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A Study of Seismic Analysis of High-Rise Structure in Different Seismic Zone Using Staad Pro

[1]Neetesh Jain
[1]PG Student, Department of Civil Engineering, Jabalpur Engineering College, MP

[2]Rakesh Grover
[2]Associate Professor, Department of Civil Engineering, Jabalpur Engineering College, MP

Abstract - In this research design of G+10 High Rise Structure has been analyzed. The earthquake is most dangerous natural hazard in manmade structure. The demand of earthquake resisting building has been increased which can be fulfilled by providing the shear wall , Structure reinforcement and the appropriate sizing of beams and columns in the structure for resisting lateral forces. Shear walls also have high stiffness and strength which can be used to resist horizontal loads and gravity loads making useful in various structural engineering design. The study focuses on G+ 10 high rise structures located in seismic zones II, III, IV and V of India with shear walls at corners of the external walls. In this study a Comparison of Base Shear, Storey Displacement and Storey Drift for stiffness criteria different seismic zone is included . The analysis is done by using STAAD Pro Connect Edition V22 software. The IS codes used for the analysis and designing is IS 1893 (Part-1):2016 (criteria for earthquake resistant design of structures), IS 456:2000 (plain and reinforced concrete) and SP 16: 1980 (design aids for reinforced concrete to IS : 456)

Keywords- STAAD Pro Connect Edition V22, Shear Wall, Seismic Analysis, High Rise Building, Lateral Force, Base Shear, Average Storey Displacement, Storey Drift

I. INTRODUCTION

Now a days earthquake has become the biggest disaster, so many of them are threatening some of them are still suffering from this fatal incident. As the population continues to grow incrementally, the demand for the survival resources also escalates. Consequently, it is imperative to ensure the safety and comfort of every individual affected by these seismic events.

II. OBJECTIVE

The present work is to analyze G+10 High Rise Structure buildings with RCC structure building against siesmic zone II , zone III , zone IV , zone V. The components of objectives are as follows

- To design and evaluate the seismic behavior of RCC building having different siesmic zone.
- To obtain and analyze the various loads acting on the structure.
- To study the variations in parameters such as Shear Force, Bending moment and Displacement in all seismic zones as per IS 1893 (Part-1):2016.
- To evaluate the storey drift and average storey displacement of the high rise building.

III. SCOPE OF THE STUDY

- Any structural engineer can use this paper as a guide line for seismic analysis of any multistory building.
- The study highlights the effect of seismic zone factor in different zones i.e. Zone II, Zone III, Zone IV and Zone V which is considered in the seismic performance evaluation of buildings.
- The design of structures must incorporate appropriate features for resisting earthquakes, thereby ensuring their capability to withstand lateral forces exerted during seismic events across various seismic zones.Additionally, it is essential to consider both the cost- effectiveness and efficiency of these measures in mitigating potential earthquake- related damage to the structures.

IV. LITERATURE REVIEW

A. Saha Purnachandra, Teja P.Prabhu & P Kumar Vijay (2012)**:** This research is mainly focuses on variation in percentage of steel when building is designed for different seismic zones. As per their research work they concluded that percentage variation of steel in beams are not varying much as compared to columns. Variation is around 0.07% in columns and overall variation is around 0.91% from Zone-2 to Zone-5.

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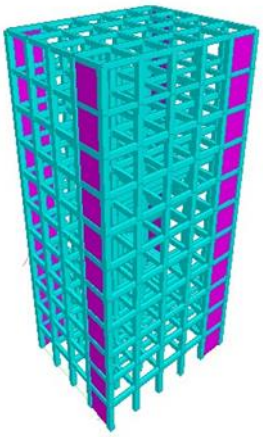

B. Babu B. Giresh (2017): Design of G + 7 Residential Building using STAAD Pro. Earthquake, or Seismic analysis, to calculate the response of a structure subjected to earthquake excitation. He collected various necessary seismic data to carry out the seismic analysis of the structure. In this study, the structures seismic response was investigated under earthquake excitation expressed in member forces, join displacement, support reaction, and story drift.

C. Kankuntala Rani. (2018): They used STAAD Pro to design and assess the G + 4 Building. It was a three dimensional framed design that included load calculations and STAAD Pro analysis of the entire structure. Limit State Design was utilized in the STAAD-Pro analysis, which followed the Indian Standard Code of Practice. The outcomes were extremely accurate.

D.. Sonkar Ankit , Verma Srishti(2023): In their study they compare & analyze of high rise buildings, specifically examining the impacts of seismic activity and wind forces. In past years many research has done on Analysis of building with and without shear walls. All the same they work for little. Analysis of high rise building (G+ 10) with & without shear walls. The current work consist the correlation between framed & framed with shear wall building in presence of the wind force, earthquake force etc, for seismic design of buildings, reinforcement concrete structural walls or shear walls are higher earthquake resisting members which abstain from lateral load resistance.

V. METHOD & DESCRIPTION

In this study the behavior of G+10 High Rise Structure as residential building under seismic loads have been analyzed for various location of India in seismic zone like zone II, zone III, zone IV, zone V with shear walls at different corners . An analysis of structure has been carried out for comparison of Base Shear, Storey Displacement and Storey Drift in different seismic zone. The analysis of the building has been carried out by static coefficient method or equivalent lateral force method approach using STAAD-Pro Connect Edition V22. The size of the building plan is 20mX16m and height of structure is 38.5 m.

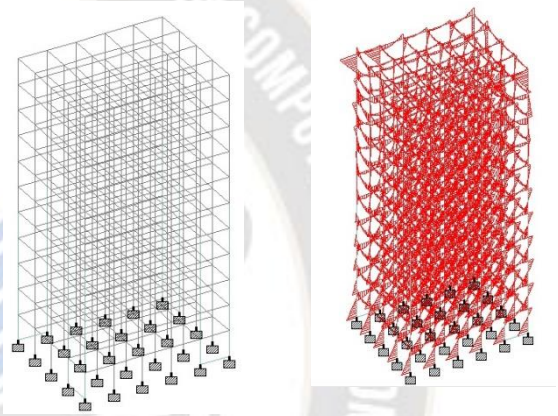

Figure 1. Staaad Pro Plan , Elevation, 3D rendering View, Bending Moment Diagram

Seismic Zone	**Zone II**	**Zone III**	**Zone IV**	**Zone V**
Zone Factor (Z)	0.1	0.16	0.24	0.36
Importance Factor(I) All other building	1.2			
Response Reduction Factor Ordinary Shear Wall With SMRF (R)	4			
Type Of Soil	TYPE I			
Damping Percent	5%			
Natural Time Period (Ta) SEC X Direction	0.7747			

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Natural Time Period (Ta) Z Direction	0.8662			
Sa/g X Direction	1.291			
Sa/g Z Direction	1.154			
Cefficient of Horizontal Acceleration Ah X Direction	0.0194	0.031	0.0465	0.0697
Ah Z Direction	0.0173	0.0277	0.0416	0.0623

TABLE I: Seismic Parameters

Load Assignment

i. Dead load ii. Live load iii. Seismic Load

Types of seismic analysis methods -

a. Static Analysis
Equivalent Lateral Force Method & Pushover Analysis

b. Dynamic Analysis
Response Spectrum Method & Time History Analysis

We using Static Analysis of Equivalent Lateral Force Method for this research

Descriptions	**Value**
Grade of Concrete	M30
Grade of Steel	Fe500
Bays in X-direction and Length	5 bays of 4m each = 20m
Bays in Z-direction and Width	4 bays of 4m each = 16m
Floor to Floor Height	11 bays of 3.5m each = 38.5m
Number of Storey	G+10
Column Size	600mmx600mm
Beam Size	10^{th} & 9^{th} Floor - 300mmx450mm
	8^{th},7^{th}, 6^{th}, 5^{th},4^{th} ,3^{th} , 2^{nd} , 1^{st} ,Ground Floor -400mmx600mm
Floor to Floor Height	3.5m
Thickness of Slab	150mm
Live Load on Roof	1.5 KN/m^2
Live Load on Floors	3 KN/m^2
Thickness of External Wall	230mm
Thickness of Internal Wall	115mm
External Plaster	15mm
Internal Plaster	12mm
Density of Concrete	25 KN/m^3
Density of Plaster	18 KN/m^3
Density of Brickwork	19 KN/m^3
Thickness of Shear Wall	230mm

TABLE II Structural Modeling For the Project Models

A.. Calculation of Load :

- DL of slab = 0.15 x 1 x 25 = 3.75 KN/m^2
- 1) DL of outer brick wall = 0.23 x (3.5-0.45) x 19 = 13.32 KN/m

DL of plaster = (0.015+0.012) x 3.5 x 18 = 1.70 KN/m

Total DL for outer wall = 13.32+1.70 = 15.02 KN/m

2) DL of outer brick wall = 0.23 x (3.5-0.6) x 19= 12.67 KN/m

DL of plaster = (0.015+0.012) x 3.5 x 18 = 1.70 KN/m

Total DL for outer wall = 12.67+1.10 = 14.37 KN/m

- 1) DL of inner brick wall = 0.115 x (3.5-0.45) x 19 = 6.66 KN/m

DL of plaster = (0.012+0.012) x 3.5 x 18 = 1.51 KN/m

Total DL for inner wall = 6.66+1.51=8.17 KN/m

2) DL of inner brick wall = 0.115 x (3.5-0.6) x 19 = 6.33 KN/m

DL of plaster = (0.012+0.012) x 3.5 x 18 = 1.51 KN/m

Total DL for inner wall = 6.33 + 1.51 = 7.84 KN/m

- DL of parapet wall = 0.23 x 1 x 19 = 4.37 KN/m

DL of plaster = (0.015+0.015) x 1 x 18 = 0.54 KN/m

Total DL for parapet wall = 4.37 + 0.54 = 4.91 KN/m

B.. Calculation of Seismic Weight:

As per IS 1893 (Part 1):2016 table 3.1 in clause 7.3.1 of "Percentage of imposed load to be considered in seismic weight calculation"

Total seismic weight floors = 3.75 + (0.25 x3) = 4.5 kN/m^2
Total seismic weight roof floors = 3.75 + 0 kN/m^2

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VI. RESULTS & DISCUSSION

In this Research all the various parameters like Base Shear, Storey Displacement, Storey Drift are obtained by STAAD-Pro Connect Edition V22 using referred IS 1893(Part 1):2016, IS 456:2000 and IS 13920: 2016 for using criteria and limitations.

A. Base Shear

Base shear is resisting lateral force due to earthquake. Base shear is cumulative sum of lateral force from top storey to bottom storey The building is stiff with provided shear walls. The structure is analyzed by equivalent lateral force method, the value of the base shear at lower floor is the maximum and upper floor is the minimum. Base shear at ground level for seismic zone II , zone III , zone IV , zone V along X direction and along Z direction respectively. Discuss the result in the table and graphs are plotted below -

Base Shear		
Zone	**V_B (KN) X Direction**	**V_B (KN) Z Direction**
Zone II	1181.27	1056.49
Zone III	1890.03	1690.38
Zone IV	2834.68	2535.57
Zone V	4252.57	3803.36

TABLE III. Base Shear Result

- Seismic zone from Zone II to Zone V the base shear result found to be increasing and is found to be highest in zones V.
- Base Shear is minimum for Zone II along X direction is 1181.27 KN and along Z direction is 1056.49 KN.
- Base Shear is maximum for Zone V along X direction is 4252.57 KN and along Z direction is 3803.38 KN.
- There is slight variation in the values of base shear in manual analysis as well as software analysis for seismic Zone II , Zone III , Zone IV , Zone V.
- When compared base shear in Zone II and Zone V is increase 72.22% along X direction and along Z direction respectively. Hence more lateral force acting on structure from top storey to bottom storey.
- Base shear when compared along X direction and along Z direction decrease 124.78 for zone II , 199.65 for zone III , 298.98 for zone IV , 449.21 for zone V. Hence more resistance and stiff of high rise structure in X direction.

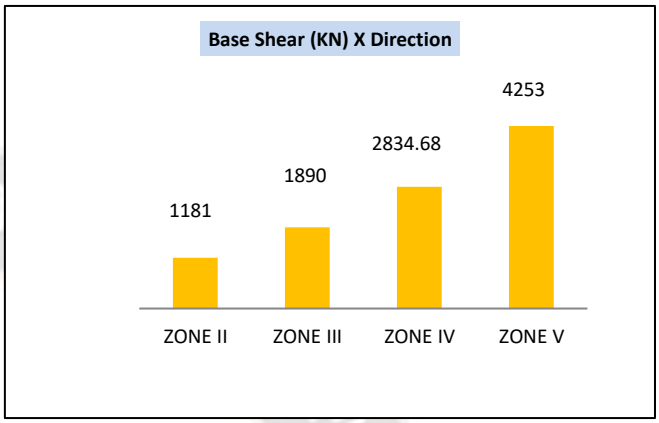

Figure 2 Base Shear Along X Direction

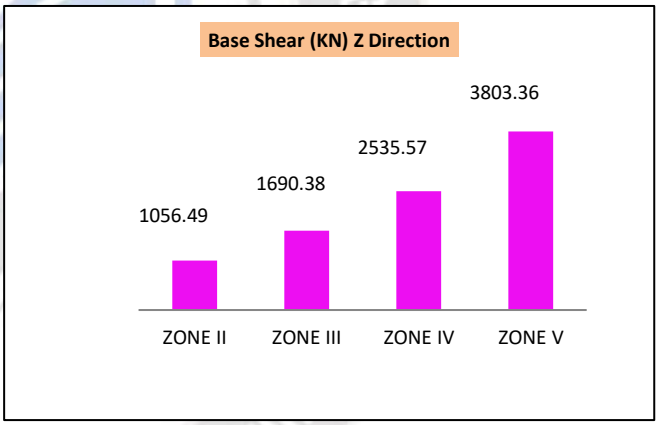

Figure 3 Base Shear Along Z Direction

B. Average Storey Displacement

The average storey displacement is average of all node displacement at that floor level due to lateral forces acting on the structure in that direction. Average Storey Displacement is in increasing order from bottom floor level to top floor level for seismic zone II , zone III , zone IV , zone V for maximum load combination i.e. load combination LC 112 for X direction and load combination LC 114 for Z direction. Discussing result in the table and graphs are plotted –

- Average storey displacement is increasing from seismic Zone II to Zone V and more average storey displacement is in Zone V.

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- The minimum average storey displacement obtained for zone II is 20.568 mm along X direction and 19.238 mm along Z direction.
- The maximum average storey displacement obtained for zone V is 74.046 mm along X direction and 69.419 mm along Z direction.
- Average storey displacement is found to be highest value for load combination LC 112 & LC 114 for seismic zone II , zone III , zone IV , zone V along X direction & alongZ direction respectively
- Overall average storey displacement of G+10 High Rise Structure is 74.046 mm.

TABLE IV. Average Storey Displacement X Direction

Avg Storey Displacement (mm) X Direction				
Floor	Zone II	Zone III	Zone IV	Zone V
0	0	0	0	0
1	1.478	2.365	3.548	5.322
2	3.785	6.055	9.082	13.624
3	6.218	9.995	14.921	22.385
4	8.648	13.837	20.753	31.133
5	11.011	17.618	26.423	39.64
6	13.242	21.187	31.777	47.672
7	15.267	24.427	36.635	54.96
8	17.002	27.203	40.709	61.206
9	18.379	29.407	44.104	66.165
10	19.486	31.178	46.761	70.151
11	20.568	32.909	49.357	74.046

TABLE V. Average Storey Displacement Z Direction

Avg Storey Displacement (mm) Z Direction				
Floor	Zone II	Zone III	Zone IV	Zone V
0	0	0	0	0
1	1.346	2.153	3.230	4.844
2	3.471	5.554	8.331	12.497
3	5.729	9.166	13.750	20.625
4	7.994	12.790	19.185	28.777
5	10.204	16.326	24.489	36.734
6	12.298	19.677	29.515	44.273
7	14.206	22.729	34.094	51.141
8	15.850	25.360	38.040	57.059
9	17.167	27.467	41.200	61.801
10	18.235	29.176	43.764	65.646
11	19.283	30.853	46.280	69.419

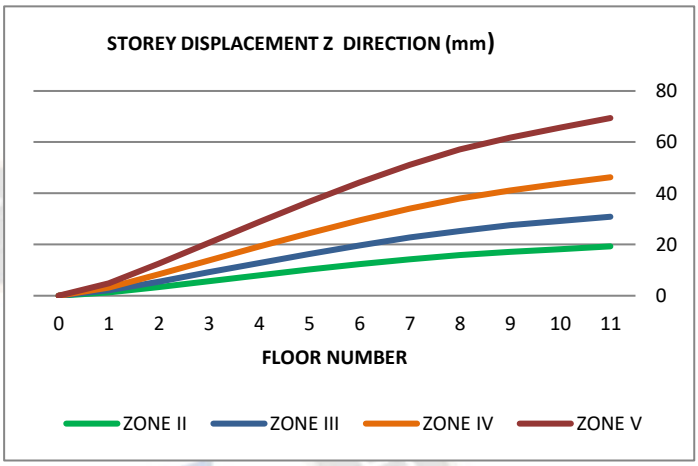

Figure 4 Storey Displacement Along X Direction

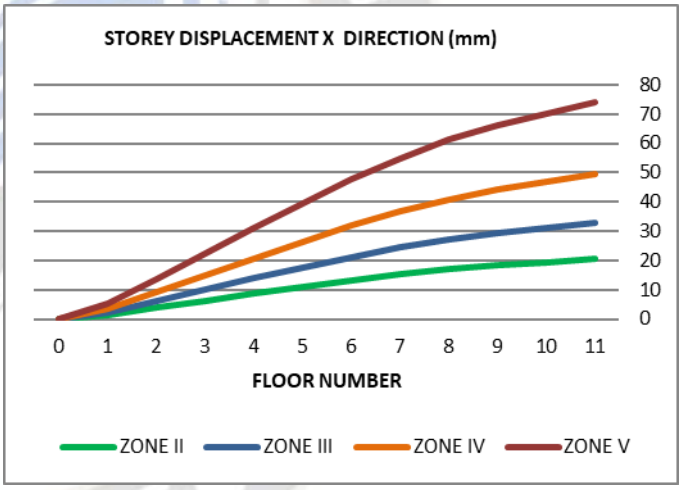

Figure 5 Storey Displacement Along Z Direction

C. Storey Drift

The storey drift is the lateral displacement of a floor relative to the floor below it. Storey Drift is different from bottom floor level to top floor level for seismic zone II , zone III , zone IV , zone V for maximum load combination i.e. load combination LC 112 for X direction and load combination LC 114 for Z direction. Discussing result in the table and graphs are plotted –

- Maximum storey drift is 2.433 mm, 3.894 mm, 5.840 mm, 8.760 mm along X direction for the seismic zone II , zone III , zone IV & zone V respectively.

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- Maximum storey drift is 2.265 mm, 3.623 mm, 5.418 mm, 8.153mm along Z direction for the seismic zone II , zone III , zone IV & zone V respectively.
- Maximum value of the storey drift for all seismic zone is 8.760 mm along X direction.
- Maximum value of the storey drift for all seismic zone is 8.153 mm along Z direction.
- The Maximum storey drift obtained for Zone V along X direction and Z direction respectively as shown in the table.
- As per Indian standard, Criteria for earthquake resistant design of structures, IS 1893(Part 1): 2016, the storey drift in any story shall not exceed 0.004 times storey height or L/250.
- Storey drift of G+10 High Rise Structure at 11th storey level 38.5 m is 1.048 mm & maximum Overall storey drift at 3rd storey at level 10.5 m is 8.760 mm.
- Maximum storey drift permitted = 0.004 x3500 = 14 mm. Hence, ok

Storey Drift (mm) X Direction				
Floor	Zone II	Zone III	Zone IV	Zone V
0	0	0	0	0
1	1.478	2.365	3.548	5.322
2	2.306	3.69	5.534	8.302
3	2.433	3.894	5.84	8.76
4	2.43	3.888	5.832	8.749
5	2.363	3.781	5.67	8.507
6	2.231	3.57	5.354	8.052
7	2.024	3.239	4.858	7.788
8	1.735	2.776	4.164	6.246
9	1.378	2.204	3.306	4.959
10	1.107	1.771	2.657	3.986
11	1.082	1.731	2.596	3.895

TABLE VI. Storey Drift X Direction

Storey Drift (mm) Z Direction				
Floor	Zone II	Zone III	Zone IV	Zone V
0	0	0	0	0
1	1.346	2.153	3.23	4.844
2	2.126	3.401	5.102	7.653
3	2.258	3.612	5.418	8.128
4	2.265	3.623	5.415	8.153
5	2.21	3.536	5.304	7.957
6	2.094	3.351	5.026	7.539
7	1.908	3.052	4.579	6.868
8	1.644	2.631	3.946	5.919
9	1.317	2.107	3.161	4.741
10	1.068	1.709	2.564	3.846
11	1.048	1.677	2.515	3.773

TABLE VII. Storey Drift Z Direction

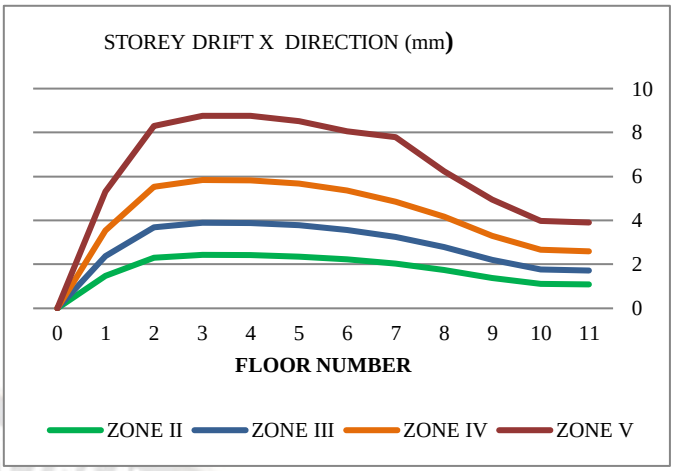

Figure 6 Storey Displacement Along X Direction

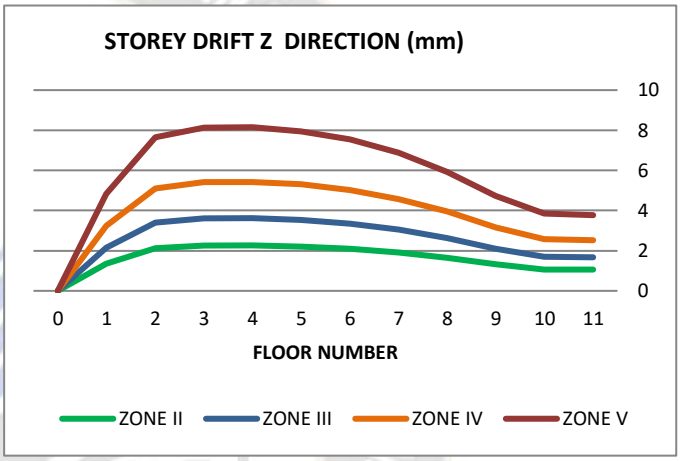

Figure 7 Storey Displacement Along Z Direction

VII. CONCLUSION

In this research our main aim is to compare base shear , average storey displacement, storey drift in Seismic zone II , zone III , zone IV & zone V by providing shear wall at all corners in different positions of the building. The data revealed by STAAD-Pro Connect Edition V22 software using seismic coefficient method and various loading combinations following conclusions are obtained :-

1. Seismic analysis was done by STAAD-Pro Connect Edition V22 software as per IS 1893-(Part 1) :2016 .
2. Calculation of seismic weight by both manual analysis as well as software analysis gives nearly same result.
3. Among all the load combinations, the load combination LC 1.5 (DL+LL), LC 1.5(DL+EQX), LC 0.9DL-1.5EQX, LC 0.9DL+1.5EQZ, LC 0.9DL-1.5EQZ are critical combination for all the seismic zone.
4. Base Shear is minimum for Zone II along X direction

is 11181.27 KN by STAAD-Pro Connect Edition V22 software . Base Shear is maximum for Zone V along X direction is 4252.57 KN by STAAD-Pro Connect Edition V22 software .

5. The minimum average storey displacement obtained for zone II is 20.568 mm along X direction and 19.238 mm along Z direction.

6. The maximum average storey displacement obtained for zone V is 74.046 mm along X direction and 69.419 mm along Z direction.

7. Storey drift of G+10 High Rise Structure at 11^{th} storey level 38.5 m is 1.048 mm & maximum Overall storey drift at 3^{rd} storey at level 10.5 m is 8.760 mm.

8. Maximum storey drift permitted = 0.004 x3500 = 14mm. Hence ok.

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