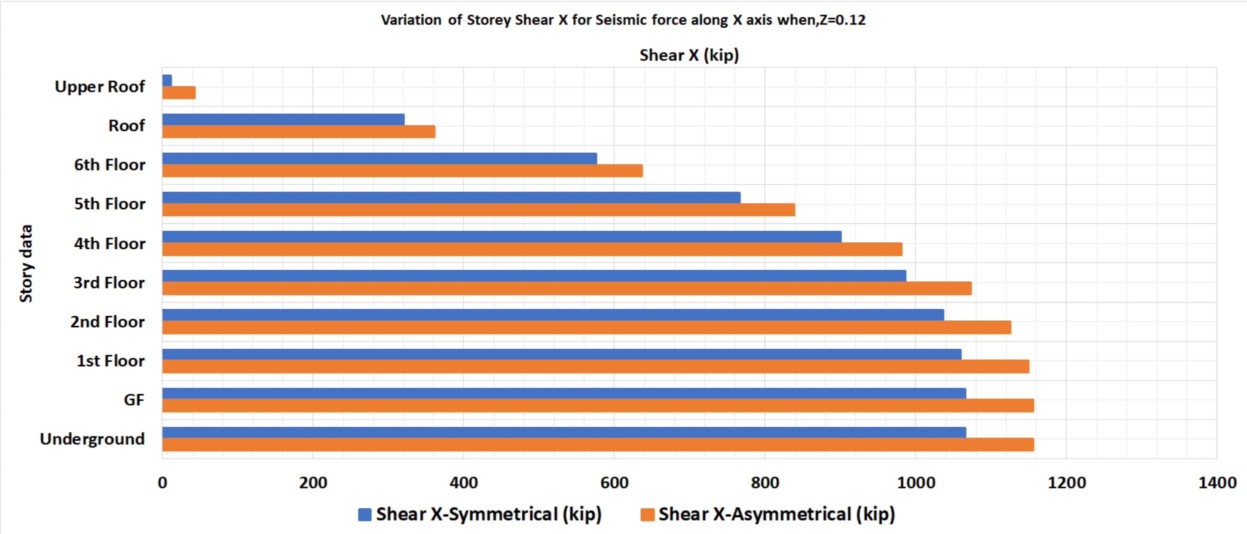

Figure 12. Variation in Storey Shear with respect to E_x.

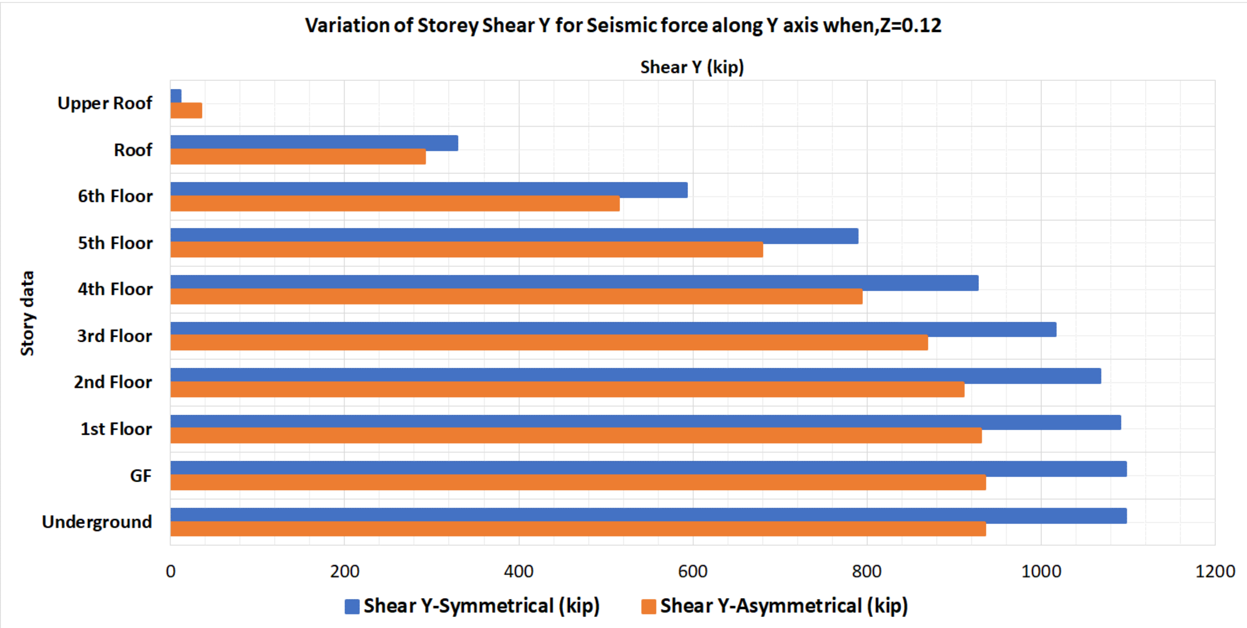

Figure 13. Variation in Storey Shear with respect to E_y.

3.1.4. Storey Stiffness Due to Seismic Load

The variation in storey stiffness with respect to storey along X-axis is displayed in Figure 14 and Table 9. Stiffness seemed to be higher for the asymmetric case as represented in the figure.

Again, the variation in storey stiffness with respect to storey along Y-axis is displayed in Figure 15 and Table 10. It is visible from the graph that stiffness is lesser for the asymmetric case but on the 6th floor, the value of stiffness seems to be the same for both cases.

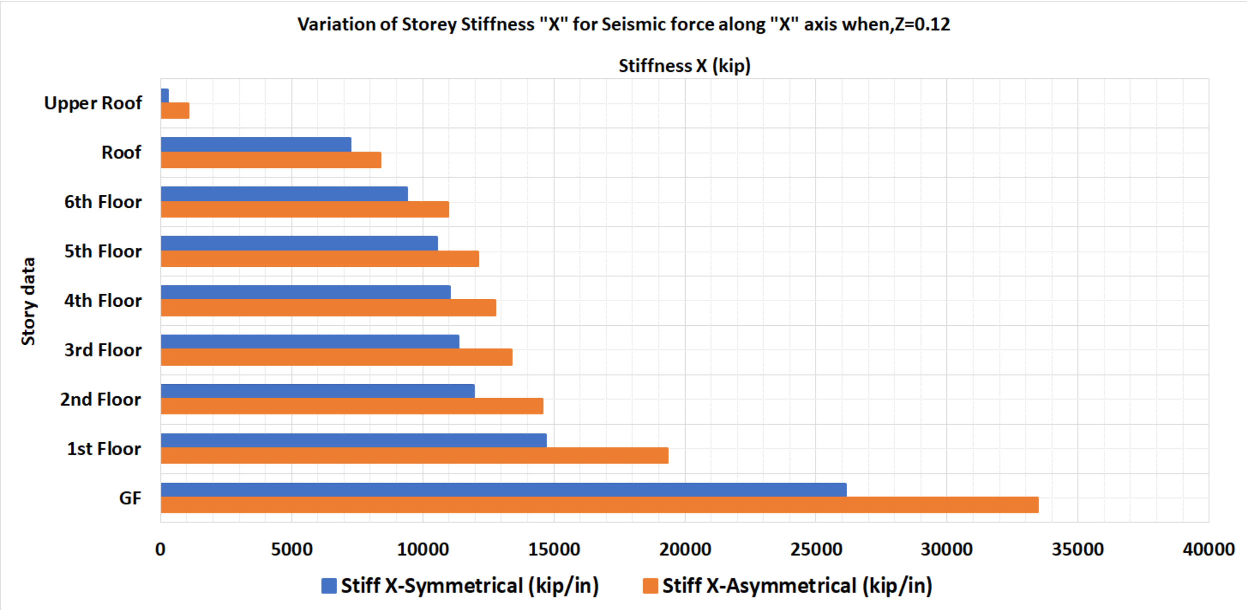

Figure 14. Variation in Storey Stiffness with respect to E_x.

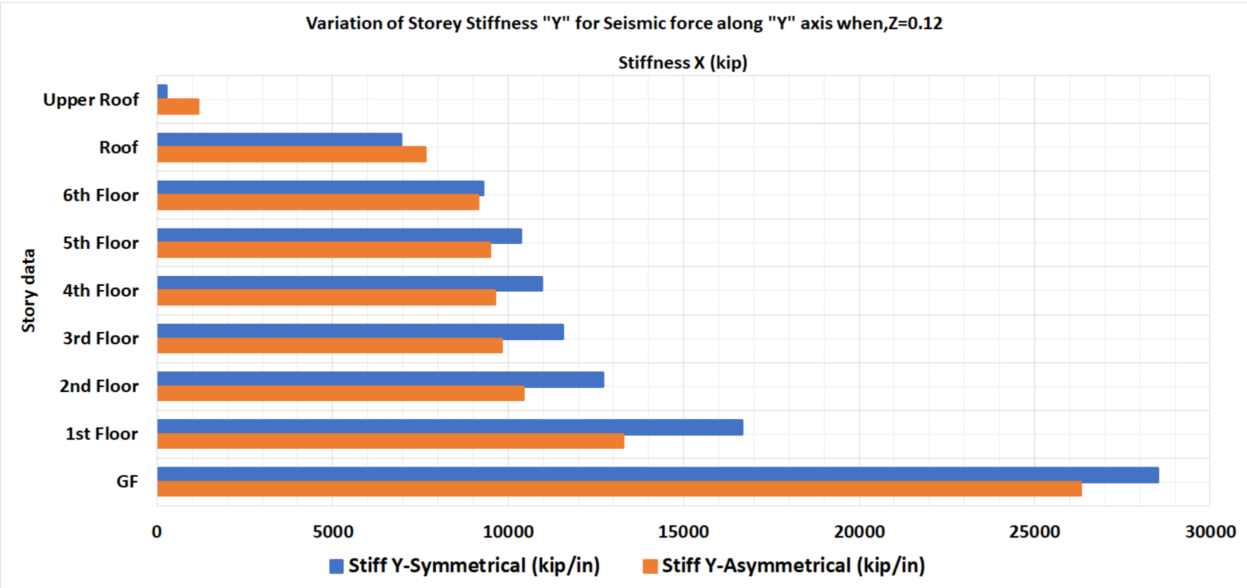

Figure 15. Variation in Storey Stiffness with respect to E_y.

3.2. Seismic Zone-II (z=0.20)

3.2.1. Maximum Storey Drift Due to Seismic Load

The variation in storey drift to storey along X-axis (longer direction) is displayed in Figure 16 and Table 11. It is visible from the figure that, drift drift is higher for symmetric cases along X-axis (longer direction).

Again, the variation in storey drift to storey along Y-axis (shorter direction) is displayed in Figure 17 and Table 12. It is portrayed from the figure that; drift is higher for asymmetric cases along Y-axis (shorter direction).

Drift is observed to be increased from the 2nd to 3rd floor and then decreased gradually for the other stories.

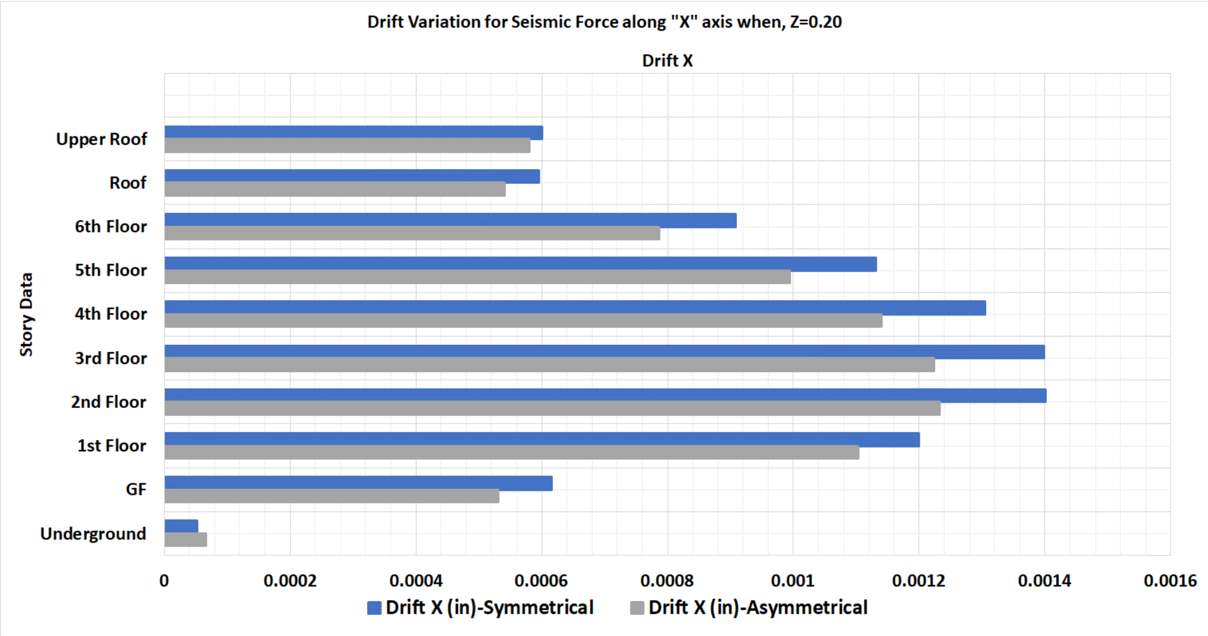

Figure 16. *Variation in Storey Drift with respect to E_x.*

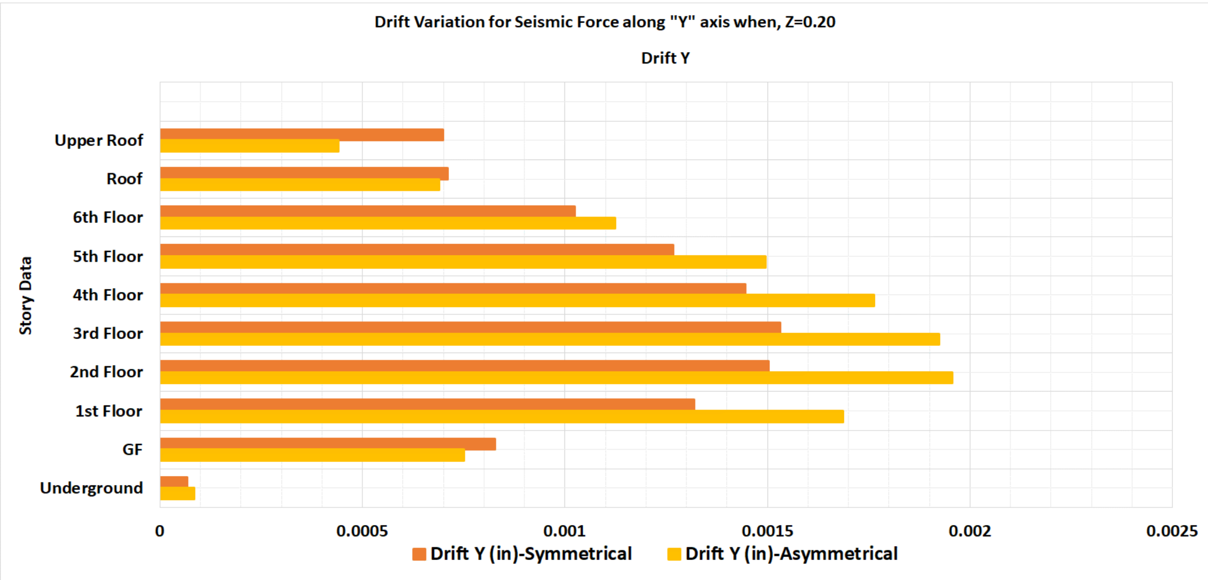

Figure 17. *Variation in Storey Drift with respect to E_y.*

3.2.2. Overturning Moment Due to Seismic Load

The variation in overturning moment with respect to storey along X-axis is displayed in Figure 18 and Table 18. It is visible from the figure that, the overturning moment for both symmetrical and asymmetrical plans is non-linear. The value is higher for asymmetric plan in this case.

Again, variation in overturning moment with respect to storey along Y-axis is displayed in Figure 19 and Table 18. It is portrayed from the figure that, the moment for both symmetrical and asymmetrical plans is non-linear and the value is lesser for the asymmetric case.

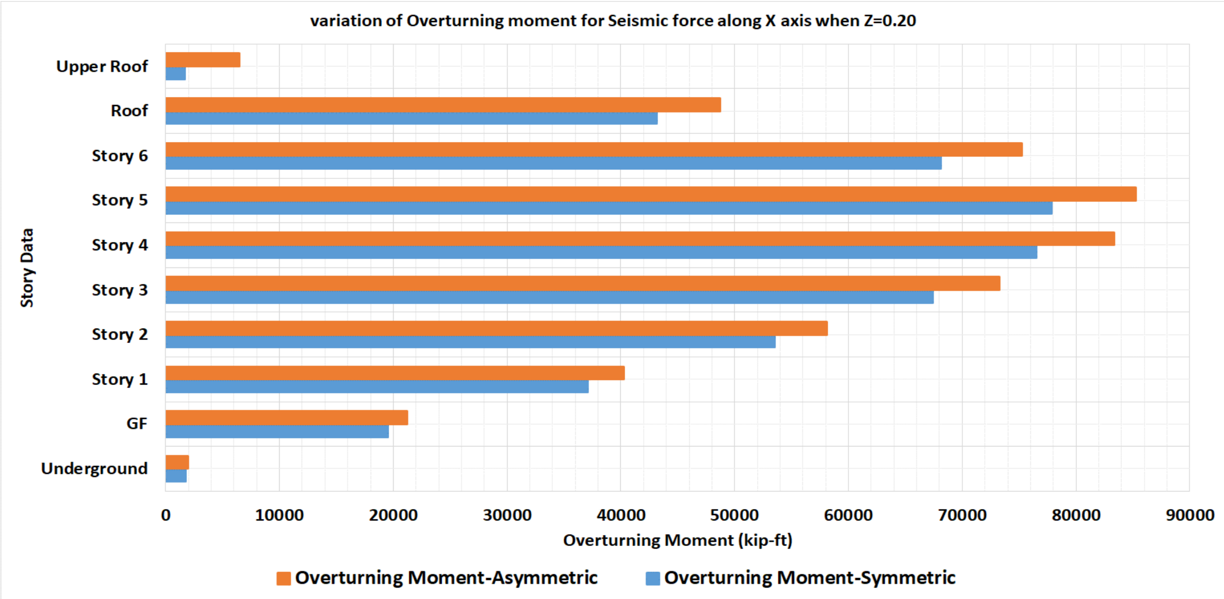

Figure 18. Variation in Overturning Moment with respect to E_x.

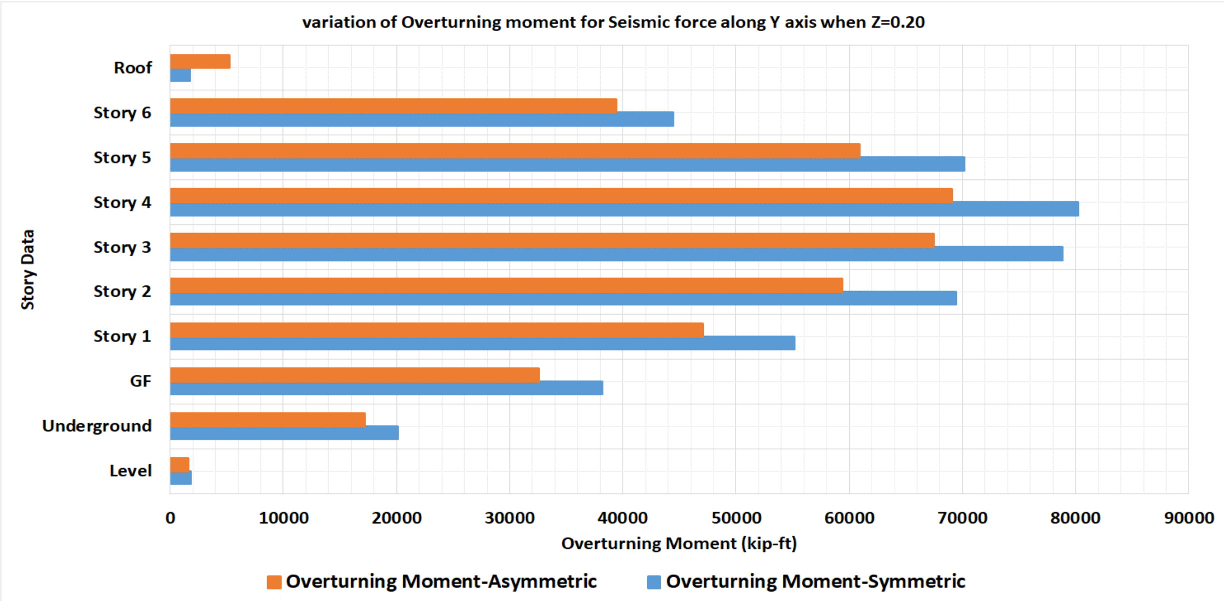

Figure 19. Variation in Overturning Moment with respect to E_y.

The overturning moment is observed to be increased till the middle of the building height and then decreased giving a parabolic shape to the graph.

3.2.3. Storey Shear Due to Seismic Load

The variation in storey shear with respect to storey along X-axis is displayed in Figure 20 and Table 11. It is visible from the figure that, storey shear for both symmetrical and asymmetrical plans is non-linear. The value is higher for asymmetric plan in this case.

Again, the variation in storey shear with respect to storey along Y-axis is displayed in Figure 21 and Table 12. It is portrayed from the figure that, the shear for both symmetrical and asymmetrical plans is non-linear and the value is lesser for the asymmetric case.

The shear for both cases gradually decreased with the increase in the height of the building.

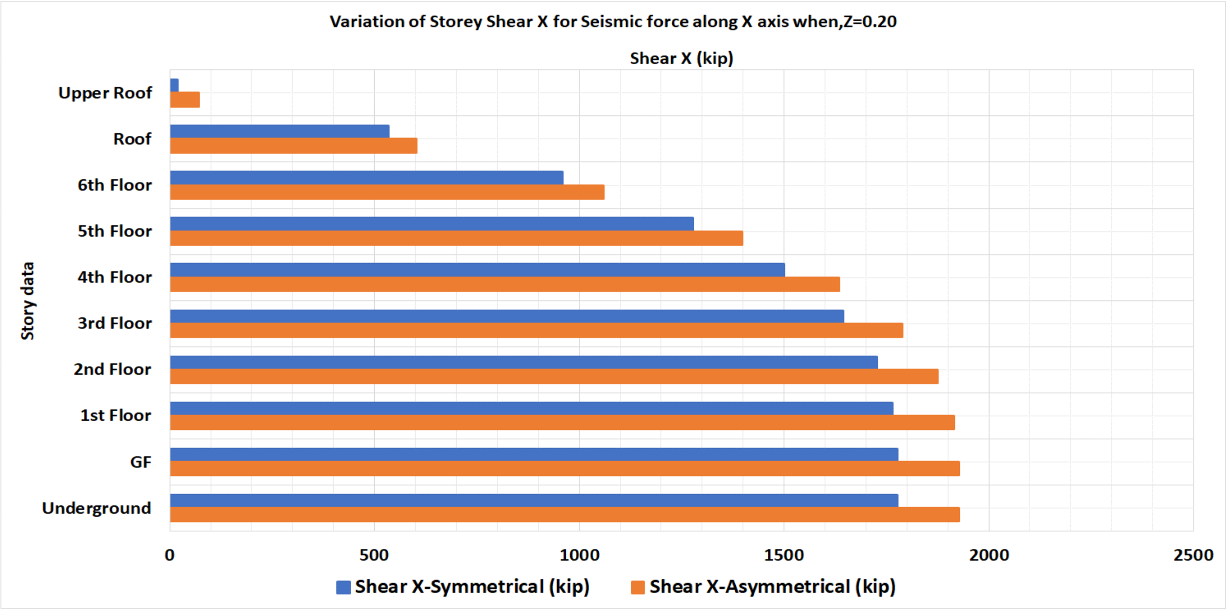

Figure 20. *Variation in Storey Shear with respect to E_x.*

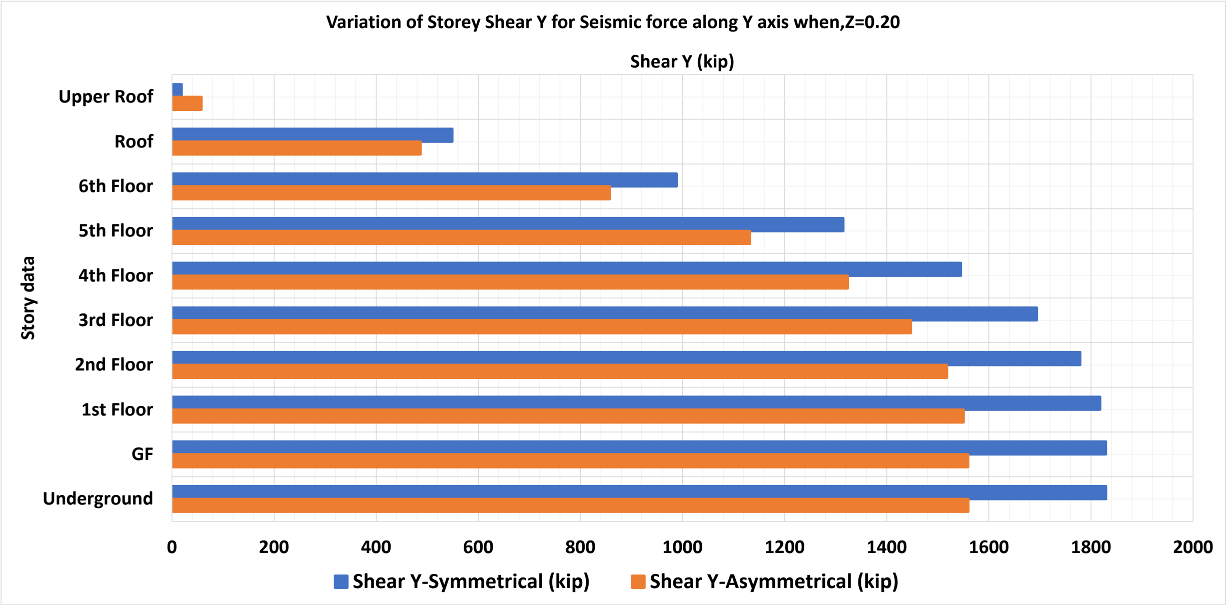

Figure 21. *Variation in Storey Shear with respect to E_y.*

3.2.4. Storey Stiffness Due to Seismic Load

The variation in storey stiffness with respect to storey along X-axis is displayed in Figure 22 and Table 11. Stiffness is seemed to be higher for the asymmetric case as represented in the figure. Again, the variation in storey stiffness with respect to storey along Y-axis is displayed in Figure 23 and Table 12. It is visible from the graph that stiffness is lesser for asymmetric cases but on the 6th floor, value of stiffness seems to be the same for both cases.

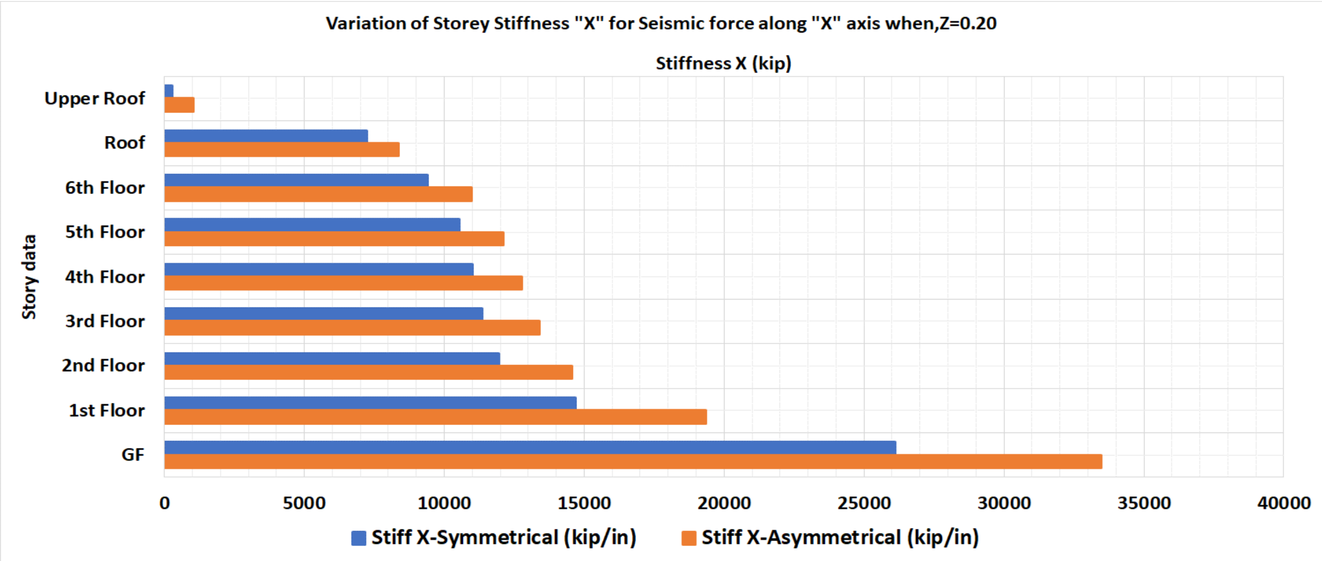

Figure 22. *Variation in Storey Stiffness with respect to* E_x.

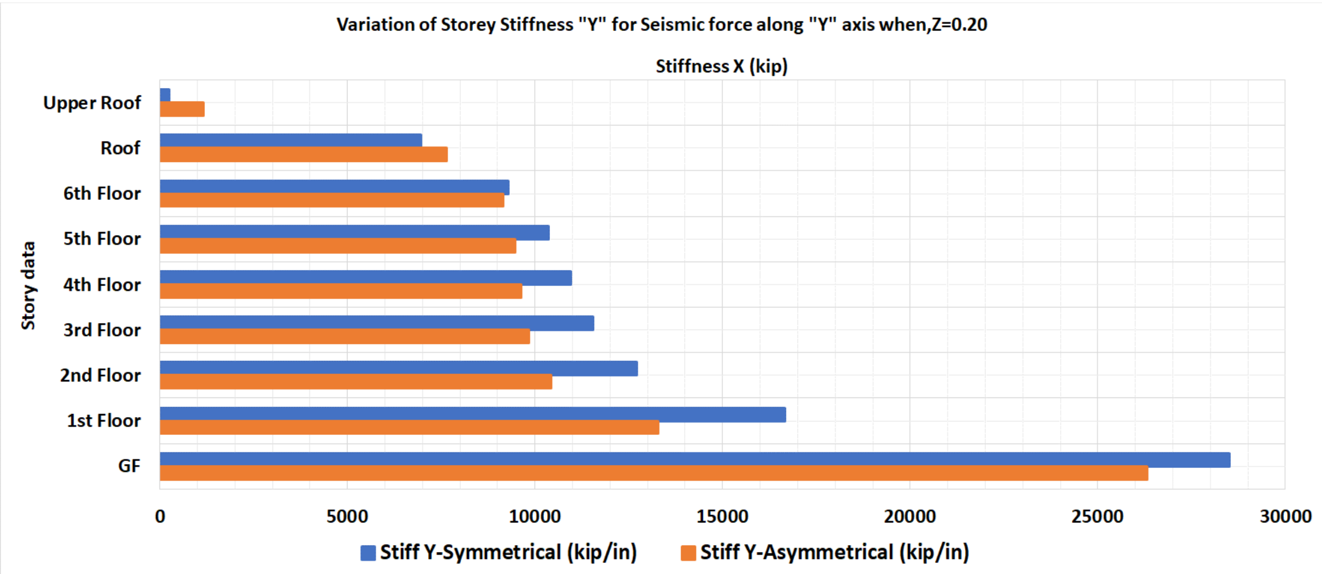

Figure 23. *Variation in Storey Stiffness with respect to* E_y.

3.3. Seismic Zone-III (z=0.28)

3.3.1. Maximum Storey Drift Due to Seismic Load

The variation in storey drift to storey along X-axis (longer direction) is portrayed in Figure 24 and Table 13. It is visible from the figure that, drift drift is higher for symmetric cases along X-axis (longer direction).

Again, the variation in storey drift to storey along Y-axis (shorter direction) is displayed in Figure 25 and Table 14. It is depicted from the figure that; drift is higher for asymmetric cases along Y-axis (shorter direction).

Drift is observed to be increased from the 2nd to 3rd floor and then decreased gradually for the other stories.

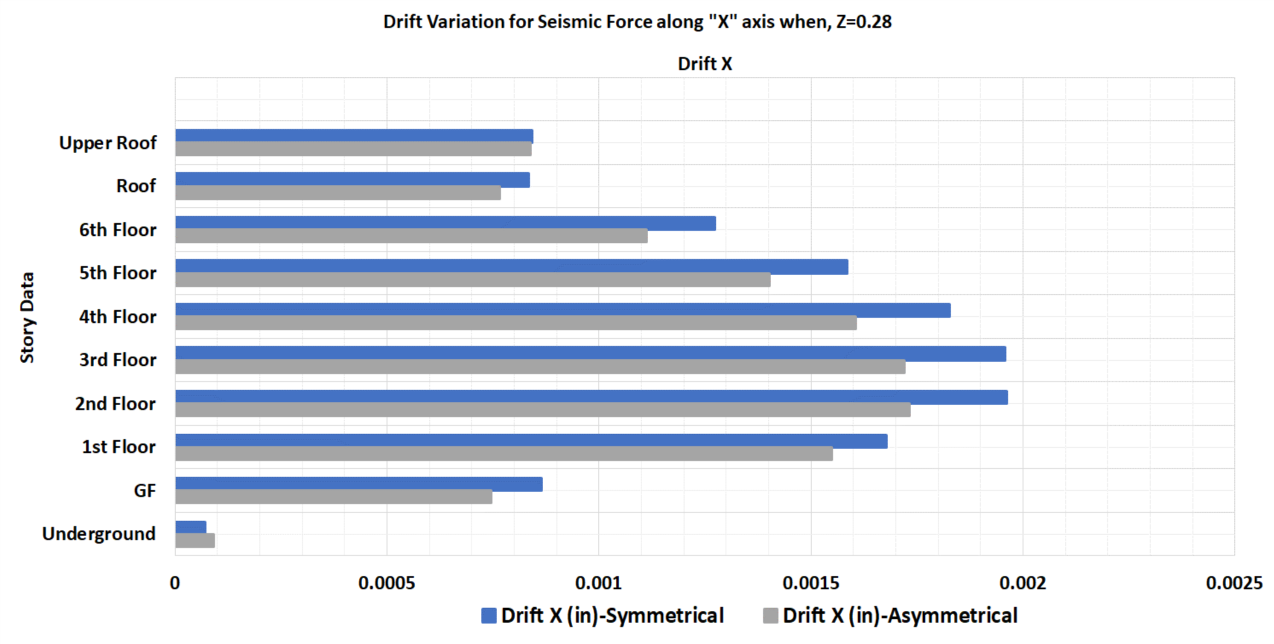

Figure 24. *Variation in Storey Drift with respect to E_x.*

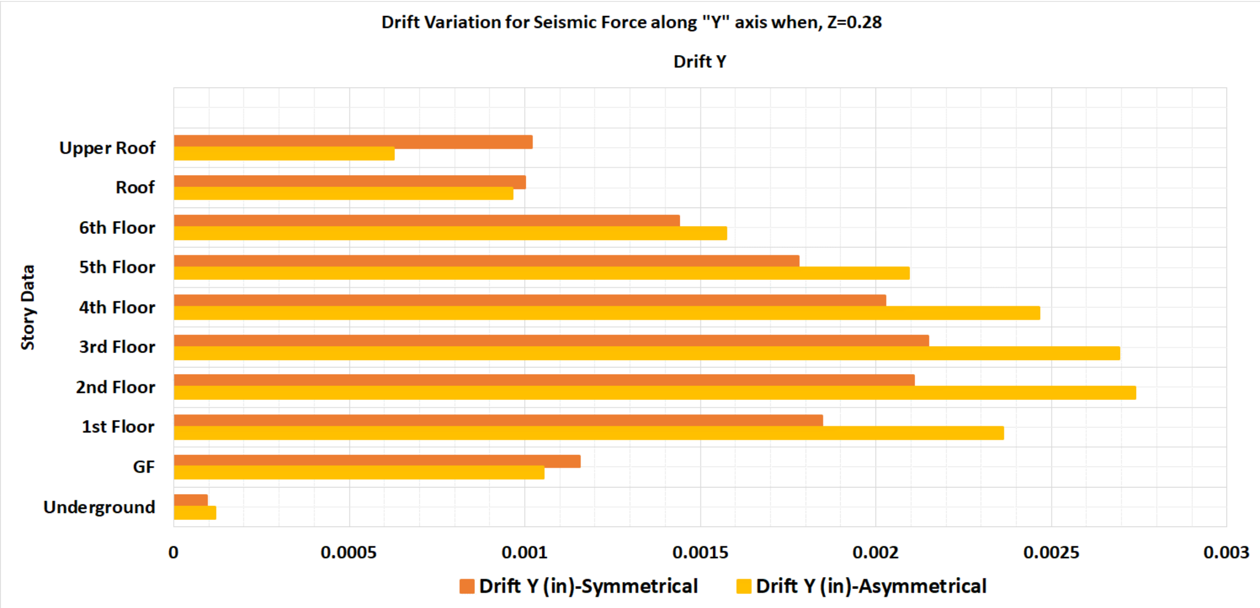

Figure 25. *Variation in Storey Drift with respect to E_y.*

3.3.2. Overturning Moment Due to Seismic Load

The variation in overturning moment with respect to storey along X-axis is portrayed in Figure 26 and Table 19. It is visible from the figure that, the overturning moment for both symmetrical and asymmetrical plans is non-linear. The value is higher for asymmetric plan in this case.

Again, the variation in overturning moment with respect to storey along Y-axis is displayed in Figure 27 and Table 19. It is portrayed from the figure that, the moment for both symmetrical and asymmetrical plan is non-linear and the value is lesser for asymmetric case.

The overturning moment is observed to be increased till the middle of the building height and then decreased giving parabolic shape to the graph.

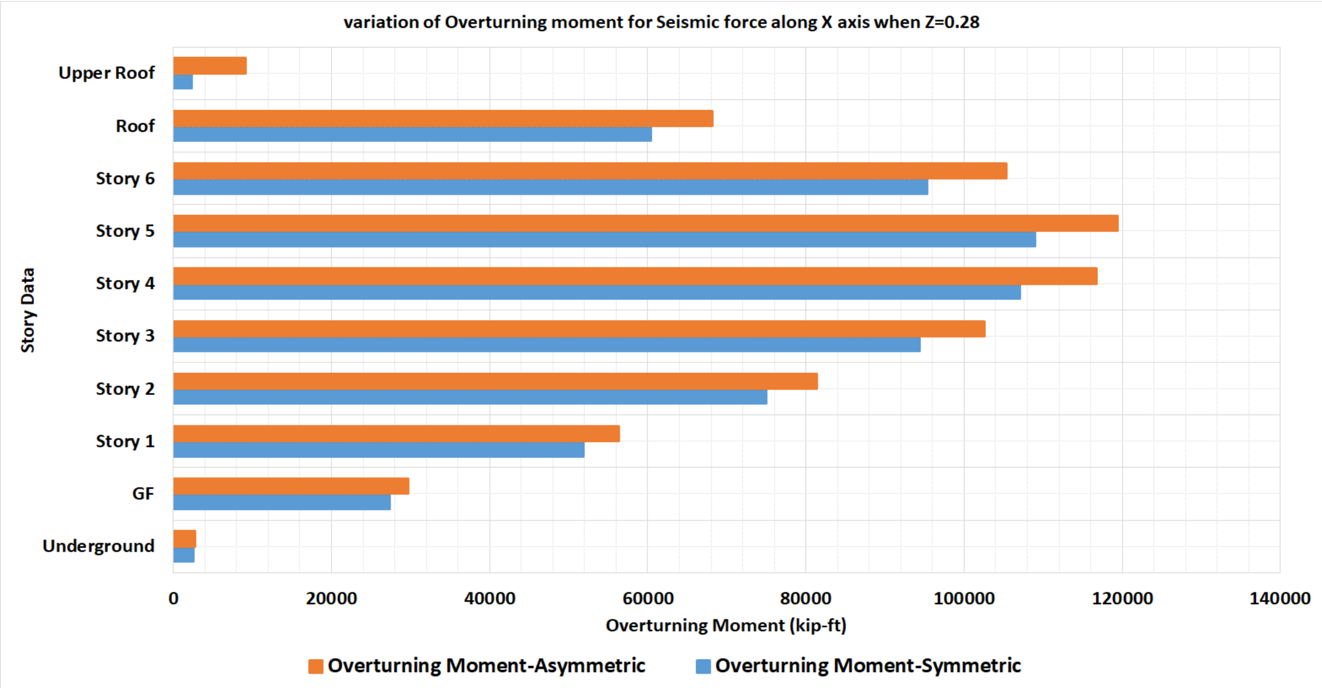

Figure 26. *Variation in Overturning Moment with respect to E_x.*

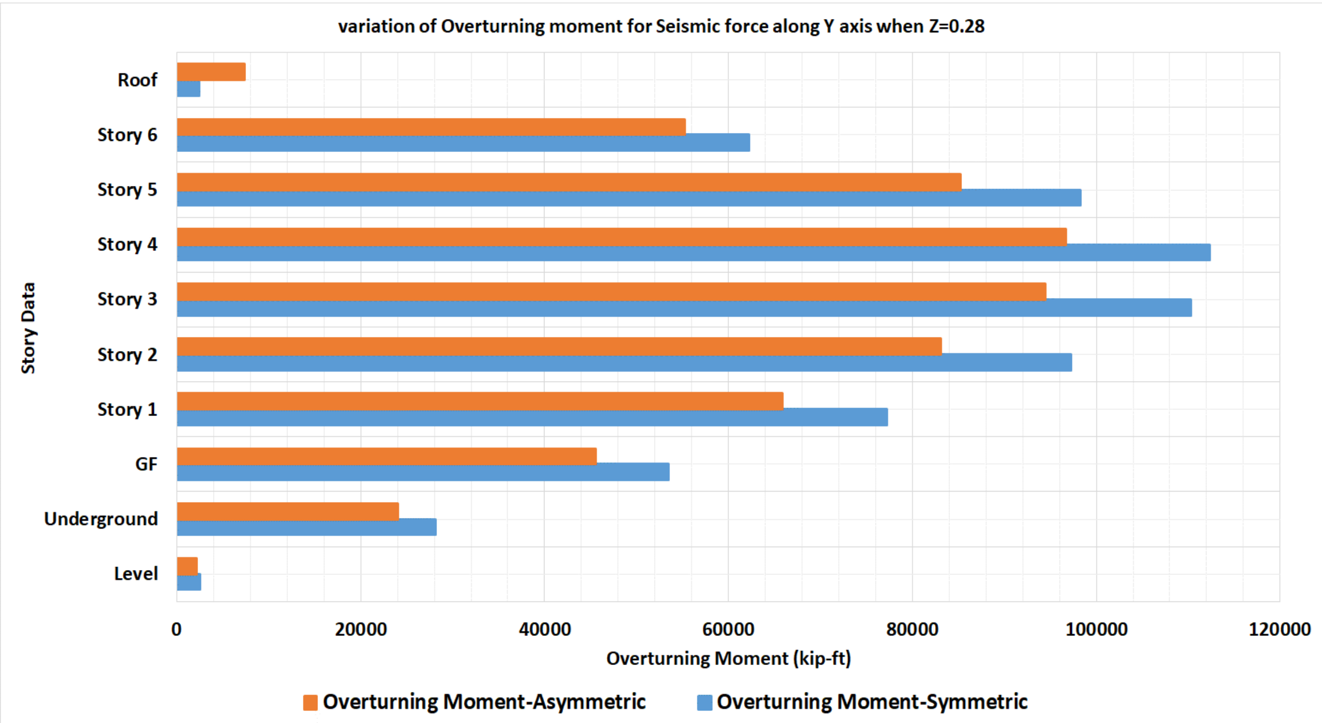

Figure 27. *Variation in Overturning Moment with respect to E_y.*

3.3.3. Storey Shear Due to Seismic Load

The variation in storey shear with respect to storey along X-axis is displayed in Figure 28 and Table 13. It is visible from the figure that, storey shear for both symmetrical and asymmetrical plans is non-linear. The value is higher for asymmetric plan in this case.

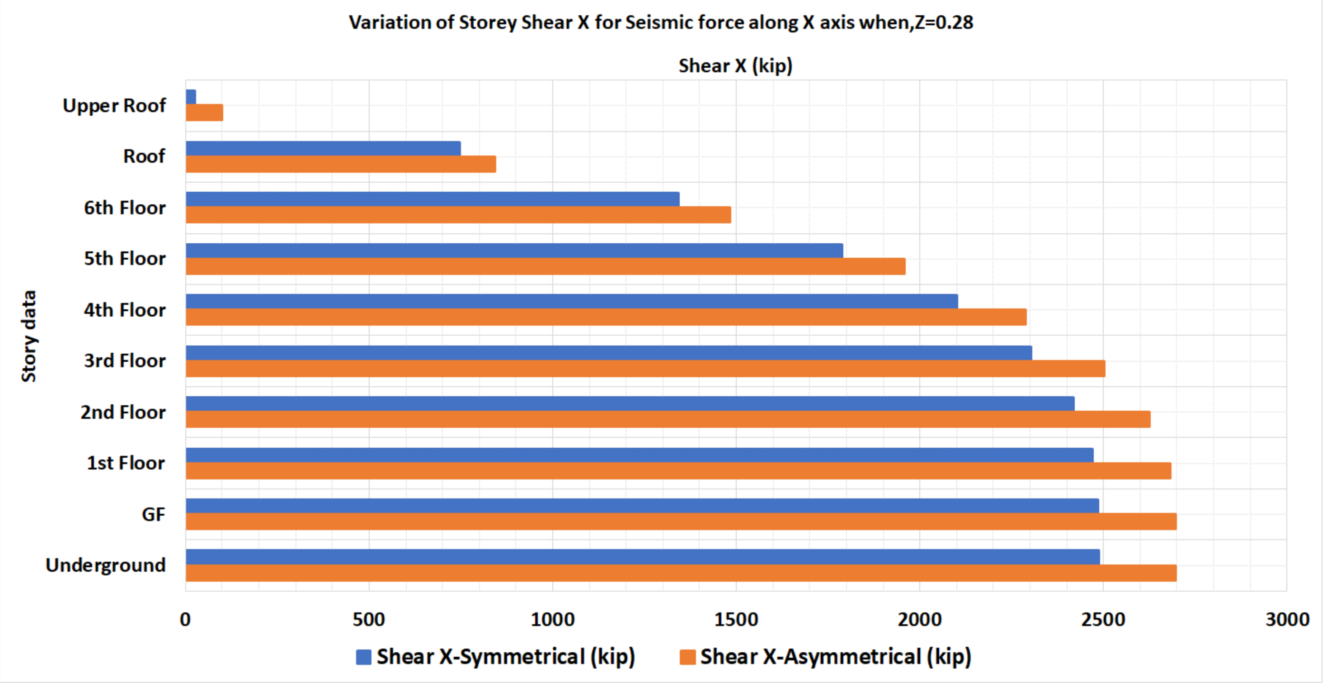

Figure 28. Variation in Storey Shear with respect to E_x.

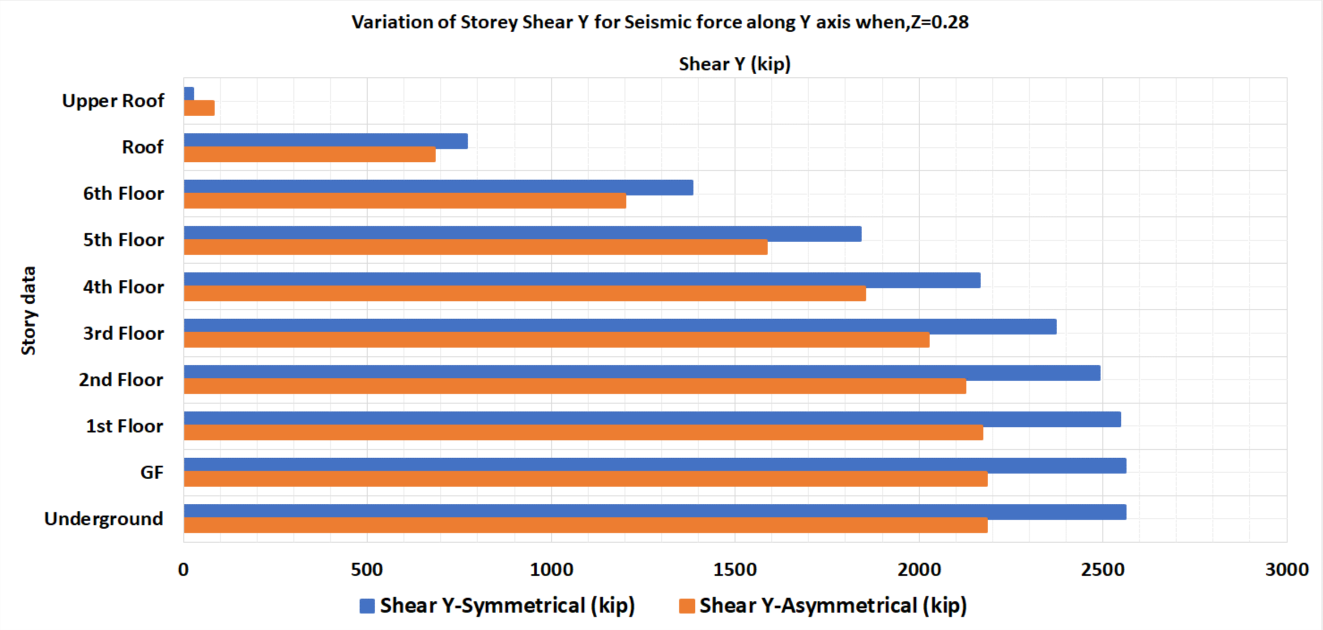

Figure 29. Variation in Storey Shear with respect to E_y.

Again, variation in storey shear with respect to storey along Y-axis is portrayed in Figure 29 and Table 14. It is visible from the figure that, the shear for both symmetrical and asymmetrical plan is non-linear and the value is lesser for asymmetric case.

The shear for both cases gradually decreased with the increase of the height of the building.

3.3.4. Storey Stiffness Due to Seismic Load

The variation in storey stiffness with respect to storey along X-axis is displayed in Figure 30 and Table 13. Stiffness seemed to be higher for the asymmetric case as represented in the figure.

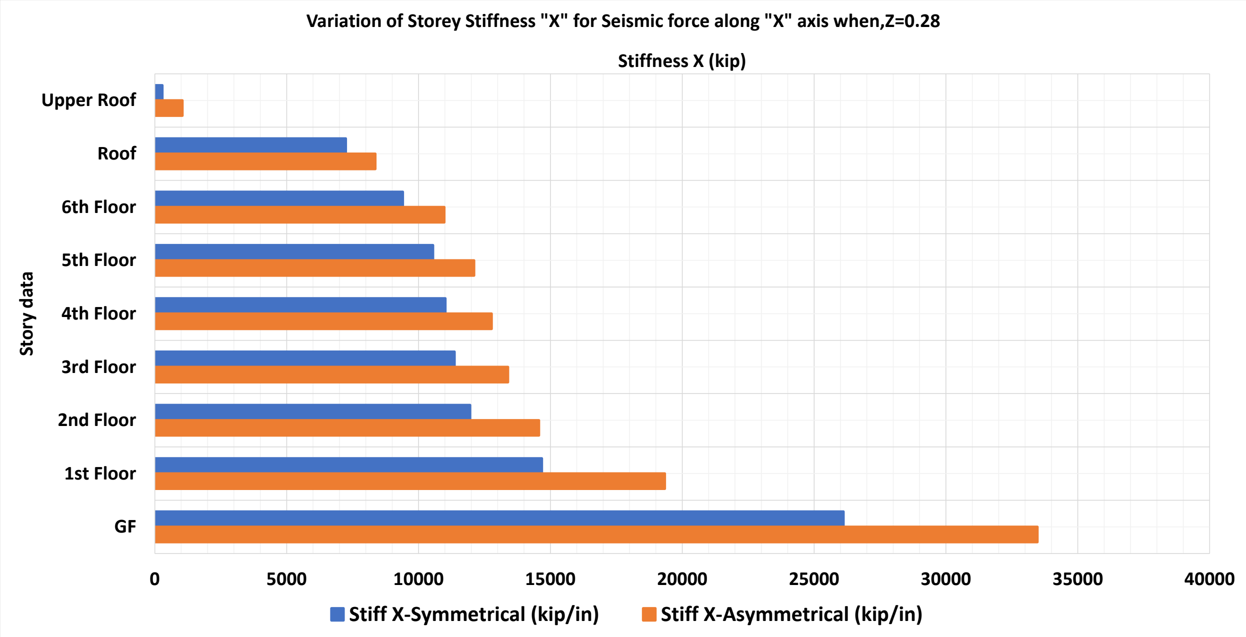

Figure 30. *Variation in Storey Stiffness with respect to* E_x.

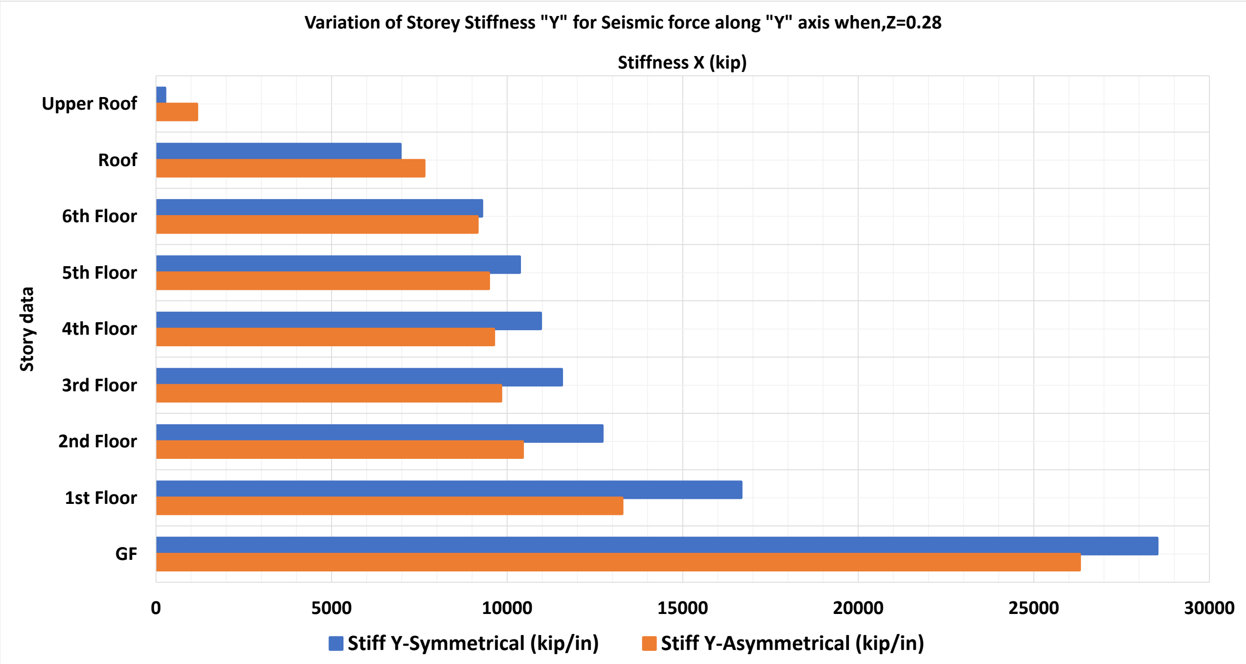

Figure 31. *Variation in Storey Stiffness with respect to* E_y.

Again, the variation in storey stiffness with respect to storey along Y-axis is displayed in Figure 31 and Table 14. It is visible from the graph that stiffness is lesser for asymmetric case but at the 6th floor, value of stiffness seems to be same for both the case.

3.4. Seismic Zone-IV (z=0.36)

3.4.1. Maximum Storey Drift Due to Seismic Load

The variation in storey drift to storey along X-axis (longer direction) is displayed in Figure 32 and Table 15. It is visible from the figure that, drift drift is higher for symmetric cases along X-axis (longer direction).

Again, the variation in storey drift to storey along Y-axis (shorter direction) is displayed in Figure 33 and Table 16. It is portrayed from the figure that; drift is higher for asymmetric cases along Y-axis (shorter direction).

Drift is observed to be increased from the 2nd to 3rd floor and then decreased gradually for the other stories.

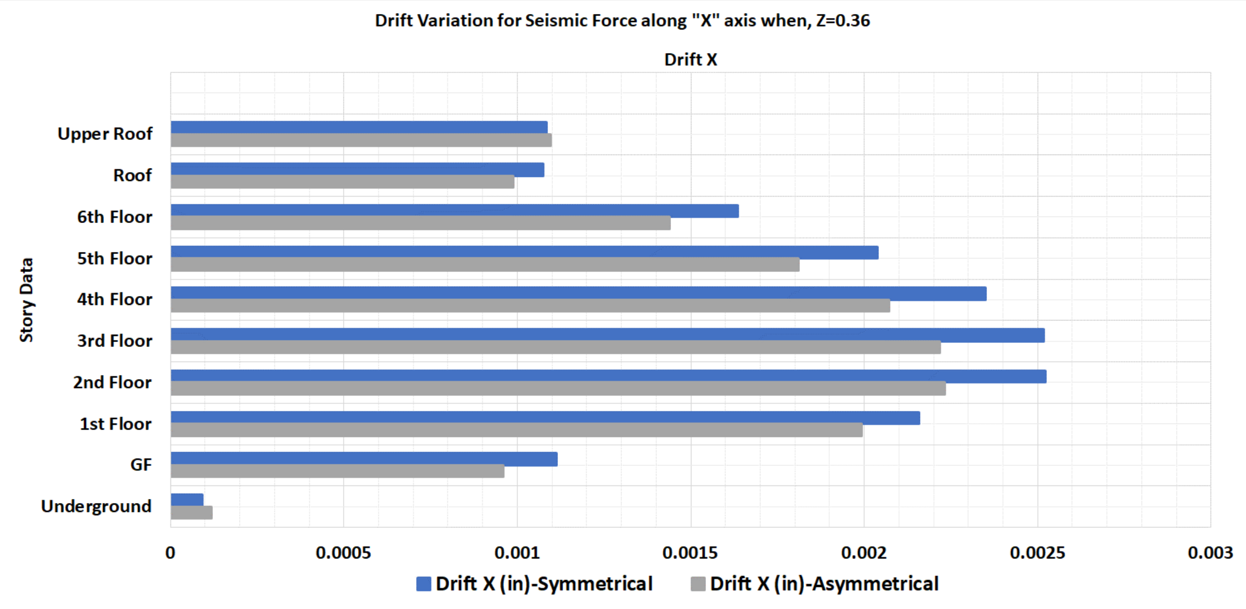

Figure 32. *Variation in Storey Drift with respect to E_x.*

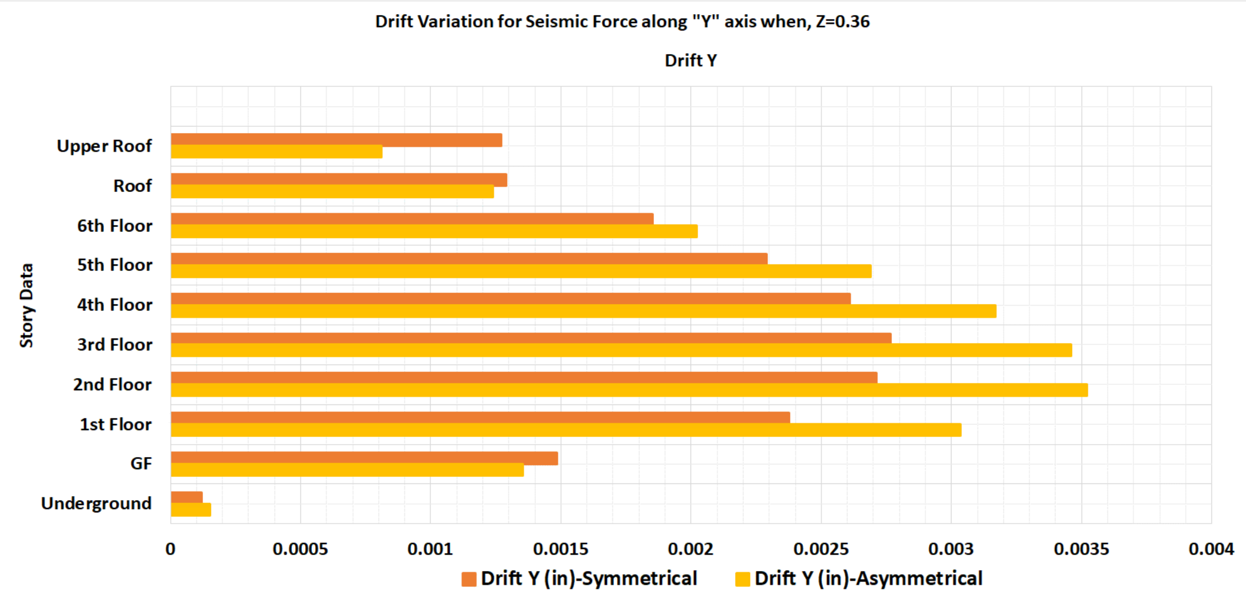

Figure 33. *Variation in Storey Drift with respect to E_y.*

3.4.2. Overturning Moment Due to Seismic Load

The variation in overturning moment with respect to storey along X-axis is displayed in Figure 34 and Table 20. It is visible from the figure that, overturning moment for both symmetrical and asymmetrical plan is non-linear. The value is higher for asymmetric plan in this case.

Again, variation in overturning moment with respect to storey along Y-axis is displayed in Figure 35 and Table 20. It is portrayed from the figure that, the moment for both symmetrical and asymmetrical plans is non-linear and the value is lesser for the asymmetric case.

The overturning moment is observed to be increased till the middle of the building height and then decreased giving parabolic shape to the graph.

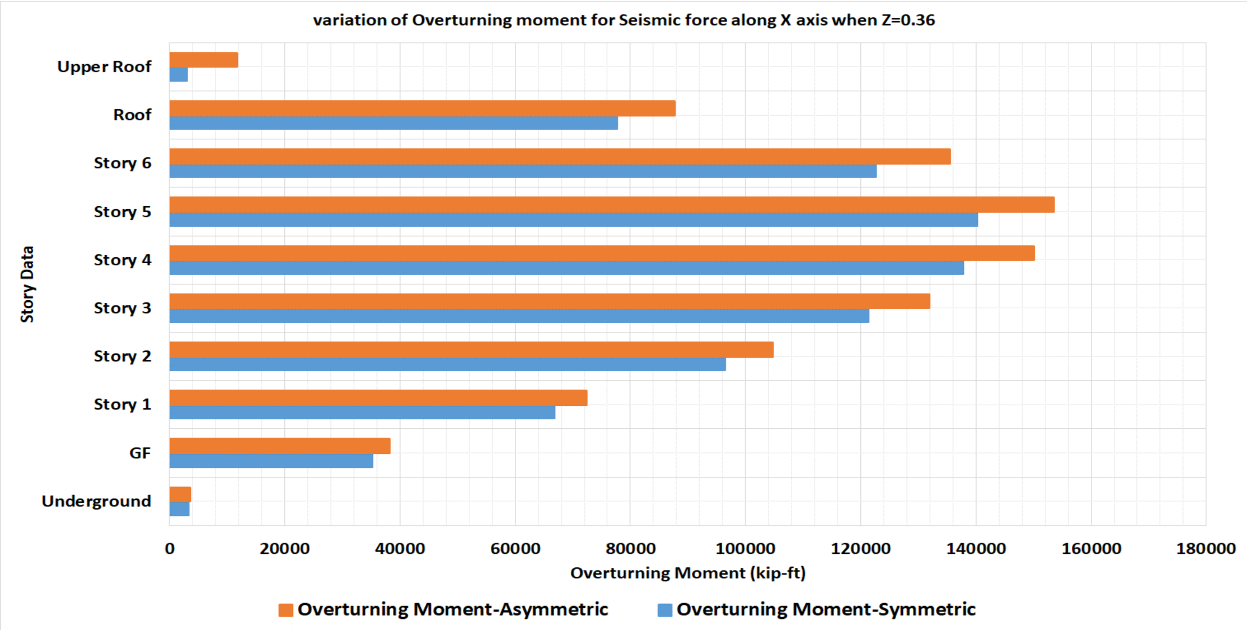

Figure 34. *Variation in Overturning Moment with respect to E_x.*

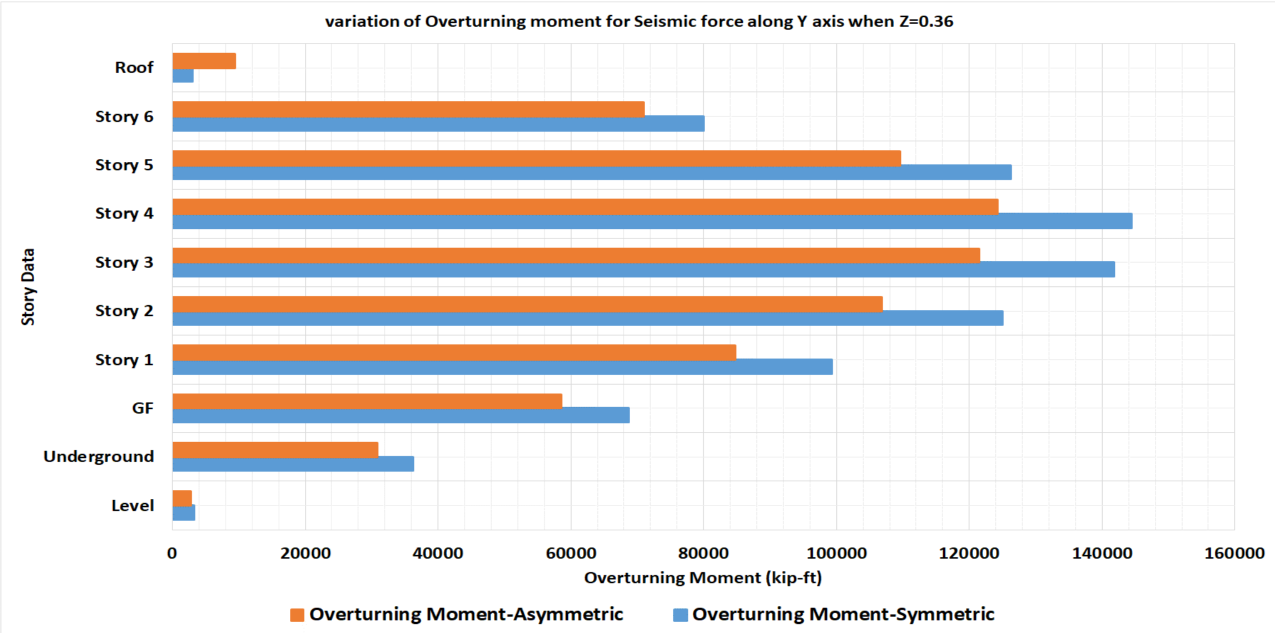

Figure 35. *Variation in Overturning Moment with respect to E_y.*

3.4.3. Storey Shear Due to Seismic Load

The variation in storey shear with respect to storey along X-axis is displayed in Figure 36 and Table 15. It is visible from the figure that, storey shear for both symmetrical and asymmetrical plan is non-linear. The value is higher for asymmetric plan in this case.

Again, the variation in storey shear with respect to storey along Y-axis is displayed in Figure 37 and Table 16. It is portrayed from the figure that, the shear for both symmetrical and asymmetrical plans is non-linear and the value is lesser for the asymmetric case.

The shear for both cases gradually decreased with the increase of the height of the building.

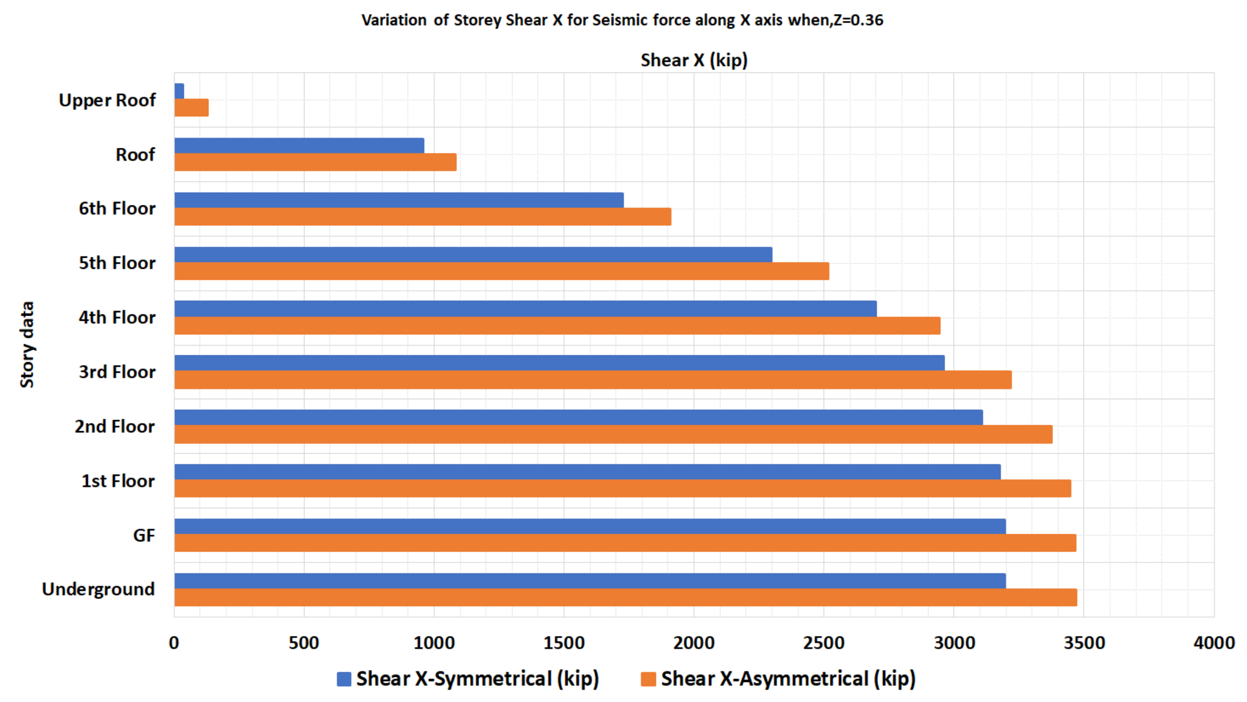

Figure 36. *Variation in Storey Shear with respect to E_x.*

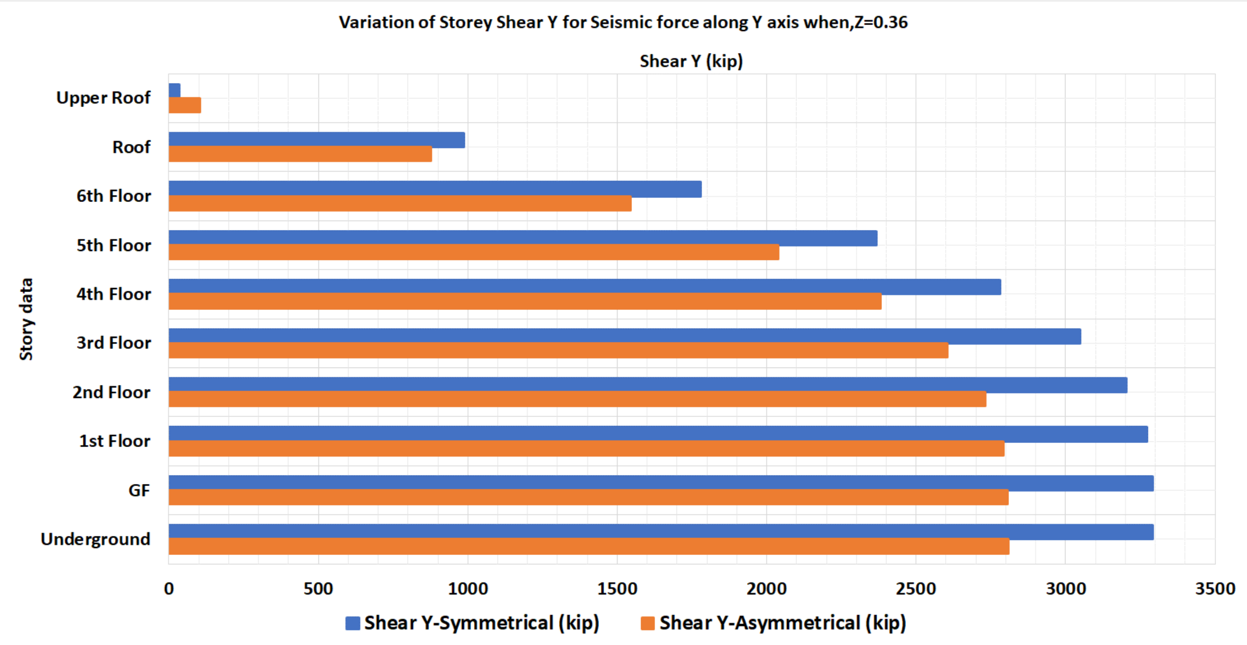

Figure 37. *Variation in Storey Shear with respect to E_y.*

3.4.4. Storey Stiffness Due to Seismic Load

The variation in storey stiffness with respect to storey along X-axis is displayed in Figure 38 and Table 15. Stiffness seemed to be higher for the asymmetric case as represented in the figure.

Again, the variation in storey stiffness with respect to storey along Y-axis is displayed in Figure 39 and Table 16. It is visible from the graph that stiffness is lesser for asymmetric cases but at the 6th floor, value of stiffness seems to be the same for both cases.

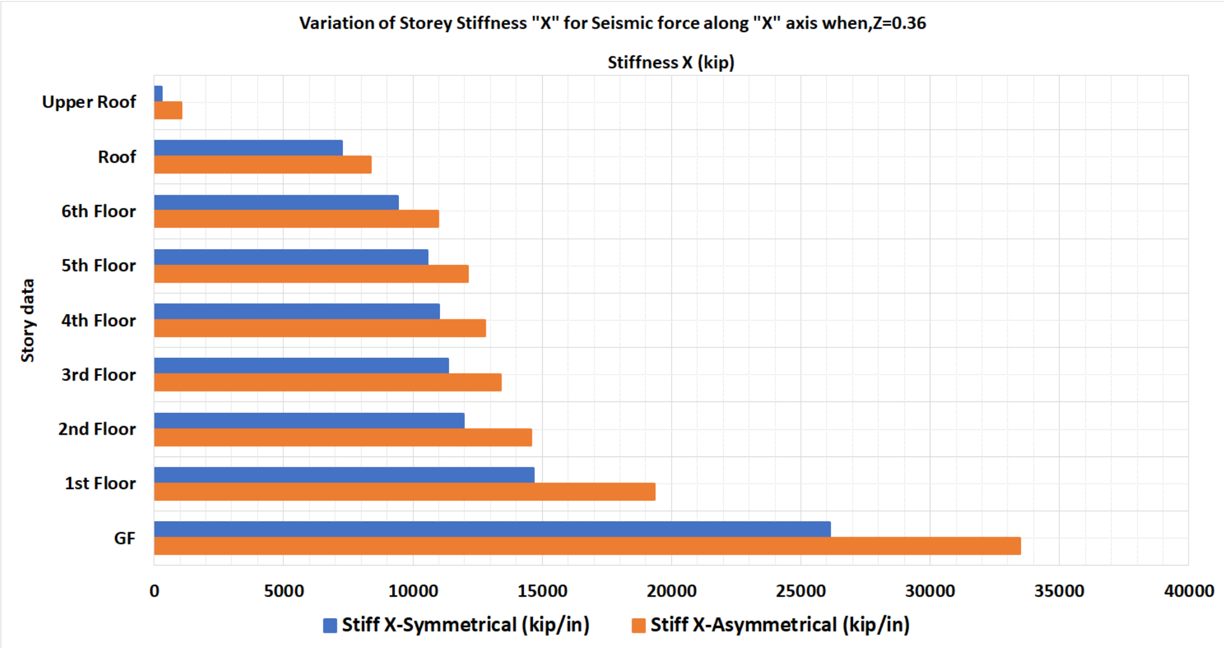

Figure 38. *Variation in Storey Stiffness with respect to* E_x.

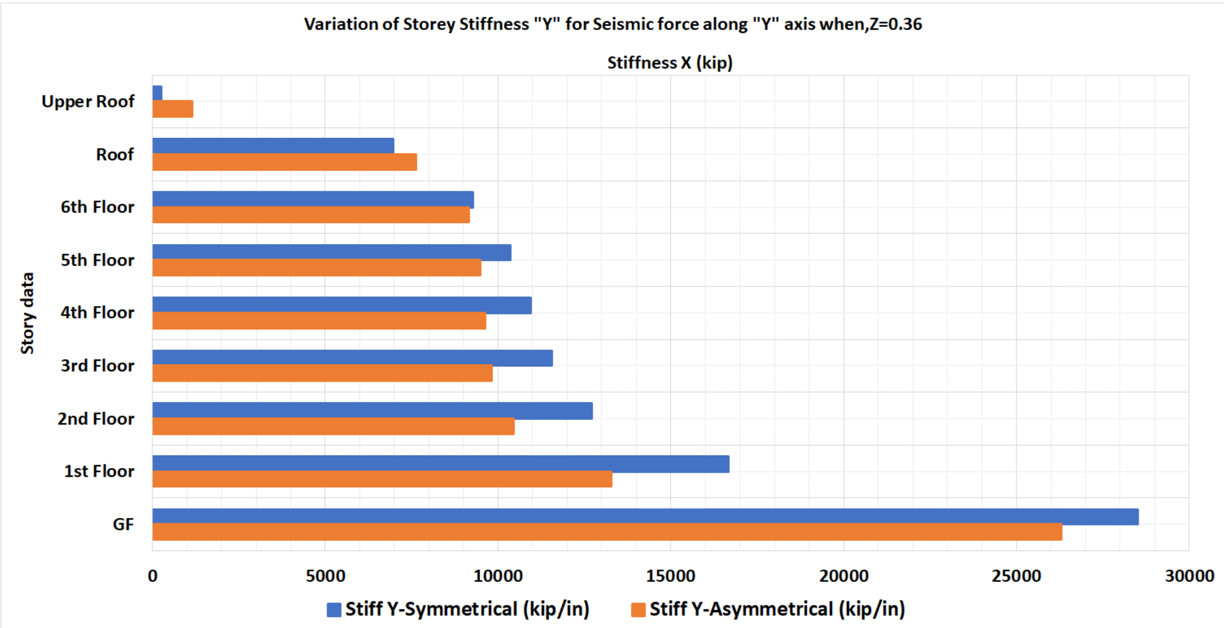

Figure 39. *Variation in Storey Stiffness with respect to* E_y.

3.5. Comparison Between ETABS & Manual Calculation

A manual calculation is performed using traditional method and MS Excel software to calculate the applied lateral force for both "X" and "Y" directions at every story. The lateral force values found from both ETABS and Excel have been compared for both symmetric and asymmetric structures. All manual calculations have been performed by following BNBC 2020.

3.5.1. For Symmetric Plan

The variation in seismic force with respect to storey height for the symmetric plan view is portrayed in Table 7.

***Table 7**. ETABS vs Manual Calculation for Symmetrical.*

		Horizontal Force Act on Floor Due to Seismic Action-Symmetrical			
Story	**Elevation (ft)**	**X-Dir-ETABS (kip)**	**Y-Dir-ETABS (kip)**	**X-Dir-EXCEL (kip)**	**Y-Dir-EXCEL (kip)**
Upper Roof	91	32.71	33.70	57.92	56.99
Roof	81	926.49	954.43	784.49	617.53
Story6	71	767.44	790.58	635.91	482.69
Story5	61	570.91	588.13	463.34	379.93
Story4	51	401.99	414.11	318.80	250.95
Story3	41	259.95	267.79	201.92	149.01
Story2	31	148.72	153.21	112.29	73.66
Story1	21	68.27	70.33	49.35	24.28
GF	11	19.35	19.94	12.35	6.08
Underground	1	0.59	0.61	0.47	0.19

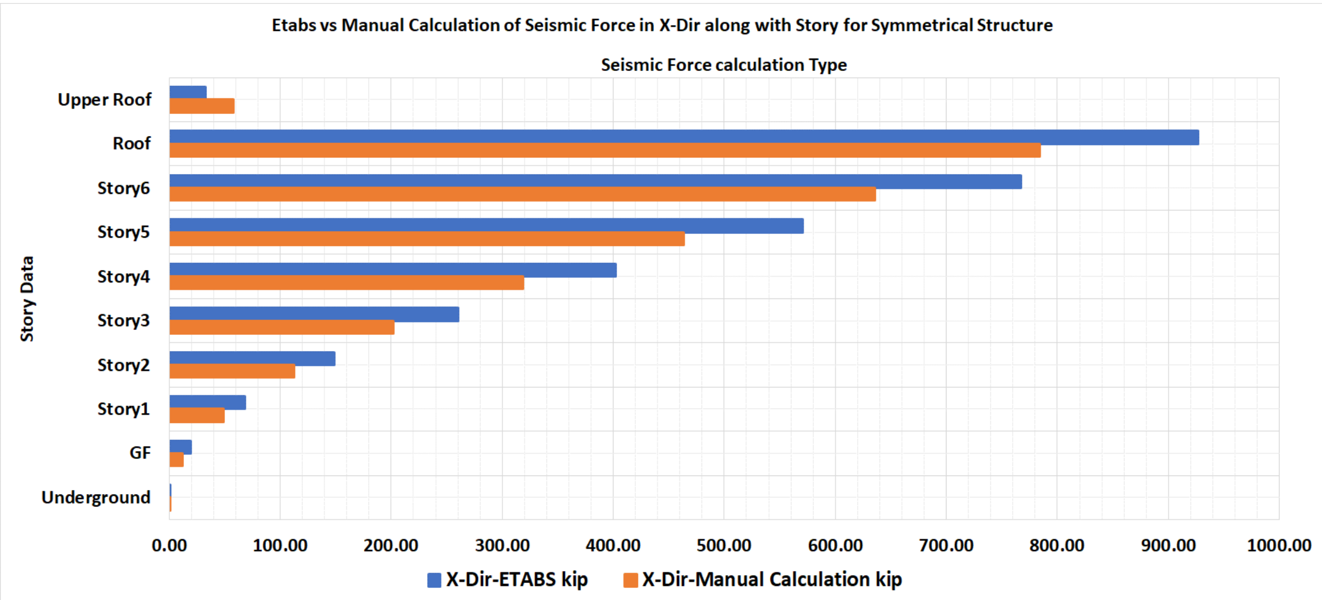

***Figure 40**. Variation in E_x with respect to Storey Height.*

The variation in seismic force along X-axis with respect to storey height for the symmetric plan view is portrayed in Figure 40. Again, the variation in seismic force along Y-axis with respect to storey height for the symmetric plan view is displayed in Figure 41.

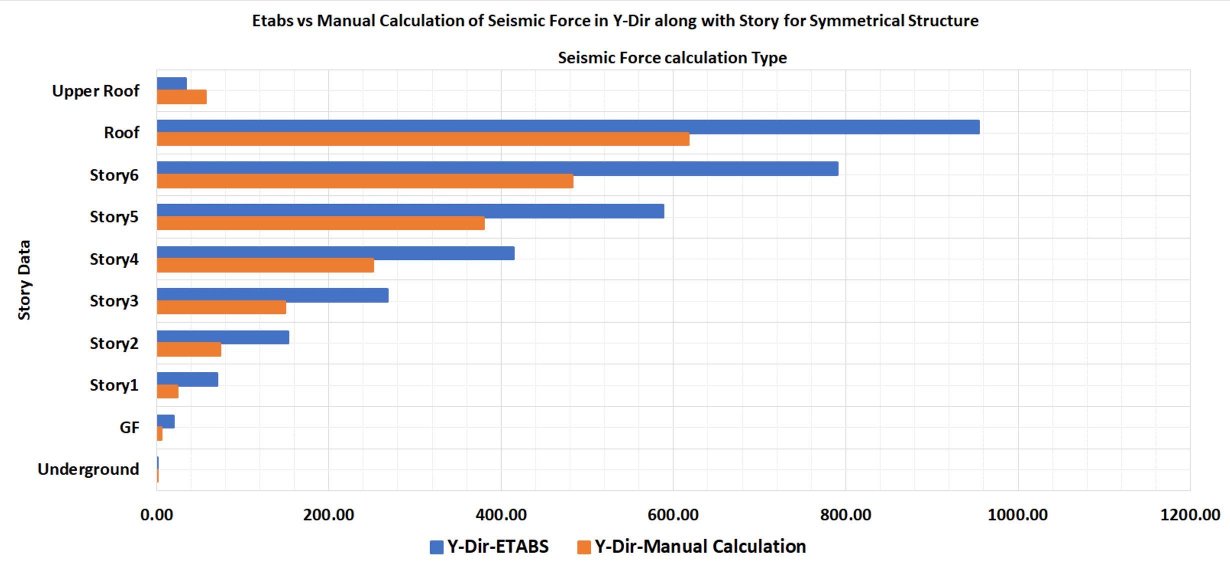

Figure 41. *Variation in* E_y *with respect to Storey Height.*

From the graph, the difference of value is near between ETABS and manual calculation at X axis. Which can be acceptable. But in Y axis, the horizontal force value varies much from story 5 to roof. This may happen because we have used complex load distribution in ETABS but in Excel, we used the total possible building load; for which ETABS shows superior values.

For the safety of the structure, software calculated value was considered for the design of the structure.

3.5.2. For Asymmetric Plan

The variation in seismic force with respect to storey height for the symmetric plan view is displayed in Table 8.

Table 8. *ETABS vs Manual Calculation for Asymmetrical.*

		Horizontal Force Act on Floor Due to Seismic Action-Asymmetrical			
Story	**Elevation (ft)**	**X-Dir-ETABS (kip)**	**Y-Dir-ETABS (kip)**	**X-Dir-EXCEL (kip)**	**Y-Dir-EXCEL (kip)**
Upper Roof	91	71.95	57.87	32.18	31.66
Roof	81	534.47	429.85	435.83	343.07
Story6	71	462.25	371.76	353.28	268.16
Story5	61	341.34	274.52	257.41	211.07
Story4	51	238.60	191.89	177.11	139.42
Story3	41	154.20	124.02	112.18	82.79
Story2	31	88.18	70.92	62.38	40.92
Story1	21	40.48	32.56	27.41	13.49
GF	11	11.31	9.10	6.86	3.38
Underground	1	0.32	0.26	0.26	0.10

The variation in seismic force along X-axis with respect to storey height for the asymmetric plan view is displayed in Figure 42. And the variation in seismic force along Y-axis with respect to storey height for the asymmetric plan view is portrayed in Figure 43.

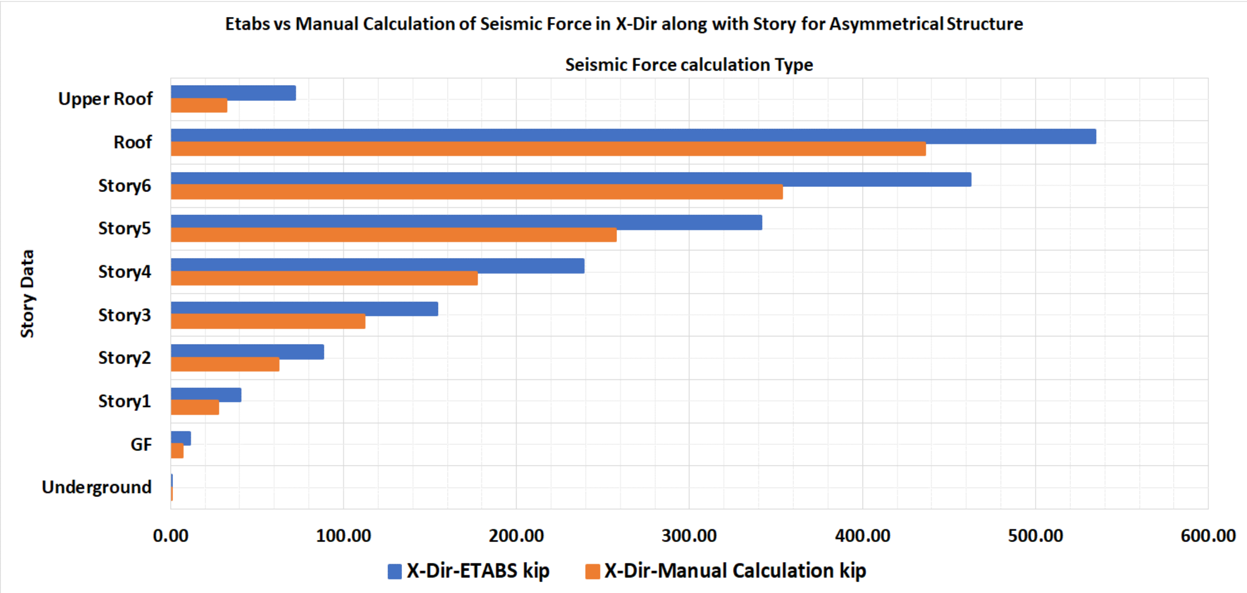

Figure 42. *Variation in* E_x *with respect to Storey Height.*

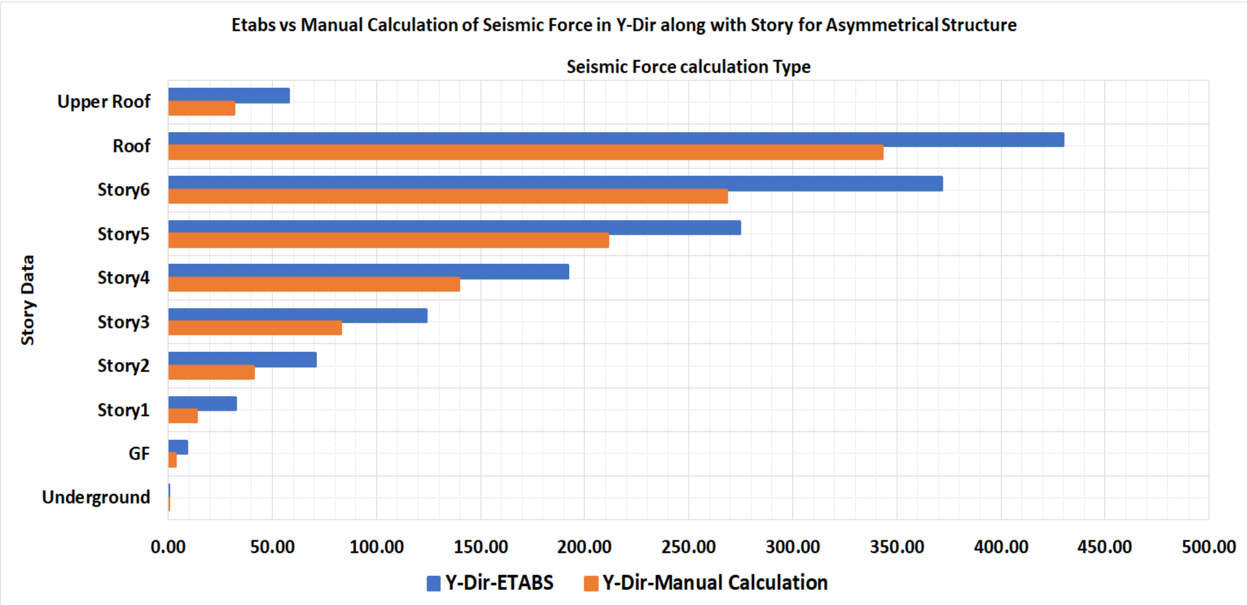

Figure 43. *Variation in* E_y *with respect to Storey Height.*

From the graph, the difference in value is near between ETABS and manual calculation at both X & Y axis; Which can be acceptable. The variation may happen because ETABS used complex load distribution but in manual approach, we used the total possible building load; for which ETABS shows superior values.

We observed Asymmetric structure shows better acceptance compared to Symmetric structure; as variation is close at both axes between ETABS and manual calculation.

However, For the safety of the structure, software calculated value was considered for the design of the structure.

4. Discussions

From our research, we have found that-

The symmetric structure has more drift along length, more stiffness along width, and more overturning moment along width.

The Asymmetric structure has more drift along width, more stiffness along length, and more overturning moment along length.

From these, we have reached a decision that-

1. The symmetric structure may be considered better in terms of stiffness along the width and resistance to

overturning moment along the width.

2. The asymmetric structure may be considered better in terms of drift along the width and stiffness along the length.

In summary, the specific project requirements, including the direction and magnitude of loads, the desired performance criteria such as- minimizing drift, maximizing stiffness, resisting overturning moments, and other factors like construction constraints and cost considerations, all play a role in determining which structure is better. Greater resistance to overturning moments in a certain direction would be preferred if that direction is required by the design.

However, an important factor is how a structure is called symmetric or asymmetric. A symmetric structure can be symmetric along both axis or either one. Again, a symmetric-looking structure can be asymmetric by internal loading arrangement. In this manuscript, emphasis has been given on the loading. For such reason, same number of columns and beams has been used in both structures and arranged differently.

5. Conclusion

From our observation, we can conclude that-

i. Symmetric structure performed better in terms of drift and stiffness along width; overturning moment and shear along length.

ii. Asymmetric structure performed better in terms of drift and stiffness along the length; overturning moment and shear along the width.

iii. The symmetric structure may be somewhat better in the absence of particular project needs or priorities because of its improved ability to withstand overturning moments along its width—a crucial factor in many structural designs. Also, symmetric structure may be preferable due to its lower drift along the width. The finding also matched the generalized preference of Engineers as asymmetricity may impose additional torsion and sway. However, the asymmetric structure might be preferred if increasing stiffness is a crucial requirement for specific construction because it has more stiffness along its length.

iv. The comparison of seismic force between manual and software calculation is another concerning interest of this study, the graphical evaluation represents a slight deviation between both the calculations. The difference may have caused due to the use of sophisticated load distribution in ETABS compared to the use of the total possible building load in the manual technique, for which ETABS offers superior figures. We observed asymmetric structure exhibits higher acceptability than symmetric structure because the difference between ETABS and manual computation is much closer throughout both axes compared to symmetric.

Abbreviations

BNBC: Bangladesh National Building Code

ETABS: Extended Three-Dimensional Analysis of Building System

EQ_X: Earthquake Load in X Direction

EQY: Earthquake Load in Y Direction

W_X: Wind Load in X Direction

W_Y: Wind Load in Y Direction

psf: Pounds Per Square Foot

ksf: Kilo-pound Per Square Foot

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Author Contributions

Md. Sohel Rana: Conceptualization, Formal Analysis, Project administration, Supervision.

Syed Fardin Bin Kabir: Software, Formal Analysis, Writing – original draft.

Samiha Tabassum Sami: Investigation, Visualization, Resources.

Md. Mahin Shahriar: Data curation, Methodology, Validation.

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Data Availability Statement

1. The data available from the corresponding author can be provided for verification purposes.
2. The data supporting the outcome of this research has also been mentioned in this manuscript.

Conflicts of Interest

The authors declare no conflicts of interest.

Appendix

All the additional tables that justify the findings of this manuscript are provided as follows-

Table 9. Storey Shear, Storey Drift and Storey Stiffness for Symmetric Structure when Z=0.12.

Story Data- Symmetrical Structure							
Story	**Case**	**Shear X-Symmetrical (kip)**	**Drift X-Symmetrical**	**Stiff X- Symmetrical (kip/in)**	**Shear Y- Symmetrical (kip)**	**Drift Y- Symmetrical**	**Stiff Y- Symmetrical (kip/in)**
Upper Roof	Eq X	10.903	0.00036	283.7037	0	-	0
Roof	Eq X	319.733	0.000357	7241.6954	0	-	0
6th Floor	Eq X	575.545	0.000543	9402.8999	0	-	0
5th Floor	Eq X	765.849	0.000678	10545.9857	0	-	0
4th Floor	Eq X	899.845	0.000782	11017.7181	0	-	0
3rd Floor	Eq X	986.494	0.000838	11365.5951	0	-	0
2nd Floor	Eq X	1036.067	0.00084	11956.0186	0	-	0
1st Floor	Eq X	1058.822	0.00072	14675.5982	0	-	0
GF	Eq X	1065.273	0.000371	26113.5454	0	-	0
Underground	Eq X	1065.47	0.000031	3118623.621	0	-	0
Upper Roof	Eq Y	0	-	0	11.232	0.000414	257.0164
Roof	Eq Y	0	-	0	329.375	0.000423	6959.2916
6th Floor	Eq Y	0	-	0	592.902	0.00061	9280.1365
5th Floor	Eq Y	0	-	0	788.945	0.000757	10359.3911
4th Floor	Eq Y	0	-	0	926.982	0.000863	10955.4339
3rd Floor	Eq Y	0	-	0	1016.244	0.000916	11555.3489
2nd Floor	Eq Y	0	-	0	1067.312	0.000898	12712.0519
1st Floor	Eq Y	0	-	0	1090.754	0.000789	16668.4111
GF	Eq Y	0	-	0	1097.4	0.000496	28514.5306
Underground	Eq Y	0	-	0	1097.602	0.00004	3343496.276

Table 10. Storey Shear, Storey Drift and Storey Stiffness for Asymmetric Structure when Z=0.12.

Story Data-Asymmetrical Structure							
Story	**Case**	**Shear X-Asymmetrical (kip)**	**Drift X-Asymmetrical**	**Stiff X-Asymmetrical (kip/in)**	**Shear Y-Asymmetrical (kip)**	**Drift Y-Asymmetrical**	**Stiff Y-Asymmetrical (kip/in)**
Upper Roof	Eq X	42.766	0.000322	1043.3535	0	-	0
Roof	Eq X	360.728	0.000317	8362.0607	0	-	0

Story Data-Asymmetrical Structure							
Story	Case	Shear X-Asymmetrical (kip)	Drift X-Asymmetrical	Stiff X-Asymmetrical (kip/in)	Shear Y-Asymmetrical (kip)	Drift Y-Asymmetrical	Stiff Y-Asymmetrical (kip/in)
Story6	Eq X	635.734	0.000461	10974.5249	0	-	0
Story5	Eq X	838.806	0.000586	12105.8438	0	-	0
Story4	Eq X	980.754	0.000675	12771.3469	0	-	0
Story3	Eq X	1072.485	0.000726	13388.8204	0	-	0
Story2	Eq X	1124.943	0.000733	14565.8617	0	-	0
Story1	Eq X	1149.025	0.000658	19336.835	0	-	0
GF	Eq X	1155.75	0.000318	33465.9957	0	-	0
Underground	Eq X	1155.941	0.00004	2665366.323	0	-	0
Upper Roof	Eq Y	0	-	0	34.623	0.000256	1162.4255
Roof	Eq Y	0	-	0	292.038	0.000415	7635.9501
Story6	Eq Y	0	-	0	514.678	0.000676	9151.027
Story5	Eq Y	0	-	0	679.081	0.000898	9477.5899
Story4	Eq Y	0	-	0	793.999	0.001058	9620.2314
Story3	Eq Y	0	-	0	868.263	0.001155	9824.6743
Story2	Eq Y	0	-	0	910.732	0.001174	10439.8795
Story1	Eq Y	0	-	0	930.228	0.001012	13274.3293
GF	Eq Y	0	-	0	935.672	0.000451	26305.6606
Underground	Eq Y	0	-	0	935.828	0.00005	2175045.588

***Table 11**. Storey Shear, Storey Drift and Storey Stiffness for Symmetric Structure when Z=0.20.*

Story Data - Symmetrical Structure							
Story	Case	Shear X-Symmetrical (kip)	Drift X-Symmetrical	Stiff X-Symmetrical (kip/in)	Shear Y-Symmetrical (kip)	Drift Y-Symmetrical	Stiff Y-Symmetrical (kip/in)
Upper Roof	Eq X	18.171	0.000601	283.7037	0	-	0
Roof	Eq X	532.888	0.000596	7241.6954	0	-	0
6th Floor	Eq X	959.241	0.000908	9402.8999	0	-	0
5th Floor	Eq X	1276.415	0.001131	10545.9857	0	-	0
4th Floor	Eq X	1499.742	0.001304	11017.7181	0	-	0
3rd Floor	Eq X	1644.156	0.001398	11365.5951	0	-	0
2nd Floor	Eq X	1726.778	0.001401	11956.0186	0	-	0
1st Floor	Eq X	1764.704	0.001199	14675.5982	0	-	0
GF	Eq X	1775.455	0.000616	26113.5454	0	-	0

Story Data - Symmetrical Structure							
Story	Case	Shear X-Symmetrical (kip)	Drift X-Symmetrical	Stiff X-Symmetrical (kip/in)	Shear Y-Symmetrical (kip)	Drift Y-Symmetrical	Stiff Y-Symmetrical (kip/in)
Underground	Eq X	1775.783	0.000052	3118623.621	0	-	0
Upper Roof	Eq Y	0	-	0	18.719	0.000699	257.0164
Roof	Eq Y	0	-	0	548.959	0.000711	6959.2916
6th Floor	Eq Y	0	-	0	988.169	0.001024	9280.1365
5th Floor	Eq Y	0	-	0	1314.909	0.001268	10359.3911
4th Floor	Eq Y	0	-	0	1544.971	0.001445	10955.4339
3rd Floor	Eq Y	0	-	0	1693.74	0.001532	11555.3489
2nd Floor	Eq Y	0	-	0	1778.854	0.001502	12712.0519
1st Floor	Eq Y	0	-	0	1817.924	0.001318	16668.4111
GF	Eq Y	0	-	0	1828.999	0.000826	28514.5306
Underground	Eq Y	0	-	0	1829.336	0.000067	3343496.276

Table 12. *Storey Shear, Storey Drift and Storey Stiffness for Asymmetric Structure when Z=0.20.*

Story Data -Asymmetrical Structure							
Story	Case	Shear X-Asymmetrical (kip)	Drift X-Asymmetrical	Stiff X-Asymmetrical (kip/in)	Shear Y-Asymmetrical (kip)	Drift Y-Asymmetrical	Stiff Y-Asymmetrical (kip/in)
Upper Roof	Eq X	71.277	0.00058	1043.3535	0	-	0
Roof	Eq X	601.213	0.000541	8362.0607	0	-	0
Story6	Eq X	1059.557	0.000787	10974.5249	0	-	0
Story5	Eq X	1398.009	0.000994	12105.8438	0	-	0
Story4	Eq X	1634.59	0.00114	12771.3469	0	-	0
Story3	Eq X	1787.476	0.001223	13388.8204	0	-	0
Story2	Eq X	1874.905	0.001233	14565.8617	0	-	0
Story1	Eq X	1915.041	0.001103	19336.835	0	-	0
GF	Eq X	1926.249	0.000531	33465.9957	0	-	0
Underground	Eq X	1926.569	0.000066	2665366.323	0	-	0
Upper Roof	Eq Y	0	-	0	57.705	0.000441	1162.4255
Roof	Eq Y	0	-	0	486.73	0.00069	7635.9501
Story6	Eq Y	0	-	0	857.796	0.001124	9151.027
Story5	Eq Y	0	-	0	1131.801	0.001495	9477.5899
Story4	Eq Y	0	-	0	1323.332	0.001762	9620.2314
Story3	Eq Y	0	-	0	1447.105	0.001923	9824.6743

Story Data -Asymmetrical Structure							
Story	Case	Shear X-Asymmetrical (kip)	Drift X-Asymmetrical	Stiff X-Asymmetrical (kip/in)	Shear Y-Asymmetrical (kip)	Drift Y-Asymmetrical	Stiff Y-Asymmetrical (kip/in)
Story2	Eq Y	0	-	0	1517.887	0.001956	10439.8795
Story1	Eq Y	0	-	0	1550.38	0.001687	13274.3293
GF	Eq Y	0	-	0	1559.454	0.000751	26305.6606
Underground	Eq Y	0	-	0	1559.713	0.000084	2175045.588

Table 13. *Storey Shear, Storey Drift and Storey Stiffness for Symmetric Structure when Z=0.28.*

Story Data - Symmetrical Structure							
Story	Case	Shear X-Symmetrical (kip)	Drift X-Symmetrical	Stiff X-Symmetrical (kip/in)	Shear Y-Symmetrical (kip)	Drift Y-Symmetrical	Stiff Y-Symmetrical (kip/in)
Upper Roof	Eq X	25.44	0.000842	283.7037	0	-	0
Roof	Eq X	746.044	0.000835	7241.6954	0	-	0
6th Floor	Eq X	1342.937	0.001272	9402.8999	0	-	0
5th Floor	Eq X	1786.981	0.001585	10545.9857	0	-	0
4th Floor	Eq X	2099.638	0.001827	11017.7181	0	-	0
3rd Floor	Eq X	2301.819	0.001958	11365.5951	0	-	0
2nd Floor	Eq X	2417.49	0.001962	11956.0186	0	-	0
1st Floor	Eq X	2470.586	0.001678	14675.5982	0	-	0
GF	Eq X	2485.638	0.000864	26113.5454	0	-	0
Underground	Eq X	2486.096	0.000072	3118623.621	0	-	0
Upper Roof	Eq Y	0	-	0	26.207	0.001018	257.0164
Roof	Eq Y	0	-	0	768.542	0.001	6959.2916
6th Floor	Eq Y	0	-	0	1383.437	0.001438	9280.1365
5th Floor	Eq Y	0	-	0	1840.873	0.00178	10359.3911
4th Floor	Eq Y	0	-	0	2162.959	0.002027	10955.4339
3rd Floor	Eq Y	0	-	0	2371.236	0.002148	11555.3489
2nd Floor	Eq Y	0	-	0	2490.396	0.002107	12712.0519
1st Floor	Eq Y	0	-	0	2545.093	0.001847	16668.4111
GF	Eq Y	0	-	0	2560.599	0.001155	28514.5306
Underground	Eq Y	0	-	0	2561.071	0.000094	3343496.276

Table 14. *Storey Shear, Storey Drift and Storey Stiffness for Asymmetric Structure when Z=0.28.*

Story Data -Asymmetrical Structure							
Story	**Case**	**Shear X-Asymmetrical (kip)**	**Drift X-Asymmetrical**	**Stiff X-Asymmetrical (kip/in)**	**Shear Y-Asymmetrical (kip)**	**Drift Y-Asymmetrical**	**Stiff Y-Asymmetrical (kip/in)**
Upper Roof	Eq X	99.788	0.000838	1043.3535	0	-	0
Roof	Eq X	841.698	0.000765	8362.0607	0	-	0
Story6	Eq X	1483.379	0.001112	10974.5249	0	-	0
Story5	Eq X	1957.213	0.001402	12105.8438	0	-	0
Story4	Eq X	2288.425	0.001605	12771.3469	0	-	0
Story3	Eq X	2502.466	0.00172	13388.8204	0	-	0
Story2	Eq X	2624.868	0.001732	14565.8617	0	-	0
Story1	Eq X	2681.058	0.001548	19336.835	0	-	0
GF	Eq X	2696.749	0.000745	33465.9957	0	-	0
Underground	Eq X	2697.196	0.000092	2665366.323	0	-	0
Upper Roof	Eq Y	0	-	0	80.787	0.000626	1162.4255
Roof	Eq Y	0	-	0	681.422	0.000964	7635.9501
Story6	Eq Y	0	-	0	1200.915	0.001572	9151.027
Story5	Eq Y	0	-	0	1584.522	0.002092	9477.5899
Story4	Eq Y	0	-	0	1852.665	0.002465	9620.2314
Story3	Eq Y	0	-	0	2025.948	0.002692	9824.6743
Story2	Eq Y	0	-	0	2125.042	0.002738	10439.8795
Story1	Eq Y	0	-	0	2170.532	0.002362	13274.3293
GF	Eq Y	0	-	0	2183.236	0.001052	26305.6606
Underground	Eq Y	0	-	0	2183.598	0.000117	2175045.588

Table 15. *Storey Shear, Storey Drift and Storey Stiffness for Symmetric Structure when Z=0.36.*

Story Data - Symmetrical Structure							
Story	**Case**	**Shear X-Symmetrical (kip)**	**Drift X-Symmetrical**	**Stiff X-Symmetrical (kip/in)**	**Shear Y-Symmetrical (kip)**	**Drift Y-Symmetrical**	**Stiff Y-Symmetrical (kip/in)**
Upper Roof	Eq X	32.708	0.001084	283.7037	0	-	0
Roof	Eq X	959.199	0.001074	7241.6954	0	-	0
6th Floor	Eq X	1726.634	0.001636	9402.8999	0	-	0
5th Floor	Eq X	2297.548	0.002039	10545.9857	0	-	0
4th Floor	Eq X	2699.535	0.002349	11017.7181	0	-	0
3rd Floor	Eq X	2959.481	0.002518	11365.5951	0	-	0

Story Data - Symmetrical Structure							
Story	Case	Shear X-Symmetrical (kip)	Drift X-Symmetrical	Stiff X-Symmetrical (kip/in)	Shear Y-Symmetrical (kip)	Drift Y-Symmetrical	Stiff Y-Symmetrical (kip/in)
2nd Floor	Eq X	3108.201	0.002523	11956.0186	0	-	0
1st Floor	Eq X	3176.467	0.002157	14675.5982	0	-	0
GF	Eq X	3195.82	0.001112	26113.5454	0	-	0
Underground	Eq X	3196.409	0.000093	3118623.621	0	-	0
Upper Roof	Eq Y	0	-	0	33.695	0.00127	257.0164
Roof	Eq Y	0	-	0	988.126	0.001288	6959.2916
6th Floor	Eq Y	0	-	0	1778.705	0.001852	9280.1365
5th Floor	Eq Y	0	-	0	2366.836	0.002291	10359.3911
4th Floor	Eq Y	0	-	0	2780.947	0.002609	10955.4339
3rd Floor	Eq Y	0	-	0	3048.732	0.002765	11555.3489
2nd Floor	Eq Y	0	-	0	3201.937	0.002711	12712.0519
1st Floor	Eq Y	0	-	0	3272.262	0.002376	16668.4111
GF	Eq Y	0	-	0	3292.199	0.001485	28514.5306
Underground	Eq Y	0	-	0	3292.805	0.000121	3343496.276

Table 16. *Storey Shear, Storey Drift and Storey Stiffness for Asymmetric Structure when Z=0.36.*

Story Data -Asymmetrical Structure							
Story	Case	Shear X-Asymmetrical (kip)	Drift X-Asymmetrical	Stiff X-Asymmetrical (kip/in)	Shear Y-Asymmetrical (kip)	Drift Y-Asymmetrical	Stiff Y-Asymmetrical (kip/in)
Upper Roof	Eq X	128.299	0.001096	1043.3535	0	-	0
Roof	Eq X	1082.183	0.000988	8362.0607	0	-	0
Story6	Eq X	1907.202	0.001438	10974.5249	0	-	0
Story5	Eq X	2516.417	0.00181	12105.8438	0	-	0
Story4	Eq X	2942.261	0.002071	12771.3469	0	-	0
Story3	Eq X	3217.456	0.002217	13388.8204	0	-	0
Story2	Eq X	3374.83	0.002231	14565.8617	0	-	0
Story1	Eq X	3447.074	0.001993	19336.835	0	-	0
GF	Eq X	3467.249	0.000959	33465.9957	0	-	0
Underground	Eq X	3467.824	0.000119	2665366.323	0	-	0
Upper Roof	Eq Y	0	-	0	103.869	0.000811	1162.4255
Roof	Eq Y	0	-	0	876.114	0.001238	7635.9501
Story6	Eq Y	0	-	0	1544.034	0.002021	9151.027

Story Data -Asymmetrical Structure							
Story	Case	Shear X-Asymmetrical (kip)	Drift X-Asymmetrical	Stiff X-Asymmetrical (kip/in)	Shear Y-Asymmetrical (kip)	Drift Y-Asymmetrical	Stiff Y-Asymmetrical (kip/in)
Story5	Eq Y	0	-	0	2037.242	0.002689	9477.5899
Story4	Eq Y	0	-	0	2381.997	0.003169	9620.2314
Story3	Eq Y	0	-	0	2604.79	0.00346	9824.6743
Story2	Eq Y	0	-	0	2732.197	0.00352	10439.8795
Story1	Eq Y	0	-	0	2790.684	0.003036	13274.3293
GF	Eq Y	0	-	0	2807.017	0.001352	26305.6606
Underground	Eq Y	0	-	0	2807.483	0.000151	2175045.588

Table 17. *Overturning Moment for Symmetric and Asymmetric Structure when Z=0.12.*

Level	Eleva-tion	Symmetric Structure; z=0.12				Asymmetric Structure; z=0.12			
		Story Force/Shear (Vx)	Over-turning Moment-X direction	Story Force/Shear (Vy)	Over-turning Moment-Y direction	Story Force/Shear (Vx)	Over-turning Moment-X direction	Story Force/Shear (Vy)	Over-turning Moment-Y direction
Underground	1	-1065.47	1065.47	-1097.602	1097.602	-1155.941	1155.941	-935.828	935.828
GF	11	-1065.273	11718.003	-1097.4	12071.4	-1155.75	12713.25	-935.672	10292.392
Story 1	21	-1058.822	22235.262	-1090.754	22905.834	-1149.025	24129.525	-930.228	19534.788
Story 2	31	-1036.067	32118.077	-1067.312	33086.672	-1124.943	34873.233	-910.732	28232.692
Story 3	41	-986.494	40446.254	-1016.244	41666.004	-1072.485	43971.885	-868.263	35598.783
Story 4	51	-899.845	45892.095	-926.982	47276.082	-980.754	50018.454	-793.999	40493.949
Story 5	61	-765.849	46716.789	-788.945	48125.645	-838.806	51167.166	-679.081	41423.941
Story 6	71	-575.545	40863.695	-592.902	42096.042	-635.734	45137.114	-514.678	36542.138
Roof	81	-319.733	25898.373	-329.375	26679.375	-360.728	29218.968	-292.038	23655.078
Upper Roof	91	-10.903	992.173	-11.232	1022.112	-42.766	3891.706	-34.623	3150.693

Table 18. *Overturning Moment for Symmetric and Asymmetric Structure when Z=0.20.*

Level	Eleva-tion	Symmetric Structure; z=0.20				Asymmetric Structure; z=0.20			
		Story Force/Shear (Vx)	Over-turning Moment-X direction	Story Force/Shear (Vy)	Over-turning Moment-Y direction	Story Force/Shear (Vx)	Over-turning Moment-X direction	Story Force/Shear (Vy)	Over-turning Moment-Y direction
Underground	1	-1775.783	1775.783	-1829.336	1829.336	-1926.569	1926.569	-1559.713	1559.713
GF	11	-1775.455	19530.005	-1828.999	20118.989	-1926.249	21188.739	-1559.454	17153.994

Level	Eleva-tion	Symmetric Structure; z=0.20				Asymmetric Structure; z=0.20			
		Story Force/Shear (Vx)	Over-turning Moment-X direction	Story Force/Shear (Vy)	Over-turning Moment-Y direction	Story Force/Shear (Vx)	Over-turning Moment-X direction	Story Force/Shear (Vy)	Over-turning Moment-Y direction
Story 1	21	-1764.704	37058.784	-1817.924	38176.404	-1915.041	40215.861	-1550.38	32557.98
Story 2	31	-1726.778	53530.118	-1778.854	55144.474	-1874.905	58122.055	-1517.887	47054.497
Story 3	41	-1644.156	67410.396	-1693.74	69443.34	-1787.476	73286.516	-1447.105	59331.305
Story 4	51	-1499.742	76486.842	-1544.971	78793.521	-1634.59	83364.09	-1323.332	67489.932
Story 5	61	-1276.415	77861.315	-1314.909	80209.449	-1398.009	85278.549	-1131.801	69039.861
Story 6	71	-959.241	68106.111	-988.169	70159.999	-1059.557	75228.547	-857.796	60903.516
Roof	81	-532.888	43163.928	-548.959	44465.679	-601.213	48698.253	-486.73	39425.13
Upper Roof	91	-18.171	1653.561	-18.719	1703.429	-71.277	6486.207	-57.705	5251.155

Table 19. Overturning Moment for Symmetric and Asymmetric Structure when Z=0.28.

Level	Eleva-tion	Symmetric Structure; z=0.28				Asymmetric Structure; z=0.28			
		Story Force/Shear (Vx)	Over-turning Moment-X direction	Story Force/Shear (Vy)	Over-turning Moment-Y direction	Story Force/Shear (Vx)	Over-turning Moment-X direction	Story Force/Shear (Vy)	Over-turning Moment-Y direction
Underground	1	-2486.096	2486.096	-2561.071	2561.071	-2697.196	2697.196	-2183.598	2183.598
GF	11	-2485.638	27342.018	-2560.599	28166.589	-2696.749	29664.239	-2183.236	24015.596
Story 1	21	-2470.586	51882.306	-2545.093	53446.953	-2681.058	56302.218	-2170.532	45581.172
Story 2	31	-2417.49	74942.19	-2490.396	77202.276	-2624.868	81370.908	-2125.042	65876.302
Story 3	41	-2301.819	94374.579	-2371.236	97220.676	-2502.466	102601.10	-2025.948	83063.868
Story 4	51	-2099.638	107081.53	-2162.959	110310.90	-2288.425	116709.67	-1852.665	94485.915
Story 5	61	-1786.981	109005.84	-1840.873	112293.25	-1957.213	119389.99	-1584.522	96655.842
Story 6	71	-1342.937	95348.527	-1383.437	98224.027	-1483.379	105319.90	-1200.915	85264.965
Roof	81	-746.044	60429.564	-768.542	62251.902	-841.698	68177.538	-681.422	55195.182
Upper Roof	91	-25.44	2315.04	-26.207	2384.837	-99.788	9080.708	-80.787	7351.617

Table 20. Overturning Moment for Symmetric and Asymmetric Structure when Z=0.36.

Level	Eleva-tion	Symmetric Structure; z=0.36				Asymmetric Structure; z=0.36			
		Story Force/Shear (Vx)	Over-turning Moment-X direction	Story Force/Shear (Vy)	Over-turning Moment-Y direction	Story Force/Shear (Vx)	Over-turning Moment-X direction	Story Force/Shear (Vy)	Over-turning Moment-Y direction
Underground	1	-3196.409	3196.409	-3292.805	3292.805	-3467.824	3467.824	-2807.483	2807.483
GF	11	-3195.82	35154.02	-3292.199	36214.189	-3467.249	38139.739	-2807.017	30877.187

Level	Elevation	Symmetric Structure; z=0.36				Asymmetric Structure; z=0.36			
		Story Force/Shear (Vx)	Overturning Moment-X direction	Story Force/Shear (Vy)	Overturning Moment-Y direction	Story Force/Shear (Vx)	Overturning Moment-X direction	Story Force/Shear (Vy)	Overturning Moment-Y direction
Story 1	21	-3176.467	66705.807	-3272.262	68717.502	-3447.074	72388.554	-2790.684	58604.364
Story 2	31	-3108.201	96354.231	-3201.937	99260.047	-3374.83	104619.73	-2732.197	84698.107
Story 3	41	-2959.481	121338.72	-3048.732	124998.01	-3217.456	131915.69	-2604.79	106796.39
Story 4	51	-2699.535	137676.28	-2780.947	141828.29	-2942.261	150055.31	-2381.997	121481.84
Story 5	61	-2297.548	140150.42	-2366.836	144376.99	-2516.417	153501.43	-2037.242	124271.76
Story 6	71	-1726.634	122591.01	-1778.705	126288.05	-1907.202	135411.34	-1544.034	109626.41
Roof	81	-959.199	77695.119	-988.126	80038.206	-1082.183	87656.823	-876.114	70965.234
Upper Roof	91	-32.708	2976.428	-33.695	3066.245	-128.299	11675.209	-103.869	9452.079

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Biography

Md. Sohel Rana is currently working as a lecturer at Rajshahi University of Engineering & Technology, Department of Civil Engineering. He acquired his B.Sc. in Civil Engineering from Rajshahi University of Engineering & Technology in 2019 and currently doing Master's in Civil Engineering from the same institution. He has published various research works and conference papers in recent years.

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