Design and Analysis of G+4 Steel Building And Seismic Analysis

[1]E. DEVENDHAR [2]M. ESHWAR NAIK [3]J. THIRUPATHI [4]V. DINESH [5] D. RAJENDRA BABU
[1,2,3,4] U.G. Scholar, Department of Civil, Sri Indu College of Engineering and Technology, Ibrahimpatnam, Hyderabad.
[5]Assistant Professor, Department of Civil, Sri Indu College of Engineering and Technology, Ibrahimpatnam, Hyderabad.

ABSTRACT

Designing a structure to be safe, serviceable, long-lasting, cost-effective, and aesthetically pleasing is the primary goal of structural design. The entire structural design process necessitates a broad range of expertise, creativity, and experience. The theoretical design parameters and framed structure analysis—that is, the analysis and design of a G+4-story residential building using the IS Code approach in STAAD Pro software—are the foundation of this project. All of the drafting and detailing was completed with AutoCAD, which transfers the structure to STAAD Pro for analysis and design. Using the "Limit State Method" and Staad.Pro software, the beam, column, slab, and foundation designs for this project are first finished in seismic zone-II. Other loads on the member are taken into account in compliance with IS: 875-2016 (part 1, part 2) and IS: 1893-2005 for seismic load. Measurements and analyses are performed to determine whether bending moment, storey displacement, storey drift, base shear, and other outputs meet serviceability requirements. The same input design is then finished in seismic zone-IV under the same loading conditions using Staad.Pro software. Lastly, the findings are verified in line with the project's objective by comparing the seismic zone-IV design's results with the seismic zone-II design's results.

Keywords: Staad Pro, AutoCAD, Seismic, Analysis, Design, Multistorey Building

I. INTRODUCTION

In Major construction projects are becoming more and more necessary in emerging nations like India in order to develop the underdeveloped towns and cities. The technique of determining a structure's general shape, precise dimensions, and size in order to ensure that it can fulfill its intended function and safely survive the impacts that it will encounter during its useful life is known as structural analysis and planning. The entire structural planning and design process necessitates creativity, intricate computations, and extensive understanding of structural engineering, including bye-laws and design codes. Urban cities' overpopulation and rising land capital necessitate the construction of multi-story buildings to house the expanding population. The multi-story reinforced concrete structures are the result of such accommodations. However, because land is scarce, vertical construction must be used instead of horizontal development. The main obstacle to economic building methodology is time delay, so structural optimization techniques should be applied to save the structure and hasten growth. Both horizontal and vertical infrastructure development are expanding quickly in many cities and towns. The planning, analysis, and design of multi-story residential buildings in various seismic zones are the primary focus of this project. Individual components including slabs, beams, columns, staircases, and footings must be designed and analyzed while designing and analyzing a multi-story residential structure. As more time is required in manual calculations for high rise construction and also the chances of human errors get magnified. Hence, three software's used in this project are as follows:

- AutoCAD is a drafting software which is used for modelling 2-Dimensional and 3-Dimensional structures.
- STAAD means Structural Analysis and Design. STAAD.Pro is one of the most popular software that is widely used in the design and analysis of structures like – buildings, bridges, industries, transportation facilities and utility structures such as steel structures, etc.
- STAAD Foundation is a versatile software used to design the footing and calculate the footing details i.e., showing geometry and reinforcement details.

II. OBJECTIVE

The main objective is to design and analyze (G+4) residential building in seismic zone-II and seismic zone-IV, and compare the results on various parameters by using STAAD Pro.

III. LITERATURE REVIEW

Yogesh Solanki, et al. (December 2021): Analysis and Design of High-Rise Residential Building with Shear Wall by Staad.Pro: G+16 multi-storey structure was planned, analysed & designed. It was a G+16 multi-storeyed building with the facility of vehicles parking in the ground floor and the remaining floors are occupied with apartments. The complete structural elements were designed manually and detailing was done using AutoCAD. Analysis and design were done according to standard specification using Staad.Pro for static and dynamic loads. Deflection of members was checked under various loading combinations. This design project was mainly focused with the analysis and design of high rise multi-storey residential building describing all possible cases of loading using Staad.pro in a conceptual way to meet the design challenges. All active load case was tested to calculate reinforcement required.

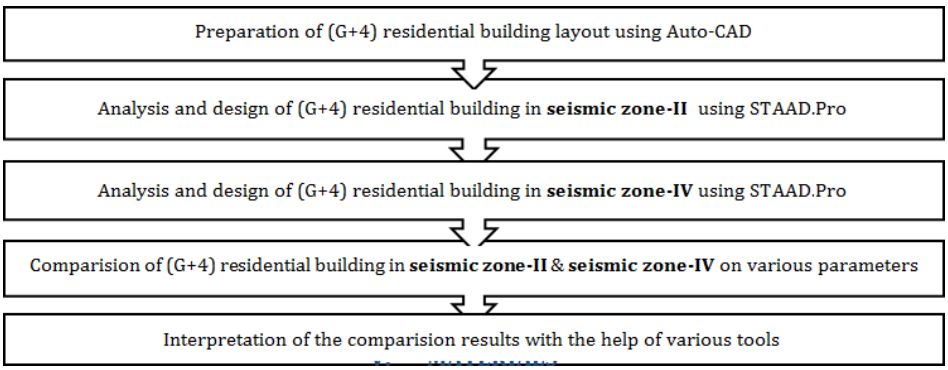
Shaikh Ibrahim, et al. (April 2019): Design and Analysis of Residential Building: After analyzing the G+4 storeyed residential building structure, it was concluded that the structure was safe in loading like dead load, live load, wind load and seismic loads. Structural member dimensions (Beam, column, slab) were assigned by determining the type of load and its intensity applied on it. AutoCAD gives the detailed information of the structural members size and numbers . STAaD.Pro runs the programs. Beams were designed for flexure, shear and tension with details of number, position and spacing.

Dunnala Lakshmi Anuja, et al. (2019): Planning, Analysis and Design of Residential Building (G+5) By using STAAD.Pro: The analysis of the framed structure was done by STAAD.Pro software. Structural Elements such as Slab, beams, staircase, footings were designed as per IS code 456: 2000 and Columns were designed as per IS 456: 2000 along with SP-16 design charts. The properties such as shear, deflection, development, torsions were observed to be in accordance to the IS code provisions. Complete design of structural members was done in limit state method which is safe in deflections criteria.

Mr. K. Prabin kumar, et al. (2018): A Study on Design of Multi-Storey Residential Building - A Review: The main objective of the project was designing and analysing a multi-storey building using STAAD.Pro. Dead load, imposed load and wind load were detremined and applied to the structural members. The design calculations were based on Limit State Method. The calculation of the reinforcement required for any concrete section was carried out by STAAD.Pro. Structural action such as axial load, flexure, torsion, etc. is considered on members. Beams were designed for flexure, shear and torsion. Pillars were designed for axial forces and biaxial moments at the ends. The complete structural building frame was planned as per IS 456: 2000.

D.R. Deshmukh, et al. (July 2016): Analysis and Design of G+19 Storied Building Using STAAD.Pro: The structural program contains a number of parameters which were designed as per IS 456: 2000 and IS 1893: 2002 to find lateral deflection due to earthquake load. Various structural action was considered on members such as axial, flexure, torsion, etc. based on their response. Beams were designed for flexure and Columns were designed for axial forces, uniaxial and biaxial moments at the ends. Deflection obtained by STAAD.Pro is verified by IS Codal limitation for serviceability criteria.

IV. METHODOLOGY



V. MATERIALS

Basic Details:

Purpose of Building	Residential	
Type of Structure	Multi Storey RCC Framed	
No. of Stories	G+4	
Floor to Floor Height	3 meters	
Type of Wall	Brick Wall	
Area of Building	383 m^2	
Zone	II	IV

Material Specification	
Grade of Concrete, M25	25 N/mm^2
Grade of Steel, Fe500	500 N/mm^2

Plan of G+4 Multistorey Residential Building:

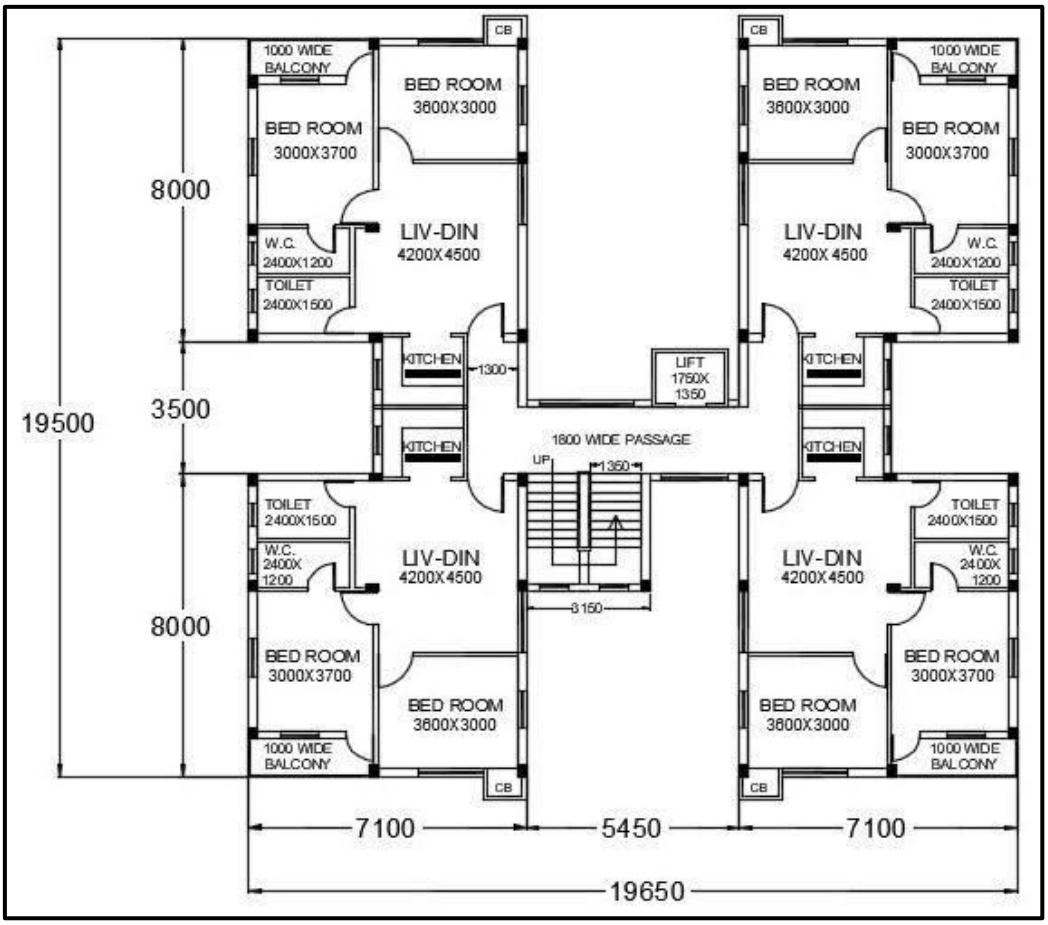


Figure 1: Floor Plan of G+4 multistorey Building

Section Properties:

Structural Member	Seismic Zone		
	Zone-II	Zone-IV	Zone-IV*
Beam Size	0.23 m x 0.23 m	0.23 m x 0.23 m	0.30 m x 0.23 m
Column Size	0.23 m x 0.35 m	0.23 m x 0.35 m	0.30 m x 0.45 m
Slab Thickness	0.125 m	0.125 m	0.125 m

***represents changed dimensions of Section after failure of sections in zone-IV analysis.**

Loading Parameters:

- ✓ Unit Weight of Concrete = 25 KN/m3
- ✓ Unit Weight of Brick = 20 KN/m3
- ✓ Thickness of External walls = 230 mm including plaster
- ✓ Thickness of Internal walls = 125 mm including plaster
- ✓ Thickness of Parapet walls = 125 mm including plaster
- Dead Load Calculations:

  Dead Load due to Wall Load for Beam:
  - External= 20 x 0.23 x 3 = 13.8 KN/m
  - Internal= 20 x 0.125 x 3 = 7.5 KN/m
  - Parapet (Roof) = 20 x 0.125 x 1.2 = 3 KN/m

  Floor Load:
  - Self Weight of Slab = 25 x .125 = 3.125 KN/m^2
  - Floor Finish = 1.5 KN/m^2
- Live Load Calculations:
  - Live Load on all Floor = 2.5 KN/m^2
- Seismic Load Parameters:

Parameters	Seismic Zone	
	Zone-II	Zone-IV
Zone Factor	0.1	0.24
Response Reduction Factor	5	5
Importance Factor	1	1
Damping Ratio	0.05	0
Soil Type	Medium (Drained)	Medium (Drained)
Unit weight of Soil	22 KN/m^3	22 KN/m^3
Soil SBC	100 KN/m^2	100 KN/m^2

- Load Combinations:

For Superstructure	For Substructure
1.5 x DL + 1.5 x LL	DL + LL
1.5 x DL ± 1.5 x EL (X, Z)	DL + 0.5 x LL ± EL (X, Z)
1.2 x DL + 1.2 x LL ± 1.2 x EL (X, Z)	DL ± EL (X, Z)

3-D View of Framed Structure in STAAD.Pro:

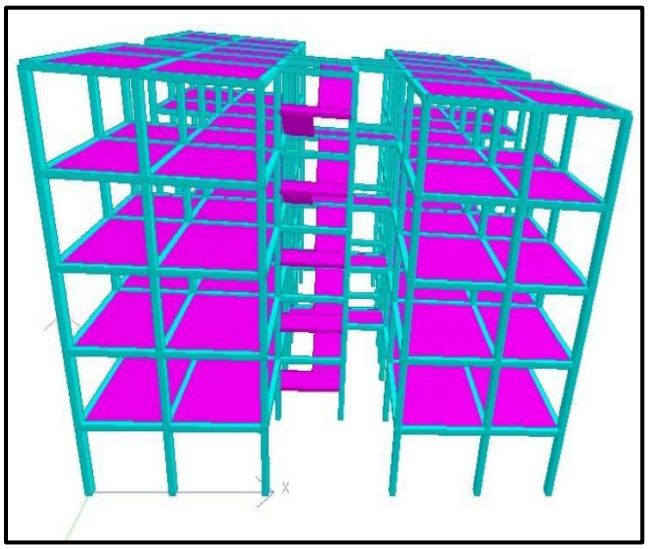


Figure 2: 3D Rendering Model of Building Plan

VI. ANALYSIS & DESIGN

Design of Slab:

ELEMENT DESIGN SUMMARY

ELEMENT	LONG. REINF (SQ.MM/ME)	MOM-X /LOAD (KN-M/M)	TRANS. REINF (SQ.MM/ME)	MOM-Y /LOAD (KN-M/M)
521 TOP :	126.	1.16 / 7	126.	0.84 / 7
BOTT:	126.	-0.03 / 2	126.	-0.04 / 4
522 TOP :	126.	0.92 / 8	126.	0.02 / 2
BOTT:	126.	-0.19 / 2	126.	-0.08 / 8
523 TOP :	126.	0.86 / 12	126.	0.75 / 7
BOTT:	126.	-0.10 / 2	126.	-0.05 / 3
524 TOP :	126.	0.99 / 15	126.	0.18 / 3
BOTT:	126.	-0.04 / 3	126.	-0.76 / 15
525 TOP :	126.	0.06 / 1	126.	0.04 / 4
BOTT:	126.	-1.06 / 7	126.	-0.82 / 7
526 TOP :	126.	0.23 / 1	126.	0.06 / 13
BOTT:	126.	-0.92 / 9	126.	-0.02 / 1
527 TOP :	126.	0.08 / 1	126.	0.06 / 3
BOTT:	126.	-0.90 / 7	126.	-0.74 / 7
528 TOP :	126.	0.98 / 7	126.	0.68 / 7
BOTT:	126.	-0.03 / 2	126.	-0.04 / 4
529 TOP :	126.	0.87 / 8	126.	0.02 / 3
BOTT:	126.	-0.18 / 2	126.	-0.14 / 7

Figure 3: Detailing of Slab element in Seismic Zone - II

ELEMENT DESIGN SUMMARY

ELEMENT	LONG. REINF (SQ.MM/ME)	MOM-X /LOAD (KN-M/M)	TRANS. REINF (SQ.MM/ME)	MOM-Y /LOAD (KN-M/M)
521 TOP :	156.	0.84 / 7	156.	0.62 / 14
BOTT:	156.	-0.08 / 2	156.	-0.08 / 4
522 TOP :	156.	1.28 / 12	156.	0.05 / 3
BOTT:	156.	-0.55 / 2	156.	-0.12 / 15
523 TOP :	156.	0.92 / 12	156.	0.63 / 15
BOTT:	156.	-0.26 / 2	156.	-0.11 / 3
524 TOP :	156.	0.81 / 15	156.	0.44 / 3
BOTT:	156.	-0.09 / 3	156.	-1.03 / 15
525 TOP :	156.	0.14 / 1	156.	0.08 / 4
BOTT:	156.	-0.86 / 13	156.	-0.61 / 14
526 TOP :	156.	0.59 / 1	156.	0.11 / 15
BOTT:	156.	-1.29 / 13	156.	-0.04 / 3
527 TOP :	156.	0.21 / 1	156.	0.12 / 3
BOTT:	156.	-0.90 / 13	156.	-0.64 / 15
528 TOP :	156.	0.68 / 7	156.	0.52 / 14
BOTT:	156.	-0.07 / 2	156.	-0.08 / 4
529 TOP :	156.	1.22 / 12	156.	0.05 / 3
BOTT:	156.	-0.54 / 2	156.	-0.16 / 15

Figure 4: Detailing of Slab element in Seismic Zone - IV

Design of Beam:

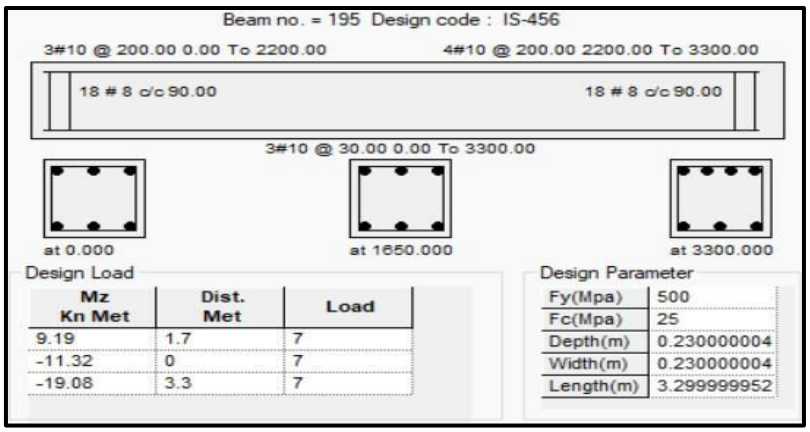


Figure 5: Beam design in Seismic Zone – II

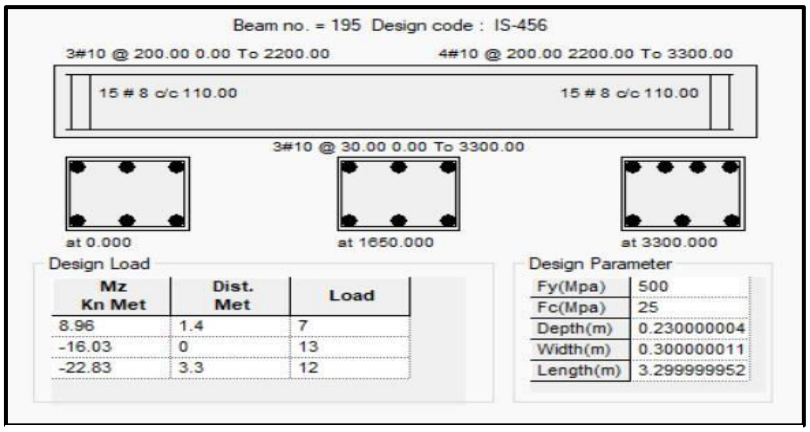


Figure 6: Beam design in Seismic Zone – IV

Design of Column & Footing:

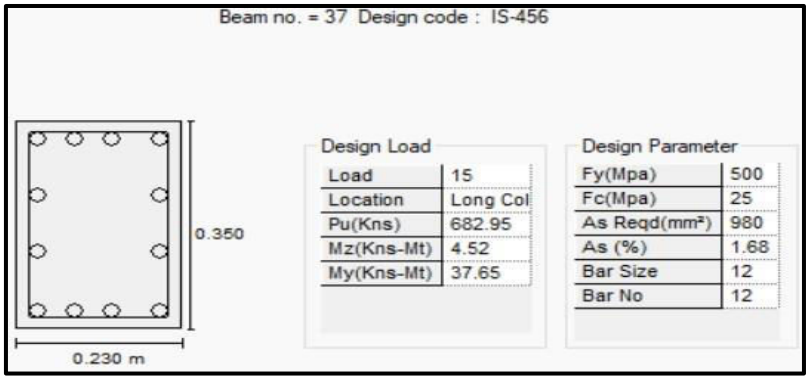


Figure 7: Column design in Seismic Zone – II

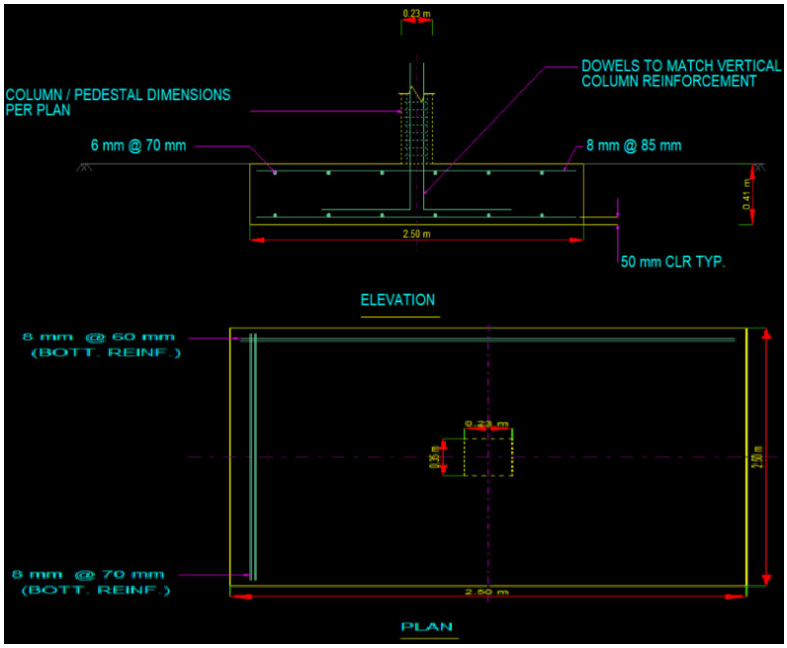


Figure 8: Footing Reinforcement details in Seismic Zone-II

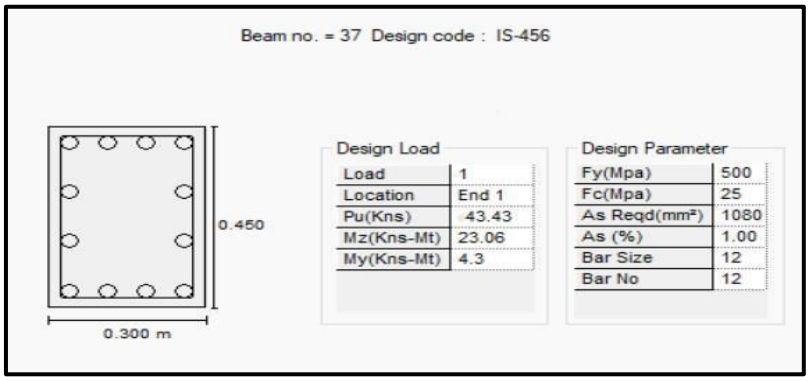


Figure 9: Column design in Seismic Zone – IV

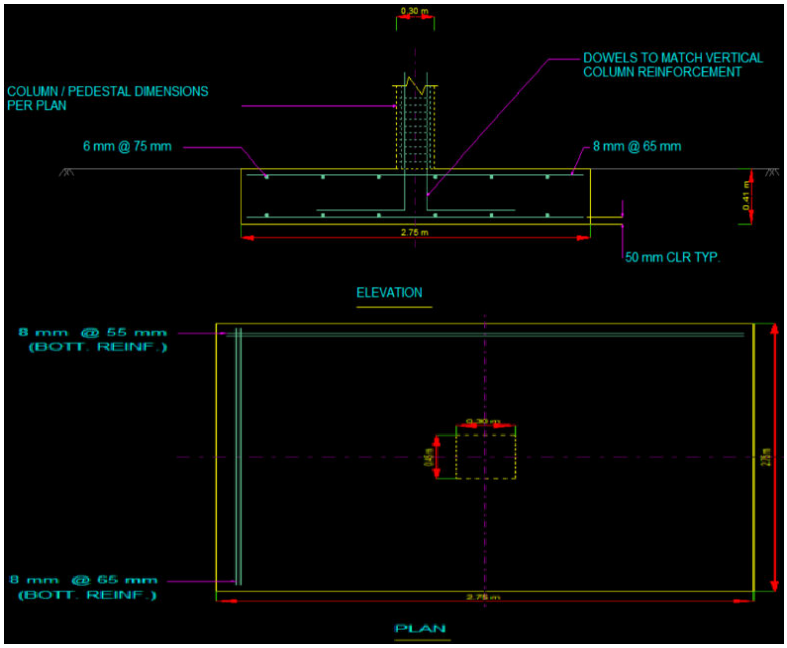


Figure 10: Footing Reinforcement details in Seismic Zone-IV

VII. RESULTS

Storey Drift:

STOREY DRIFT (in cm)				
Storey Height (in m)	Zone - II		Zone - IV	
	X-direction	Z-direction	X-direction	Z-direction
0	0.0005	0.0002	0.0007	0.0002
3	0.0759	0.0864	0.1723	0.1451
6	0.0969	0.1146	0.2262	0.2066
9	0.0963	0.1243	0.2312	0.2247
12	0.0873	0.1141	0.2111	0.2105
15	0.0744	0.0945	0.1709	0.1820

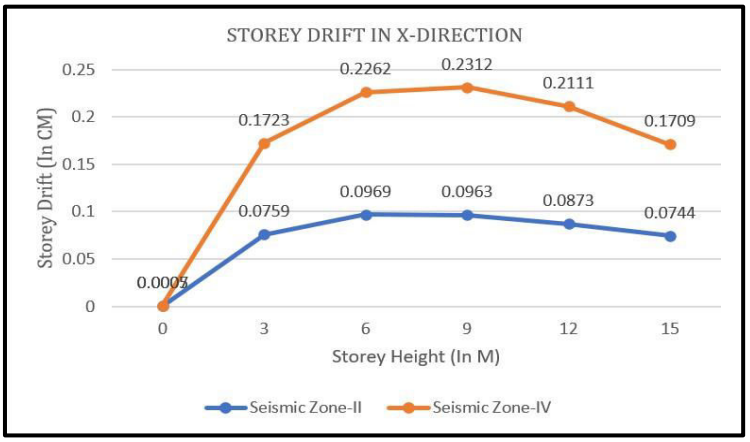


Chart 1: Storey Drift in X-direction

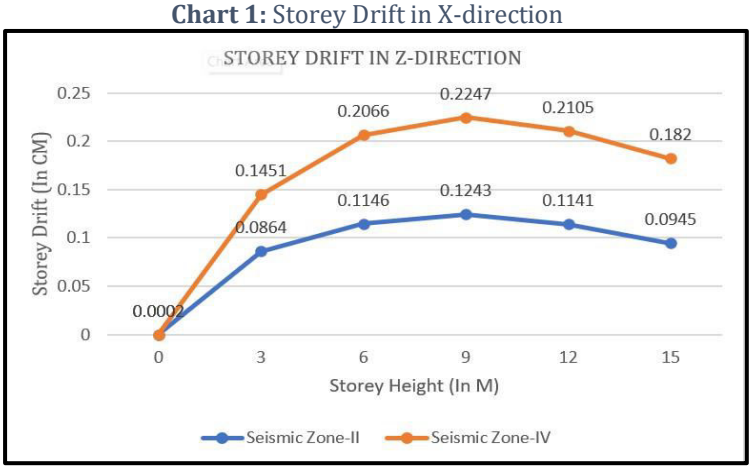


Chart 2: Storey Drift in Z-direction

Storey Displacement:

STOREY DISPLACEMENT (in cm)				
Storey Height (in m)	Zone - II		Zone - IV	
	X-direction	Z-direction	X-direction	Z-direction
0	0.0005	0.0002	0.0007	0.0002

3	0.2542	0.1514	0.3483	0.2217
6	0.6033	0.3906	0.8840	0.6119
9	0.9293	0.6242	1.3995	1.0079
12	1.1906	0.8163	1.8169	1.3394
15	1.3497	0.9424	2.0810	1.5698

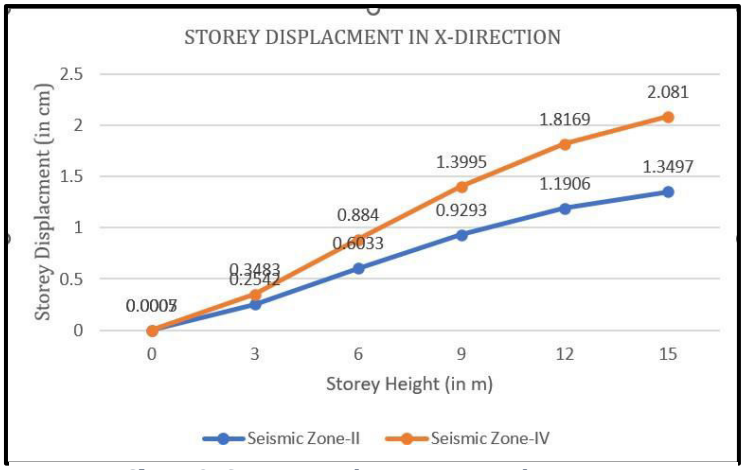


Chart 3: Storey Displacement in X-direction

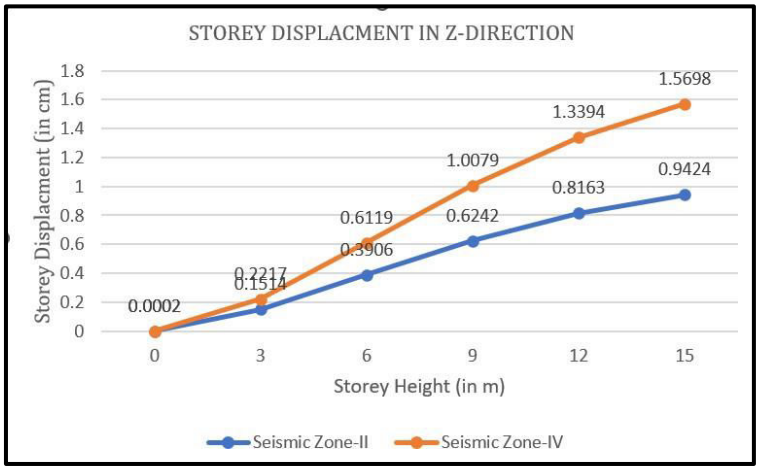


Chart 4: Storey Displacement in Z-direction

Base Shear:

Direction	BASE SHEAR (in KN) Zone - II	BASE SHEAR (in KN) Zone - IV
X-direction	190.21	571.44
Z-direction	190.21	571.44

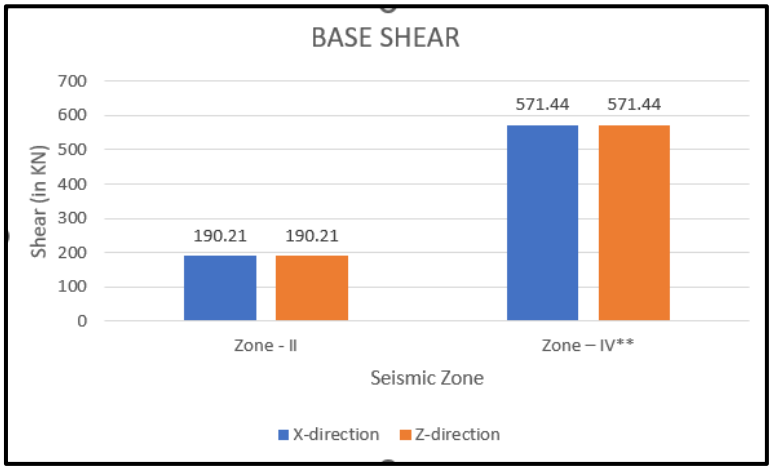


Chart 5: Base Shear (in KN) in X-direction & Z-direction

VIII. CONCLUSION

1. The Storey Drift increases with the increase in storey height. The variation of storey drift is observed more in seismic zone-IV as compared to seismic zone-II. The storey drift in seismic zone-IV analysis is found to be 129.7 % more than the storey drift in seismic zone-II analyis in X-direction whereas the storey drift in seismic zone-IV analysis is found to be 92.6 % more than the storey drift in seismic zone-II analyis in Z-direction at the top of the building. The storey drift in any storey is less than 0.004 times the storey height which validates as per Indian Standard Criteria for earthquake resistant design of structures, IS 1893 (Part 1): 2016.
2. The Storey Displacement also increases with the increase in storey height. The storey displacement in seismic zone-IV analysis is found to be 54.2 % more than the storey displacement in seismic zone-II analyis in X-direction whereas the storey displacement in seismic zone-IV analysis is found to be 66.6 % more than the storey displacement in seismic zone-II analyis in Z-direction at the top of the building.
3. Base Shear value is observed three times in seismic Zone-IV as compared to seismic zone-II analysis. Also Base Shear value is found equal in both X-direction and Z-direction for both the seismic zone-II and seismic zone-IV. The Base Shear value in seismic zone-IV analysis is 200 % more than the base shear value in seismic zone-II in both X-direction as well as Z-direction.
4. On analysing the G+4 multistorey building in zone-IV, it is found that the inner columns surrounding the passage gets failed due to inability of the section to accommodate required reinforcement and also in some columns, percentage reinforcement exceeds its limiting value. Thus, to accomodate required reinforcement, cross section of the column is increased from 0.23 m x 0.35 m in seismic zone-II to 0.30 m x 0.45 m in seismic zone-IV thereby increasing the cross section of column by 67.7 % and percentage reinforcement steel increases by 10.2 %. Also, the cross section of the beam is increased from 0.23 m x 0.23 m in seismic zone-II to 0.30 m x 0.23 m in seismic zone-IV thereby increasing the cross section of beam by 30.4 % and percentage reinforcement steel increases by 17.5 %.

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