BEST
BCREC Engineering & Science Transaction
Journal website: www. bcrecjournal.org

STRUCTURAL BEHAVIOUR OF TALL STRUCTURES FOR INDIAN EARTHQUAKE ZONES.

Pranoy Roy[1], Amit Kotal[2] and Anindita Pan[3]

[1] Department of Civil Engineering, DR. B. C. Roy Engineering College, Durgapur, West Bengal, India. Email: pranoy.roy@bcrec.ac.in

[2] Department of Civil Engineering, DR. B. C. Roy Engineering College, Durgapur, West Bengal, India. Email: amit.kotal@bcrec.ac.in

[3] Department of Civil Engineering, DR. B. C. Roy Engineering College, Durgapur, West Bengal, India. Email: anindita.pan@bcrec.ac.in

Abstract — Lateral forces in a structure causes vibration resulting formations leading to issues with servicibility, damage and may lead to collapse of the structures.

The earthquake zones of India is divided into four zones based on the intensity and zone factors. Therefore it is essential to find the limitations of framed tall buildings for higher seismic zones as per Indian codal provisions (IS 1893).

This paper presents the structural behaviour of tall building analyzed for four seismic zones of India. Staad-Pro software is used for development of framed structure. The worst load case is used to compare the maximum deflection, moment, and shear force of the structural components, with the allowable limits of IS Codes. The drift index and base shear force were the key components to analyze the seismic performance of the building, where it was found to be above the allowable limits as prescribed in IS: 456-2000 for higher seismic zones of India.

Keywords — ***Structural Behaviour, Seismic Effect, Beam Displacement, Storey Displacement.***

1. INTRODUCTION

Tall buildings provides an effective solution and resolve the limitation of construction site resources. Moreover, open-story multi-story buildings are quite common in India primarily to their ability to accommodate parking with reception lobbies on the base floor. The upper storeys of these buildings being stiff undergo smaller inter-story drifts, while it is large for the soft story. Systems like braced systems, shear walls, etc. stiffen the building and successfully reduce its seismic effects.

This paper deals with analyzing and designing multi-storeyed (G+10) structure by STAAD Pro considering Dead Load (D.L.), Live Load (L.L.), and Earthquake Loads (E.L.), calculated as per IS-875 Part-1, 2 and IS 1893-2002.

Kadali J.P. et.al. [5] (2015) used the pushover methodology to study the behavior of multi-storeyed RC buildings. Various configured frames were designed with details as (SMRF) Special Moment Resisting Frames and Ordinary Moment Resisting Frames (OMRF) as per (IS-1893). Ten frames were selected with variable stories, the number of bays, and infill wall configuration. SAP2000 was used for modelled and Pushover Analysis of the building.

*Corresponding author: pranoy.roy@bcrcec.ac.in

Seismic force resisting systems was employed using SMRF which resist the movement without loss of stiffness or strength. SMRF buildings perform better than SMRF buildings. Mayuri D. Bhagwat et.al. [8] (2014) worked on the dynamic analysis of the G+12 building affected by the Koyna and Bhuj earthquakes. Seismic responses were comparatively studied and modelled using ETABS software to develop different acceptable criteria. Shome and Cornell [9] (2000) presented a new methodology for computing the seismic demand, which simplifies the demand use of the seismic demand curve for multi-level performance evaluation. Based on the literature survey a model of a framed structure has been created and analysed under loading conditions as per Indian Codal provisions.

2. MODAL GENERATION AND ANALYSIS

An RC framed building of height 40m above ground level (G+10), having a floor area of 36m by 24m as shown in Figure 1. The loads acting are DL, LL, and EL. The dimensional properties of the building are shown in the Table1 and Table 2.

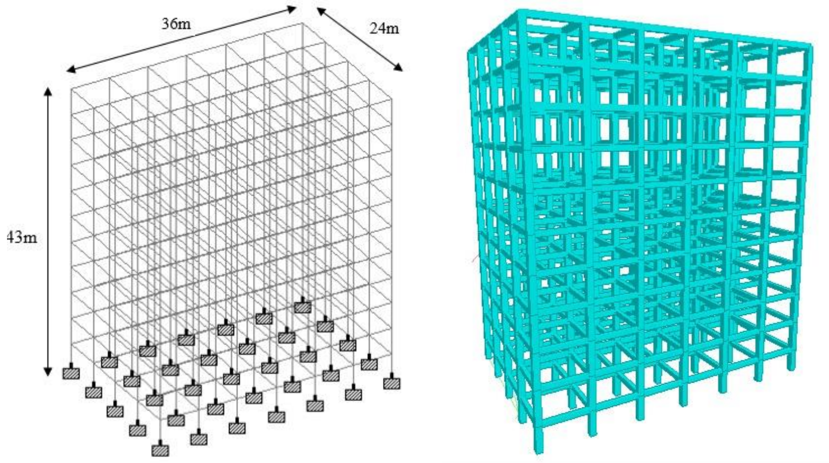

Figure 1. Models used for the investigation

Table-1. Sectional characteristics of the building

Height of the ground story	3m
Height of upper storey's	4m
Column	700mm x 700mm
Beam	600mm x 450mm
Thickness of Slab	150 mm
Roof slab (finishing	75 mm
Size of walls	Full brick masonry
No. of bays in X and Z-direction	6 bays @ 6.0m, 4 bays @ 6.0 m
spacing between supports	6 m
Grade of concrete	M30
Grade of steel	Fe415
Density of brickwork	19 kN/m^3

Table-2. Seismic zone factors for different zones in India

Seismic Zone of India	Seismic intensity	Seismic zone factor (z of 2002)
II	VI (L)	0.10
III	VII (M)	0.16
IV	VIII (S)	0.24
V	IX (C)	0.36

Loads Considered

- The DL and LL at different levels considered for the current analysis is adopted as per IS-875 codal provisions below.

Wall load considered for exterior beam =19 kN/m

Wall load considered at the top-most exterior beam =4.75 kN/m

The floor load considered on each floor is =3.5 kN/m^2

- Imposed floor levels = 6.0 KN/m^2, live load reduction by 50% for seismic weight calculation of the structure as prescribed in IS 1893:2002.
- Seismic load calculations were performed as per IS 1893-2002(part I).
- The load combinations are based on IS-1893, as shown in the Table 3.

Table-3. Load Combinations

Sl. No.	Load Combinations	Sl. No.	Load Combinations	Sl. No.	Load Combinations
1	SEISMIC X	7	1.2(DL+0.5LL-EQX)	13	1.5(DL-EQZ)
2	SEISMIC Z	8	1.2(DL+0.5LL+EQZ)	14	0.9DL+1.5EQX
3	DEAD LOAD	9	1.2(DL+0.5LL-EQZ)	15	0.9DL-1.5EQX
4	LIVE LOAD	10	1.5(DL+EQX)	16	0.9DL+1.5EQZ
5	1.5(DL+LL)	11	1.5(DL-EQX)	17	0.9DL-1.5EQZ
6	1.2(DL+0.5LL+EQX)	12	1.5(DL+EQZ)		

3. POST-PROCESSING ANALYSIS OF THE STRUCTURE

The results obtained from the post-processing of the models using Staad Pro are analyzed and shown comparatively for the worst loading conditions in the structure of different seismic Zones of India.

- Node Displacement:

The maximum and minimum node displacements for beam-column junctions along the X, Y, and Z axis for worst load conditions considering models in different seismic Zones of India.

Table-5. Node Displacement for Junctions

Node Displacement in mm	Zone 2	Zone 3	Zone 4
Max X	1.63	2.664	4.043
Min X	1.63	2.664	4.043
Max Y	1.149	1.838	2.757
Min Y	0	0	0
Max Z	17.669	28.214	42.274
Min Z	-17.669	-28.214	-42.274

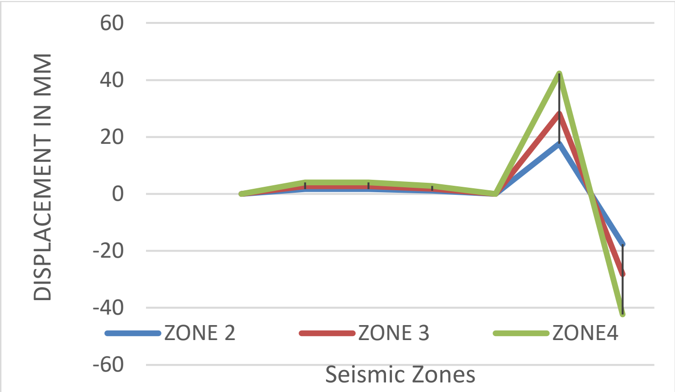

Figure 2. Nodal Displacements along the X, Y, and Z axis

- Resultant Beam Displacement:

The maximum and minimum resultant beam displacement along the X, Y, and Z axis for worst load conditions considering models in different seismic Zones of India.

Table-6. Resultant Beam Displacement

Resultant Beam Displacement in mm	Zone 2	Zone 3	Zone 4
Max R-X	8.091	11.754	11.604
Min R-X	8.091	11.754	11.604
Max R-Y	15.492	22.821	33.128
Min R-Y	15.492	22.821	33.128
Max R-Z	6.058	8.743	12.59
Min R-Z	6.058	8.743	12.59
Max Resultant Disp.	21.122	31.773	46.516

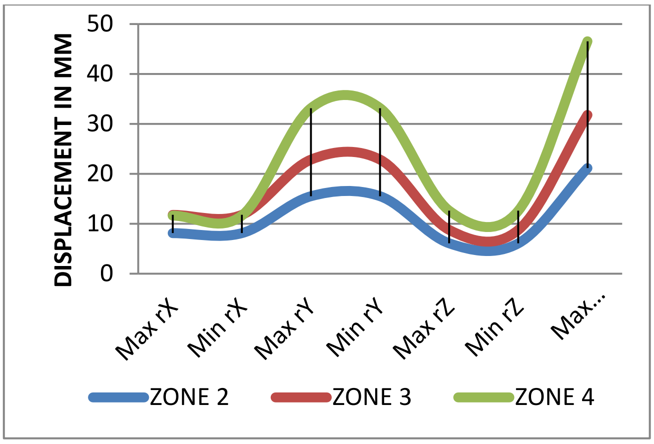

Figure 3. Resultant Beam Displacement.

- Resultant Column Displacement (Drift):

The resultant column displacement (drift) along the Z and X axis for worst loading conditions for different seismic Zones of India is shown in Fig.4.

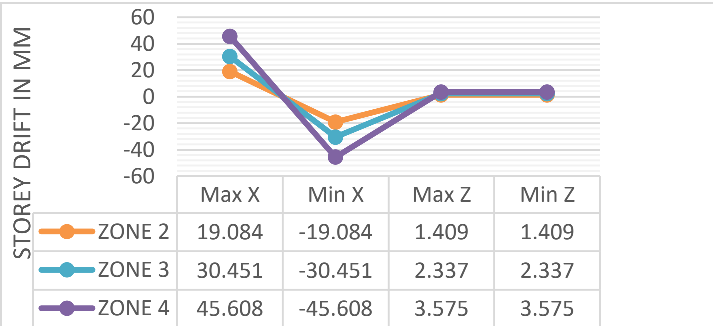

Figure 4. Resultant maximum column displacement.

- Maximum Lateral Forces in the column:

The maximum and minimum lateral forces acting in a column along the X and Z axis for worst loading conditions for different seismic Zones of India are shown in Table 8.

Table-8. Lateral Forces acting in column

Lateral Forces Acting in Column in kN	Zone 2 [FX]	Zone 3 [FX]	Zone 4 [FX]	Zone 2 [FZ]	Zone 3 [FZ]	Zone 4 [FZ]
Max Fx	7447.98	7447.98	7447.98	0	0	0
Min Fx	-131.7	-210.71	-316.07	-2.4	-3.84	-5.76
Max Fy	-2.72	-2.72	-0.545	-0.07	-0.07	0.07
Min Fy	-2.72	-2.72	-0.545	0.07	0.07	-0.07
Max Fz	354.99	4016.42	3579.17	67.29	71.42	91.79
Min Fz	354.99	4016.42	3579.17	-67.29	-71.42	-91.79
Max Mx	1614.44	1585.91	1547.87	27.423	20.34	10.9
Min Mx	1614.44	1585.91	1547.87	-27.43	-20.34	-10.9

Max My	285.715	3667.835	4154.1	67.29	-70.78	-91.48
Min My	285.715	3667.835	4154.1	-67.29	70.78	91.48
Max Mz	-2.723	-1.139	-0.55	-0.07	-0.08	-0.07
Min Mz	284.945	4036.878	4184.79	18.56	-27.15	-25.06

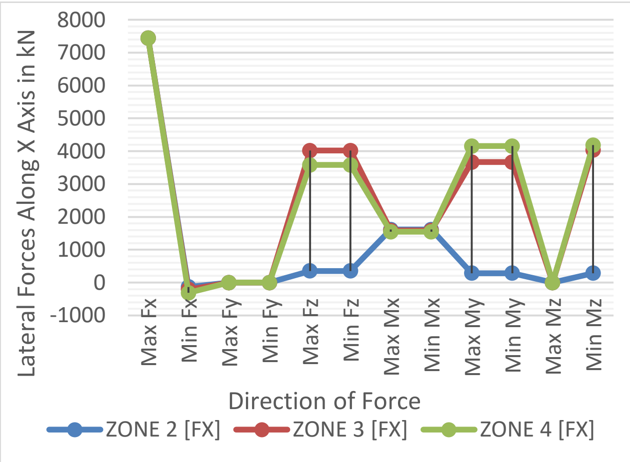

Figure 5. Resultant lateral forces in the X direction.

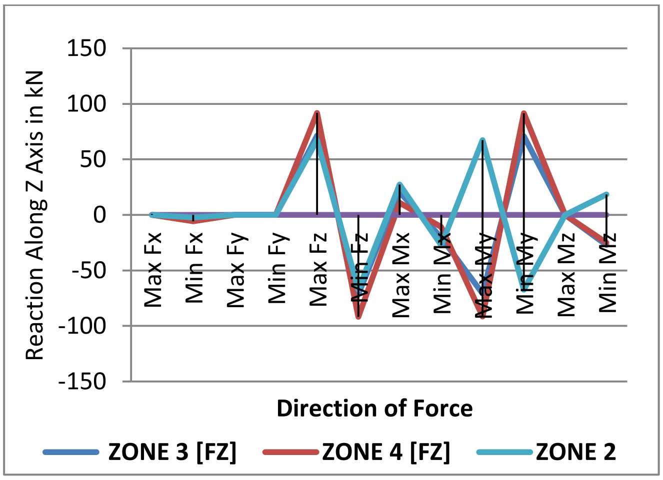

Figure 6. Resultant lateral forces in the Z direction

- Permissible Limit of Deflection in beam and Drift in Column as per IS 456-2000:

The permissible limit of deflection in beam and drift in the column as per IS 456-2000 is calculated and verified with the values received from Staad Pro and it is above the allowable/permissible deflection limit of beam and column for Zone III and IV.

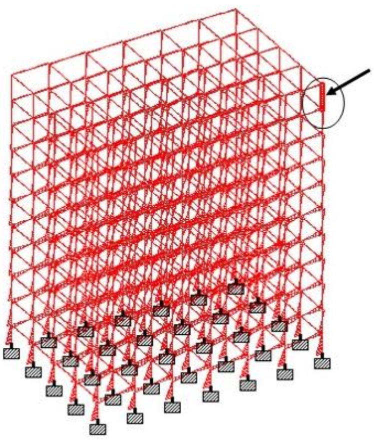

Figure 7. Upper Column (Column No. -743)

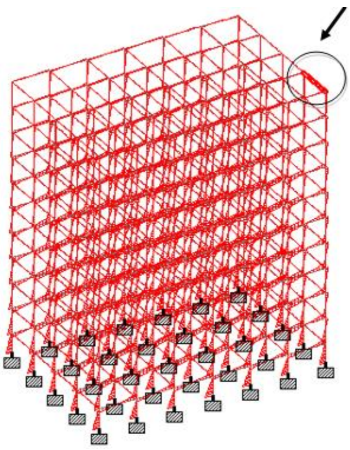

Figure 8. Upper Beam (Beam No. -1023)

Table-9. Permissible Limit of Deflection in beam and Drift in Column.

Upper Beam (Beam No. -1023)				
Deflection In mm	Zone 2	Zone 3	Zone 4	Allowable/ Permissible Limit as per IS 456
	15.925	30.451	38.039	24
Upper Column (Column No. -743)				
Deflection In mm	Zone 2	Zone 3	Zone 4	Allowable/ Permissible Limit as per IS 456
	15.925	30.451	38.039	16

4. CONCLUDING REMARKS

The result of the present study shows that open-ground multi-story buildings are not suitable for regions of higher seismic intensity. However, this type of structure can be designed for lower heights where the deflection in beam and drift in a column will remain as per the Indian Codal Permissible limits.

The following observations are listed:

- The axial strength, shear strength, deflection, and bending moment are noticed maximum in zone IV for all the above cases.
- The deflection in beam and drift in a column is found to be above the allowable/permissible deflection for zone III & zone IV as per IS 456, whereas the design is safe for Seismic Zone II.
- Comparing the tabulated data for various parameters it can be concluded that the height of the building plays a key factor in higher seismic zones. Hence it is desirable to reduce the total height of building in higher seismic zones or use seismic stiffeners, shear walls, and bracings dampers for proper dissipation of energy during earthquakes.

Acknowledgement: The research is based upon the work supported by Dr. B. C. Roy Engineering College, Durgapur.

References

[1] Yadav P., Joshi R. (2019), "Analysis of G+5 Multi-Storeyed Building with and without Shear Wall for zone III", *International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES).* ISSN: 2455-2585, Vol-5, Issue-02, pp. 1-4.

[2] Gopal K.S., Lingeshwaran N. (2017), "Analysis and Design of G+5 Residential Building by using E-TABS", *International Journal of Civil Engineering and Technology (IJCIET).* ISSN: 0976-6308, Vol-8, Issue- 4, pp. 2098-2103.

[3] Kakpure G.G. and Mundhada A.R. (2017), "Study of Static and Dynamic Seismic Analysis of Multi-storeyed RCC Building by ETAB", *International Journal of Engineering Research and Application,* ISSN: 2248-9622, Vol-7, Issue-5, pp. 06-10.

[4] Rathod P. and Chandrashekar R. (2017), "Seismic Analysis of Multi-storeyed Building for Different Plans using ETABS 2015", *International Journal of Engineering and Technology (IRJET).* ISSN: 2395-0056, Vol-4, Issue10, pp. 1101- 1108.

[5] Kadali J.P. and Rathnam M.V. (2015), "Static Analysis of Multistoreyed RC Buildings by Using Pushover Methodology", *International Journal for Innovative Research in Science & Technology,* Volume1, Issue 8, pp113-124.

[6] Jennifer J.P. and Jegidha K.J. (2015), "Seismic Design of Multi-storeyed RC Building Using Various Codes", *International Journal of Innovative Science, Engineering and Technology (IJISET),* ISSN: 2348-7968, Vol-2, Issue-10, pp. 44-46.

[7] Patil N. and Sonawane Y.N. (2015), "Seismic Analysis of Multi-storeyed Building" ,*International Journal of Engineering and Innovative Technology (IJEIT).* ISSN: 9001- 2008, Vol-4, Issue- 9, pp. 123-130.

[8] Mayuri D.B., Patil P.S. (2014), "Comparative Study of Performance of RCC Multistory Building for Koyna and Bhuj Earthquakes" ,*International Journal of Advanced Technology in Engineering and Science.* Volume No.02, Issue No. 07, ISSN (online): 2348 – 7550.

[9] Shome, N. and Cornell, C. A. (2000), "Structural seismic demand analysis: Consideration of Collapse", Proceedings of the Eighth American Society of Civil Engineers Specialty Conference on Probabilistic Mechanics and Structural Reliability.

[10] IS456 (2000), "Indian Standard Code of Practice for Plain and Reinforced Concrete (Fourth revision)", *Bureau of Indian Standards*, New Delhi.

[11] IS 1893 (Part 1) (2002), "Criteria for earthquake-resistant design of structures", *Bureau of Indian Standards.* New Delhi.

Pranoy Roy is working at Dr B. C. Roy Engineering College, Durgapur as Assistant Professor in Department of Civil Engineering from February 2016 to till date. He has completed his B Tech and ME in Civil Engineering and Pursuing PhD from NIT Durgapur as a part time scholar. His areas of research interest are confinement of columns; sustainable construction materials, repair and rehabilitation of structures, durability and sustainability of concrete structures.

Amit Kotal is a B.Tech in Civil Engineering from KIIT University and completed his M.Tech in Geotechnical Engineering from NIT Jamshedpur. Since 2016, he is working in Dr. B.C Roy Engineering College, Durgapur as an assistant professor, having more than 7 years academic experience. Presently perusing his PhD from NIT Patna as a part-time research scholar. His areas of interest or Research Interest are Geotechnical Engineering /Soil-structure interaction, Pile foundation, analysis and design of foundation, Ground Improvement.

Anindita Pan is a B.E. in Civil Engineering from Burdwan University and completed M.Tech in Structural Engineering from MAKAUT. Since 2016, she is working in Dr. B.C Roy Engineering College, Durgapur as an assistant professor, having more than 7 years academic experience. Her research Interest areas are High performance concrete, polymer based concrete, self-curing concrete, self-compacting concrete, earthquake resistant structure etc.