https://dx.doi.org/10.22161/ijaers.6.2.9 SSN: 2349-6495(P) | 2456-1908(O)

Determination of Optimum Location of Rooftop Telecommunication Tower over Multistory Building under Seismic Loading

Suyash Malviya[1], Sagar Jamle[2]

[1]M. Tech. Scholar, Department of Civil Engineering, Oriental University, Indore, India.
Email: 92mogli@gmail.com
[2]Assistant Professor, Department Civil Engineering, Oriental University, Indore, India.
Email: sj.sagarjamle@gmail.com

Abstract**—** *In the last ten years, the growing trend of telecommunication towers has seen a demanding growth. There have been many competitors among operators that have to enhance network reliability and coverage area. The location of tower is very important because it uses latitudes and longitudes with the specified height of mounted antenna which focus towards the practical necessities of the network. In urban areas, it seems that there is scarcity of land and there is no substitute but to implement roof top towers which satisfies ideal installation conditions with respect to its position and height so that spectrum covers the large area. In this work, the results are obtained in terms of the multistoried building situated in seismic Zone-IV. Staad Pro program is used on the structure which is experiencing seismic forces with telecommunication tower positioned at 5 different placing with respect to square base of tower and optimum location of tower over roof.*

Keywords**— Base shear, Optimum case, Rooftop Telecommunication Tower Location, Seismic Effects, Square base, Staad pro.**

I. INTRODUCTION

The examination of the seismic activities of the earth artificially via structural software reveals that whenever the R.C.C. multistory structure has located around the area of epicenter of any earthquake, the waves creates a harmful effect on it.

Telecommunication towers are self-supporting structures and considered now as four-legged space trussed structures which are normally square or rectangular in plan and are supported on ground or on buildings. These structures act as cantilever part which is fixed from one end and other end is free. These cantilever trusses are analyzed and designed to carry earthquake loads. These towers cover less base area, so that they are suitable in situations where there is scarcity of land in urban areas is very restricted. The most common bracing patterns are chevron and the x-bracing.

When this steel structure transferring its own weight as well as weight of accessories and fixtures over the roof of any multistory structure, the response of the host structure will not be same as before. There is always critical location of structure and along with this; the tower weight creates a disaster effect. To counteract this effect we will have to find a most suitable location of telecommunication rooftop tower placing and this work shows optimum location of the same.

II. OBJECTIVES

In this work, response spectrum analysis method is used for the determination of various response parameters occurred in the building under various location of rooftop telecommunication tower over the building. The objectives under medium soil conditions are as follows:-

1. To determine base shear in X direction (+ optimum case)
2. To find base shear in Z direction (+ optimum case)
3. To find and examine maximum nodal displacement in X, Y, Z direction (+ optimum case)
4. To evaluate maximum axial forces in columns at ground level (+ optimum case)
5. To investigate the maximum shear forces in columns (+ optimum case)
6. To find maximum bending moments in columns (+ optimum case)
7. To compare each location case for story drift in X direction (+ optimum case)
8. To compare each location case for story drift in Z direction (+ optimum case)

III. METHODOLOGY IN SEISMIC ANALYSIS

Base Shear (VB) determination of multistory building is given by

$$V_B = A_h \times W$$

https://dx.doi.org/10.22161/ijaers.6.2.9 *SSN: 2349-6495(P) | 2456-1908(O)*

Where,
Ah = design horizontal seismic coefficient
W = Weight of story

Value of A_h is given by

$$A_h = ZIS_a/2Rg$$

Where,
Z = seismic zone factor
I = importance factor
R = response reduction factor
(Sa/g) = average response acceleration coefficient

This average response acceleration coefficient depends upon fundamental time period Ta

$$Ta = (0.09xh)/(\sqrt{d})$$

The Seismic Base shear will be distributed along the height of the building is given by:-

$$Q_i = V_B \text{ x } (Wihi^2)/ (\Sigma i=1 \text{ to n } Wihi^2)$$

Where,
Q_i = design lateral force,
W_i = seismic weight,
h_i = height of the i^{th} floor measured from base of the multistory building
n = number of stories of the building.

IV. STRUCTURE MODELING

The structural modeling has been designed in Staad pro consist of five different rooftop tower placing. This residential apartment having a plinth area of 369 m^2 has been modeled in Staad pro software and model descriptions as per its properties, material, its geometry, support and loading provided are listed in Table 1. Details of loading provided viz. dead loads and live loads are listed in Table 2. Seismic loading definitions are provided in Table 3. Table 4 shows the details of loading combinations as per IS 1893 recommendations. Details of rooftop tower placing cases in multistory building are shown in Table 5 and Figure 1 shows the locations of rooftop tower placing. Figure 2 to Figure 6 shows different rooftop telecommunication tower location placing that are taken into account in this research work.

Table.1: Description of multistory building

Building configuration	G + 12 (Residential apartment)
Plinth area	369 m^2
Height of building above ground level	47.58 m
Floor height	3.66 m
Depth of footing	3 m deep
Support	Fixed
Size of beam	600 mm x 350 mm
Size of column	500 mm x 450 mm
Slab Thickness	200 mm
Steel Platform Thickness	25 mm
Concrete and Steel Grade	M25 & Fe 415 grade
Height of tower	15 m
Top width and bottom width of tower	1m and 3m

Table.2: Details of Dead and Live loading

Self-weight	Over entire structure
10 mm mortar load on above and below the slab	0.42 KN/m^2
Clay floor tiles (12.5 mm thick)	0.10 KN/m^2
Wall load (Roof Parapet)	13.65 KN/m
Wall load (External)	13.65 KN/m
Wall load (Internal)	7.66 KN/m
Weight of tower platform (25 mm thick)	2.25 KN/m^2
Point load (load consist of ladder, cage, etc.) transferred via 4 tower legs	2.4375 KN
Live load for floor and roof	3 KN/m^2 & 1.5 KN/m^2
Live load on tower (assuming 2 persons of 70 kg. weight contains each of 30 kg wt. with them)	1.9613 m^2

Table.3: Details of seismic loading definitions

Zone Factor	0.24 (Zone IV)
Response reduction factor	5
Importance factor	1
Soil Type	Medium Soil
Damping ratio	5%
Period in X and Z direction	0.9933 sec. and 0.9292 sec.

Table.4: Details of loading combinations as per IS 1893 recommendations

S. No.	Load Combinations
1	1.5 (DL+LL)
2	1.5 (DL+EQ_X)
3	1.5 (DL-EQ_X)
4	1.5 (DL+EQ_Z)
5	1.5 (DL-EQ_Z)
6	1.2 (DL+LL+EQ_X)
7	1.2 (DL+LL-EQ_X)
8	1.2 (DL+LL+EQ_Z)
9	1.2 (DL+LL-EQ_Z)
10	0.9 DL+1.5EQ_X)
11	0.9 DL-1.5EQ_X)
12	0.9 DL+1.5EQ_Z)
13	0.9 DL-1.5EQ_Z)

https://dx.doi.org/10.22161/ijaers.6.2.9 *SSN: 2349-6495(P) | 2456-1908(O)*

Table.5: Details of rooftop tower placing cases in multistory building

CASE A	Tower is located at P1 position
CASE B	Tower is located at P2 position
CASE C	Tower is located at P3 position
CASE D	Tower is located at P4 position
CASE E	Tower is located at P5 position

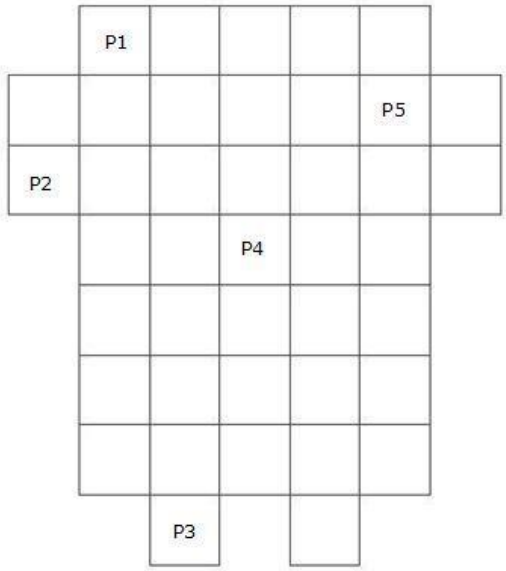


Fig.1: Details of rooftop tower placing

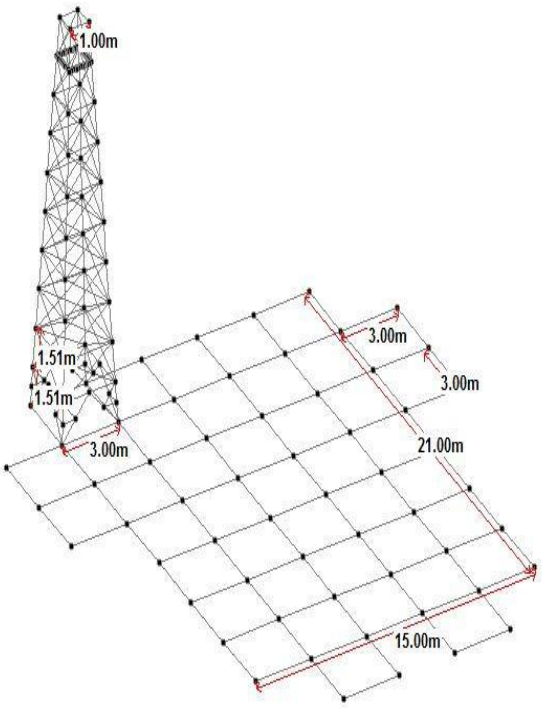


Fig.2: Case A of Telecommunication Tower Over Roof of Position P1

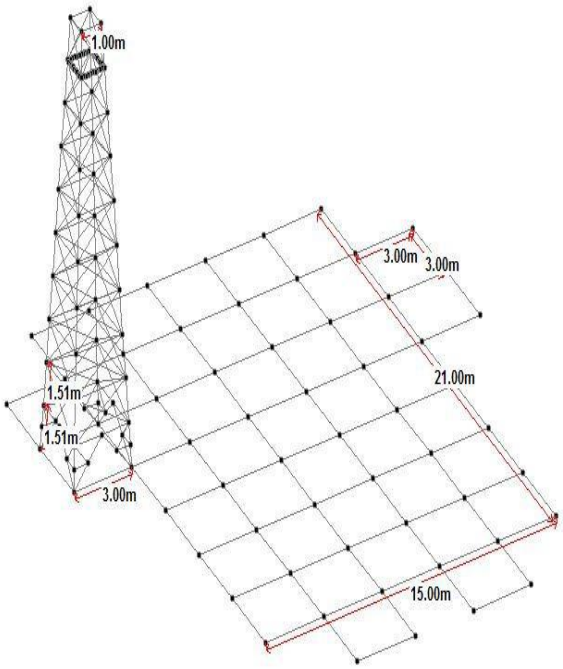


Fig.3: Case B of Telecommunication Tower Over Roof of Position P2

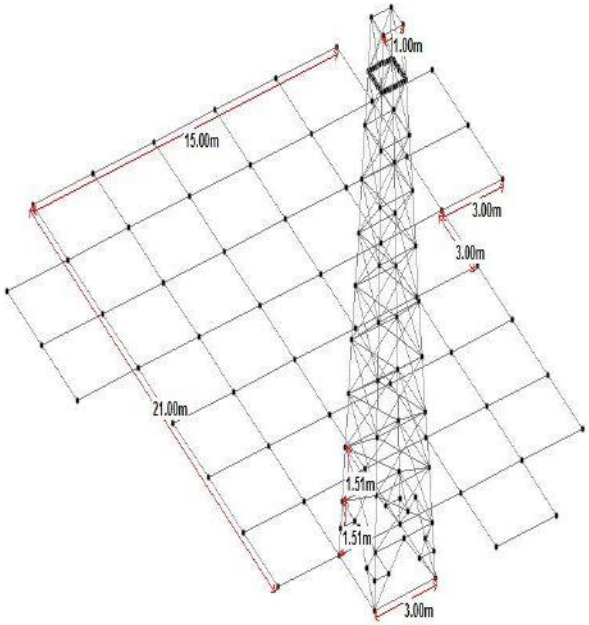


Fig. 4: Case C of Telecommunication Tower Over Roof of Position P3

https://dx.doi.org/10.22161/ijaers.6.2.9 *SSN: 2349-6495(P) | 2456-1908(O)*

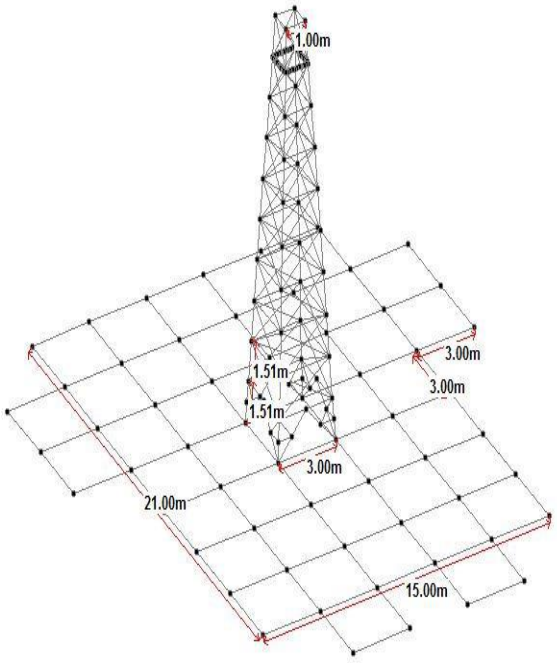


Fig. 5: Case D of Telecommunication Tower Over Roof of Position P4

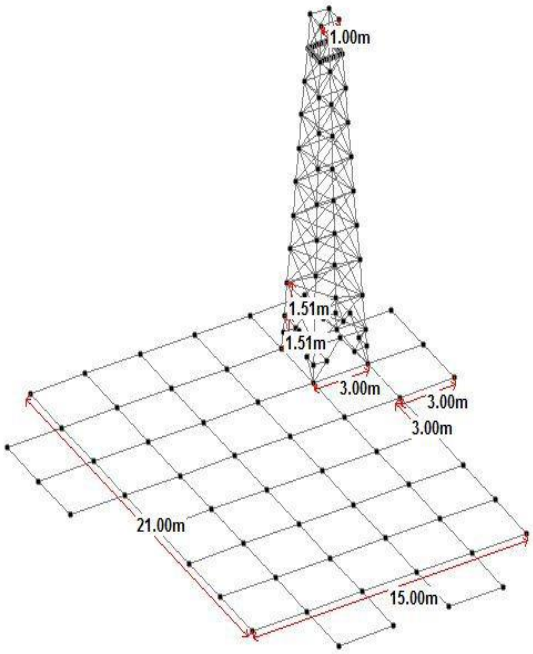


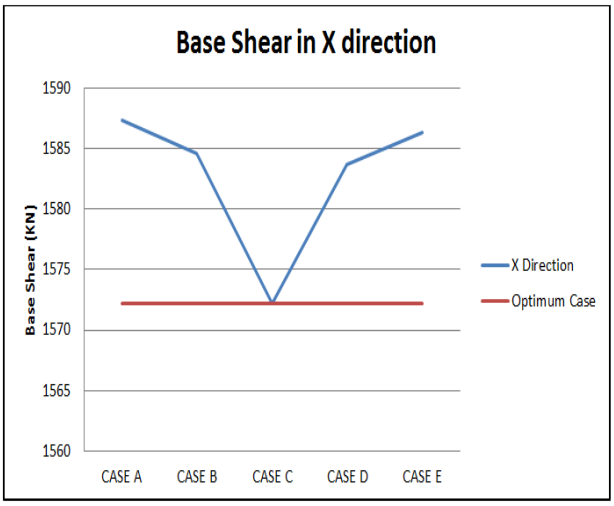
Fig. 6: Case E of Telecommunication Tower Over Roof of Position P5

V. RESULTS AND DISCUSSIONS

After the implementation of earthquake effects over the multistory building contains telecommunication tower on the roof with different location cases, analytic results for medium soil condition under seismic Zone IV are as follows:-

Table.6: Base Shear in X direction for all 5 cases under seismic Zone IV

Tower Location Cases	Base Shear X – direction (KN)	Optimum Case	Remarks
CASE A	1587.34	Case C	Whenever telecommunication tower used in G+12 story building, optimum location case for base shear parameter in X direction will be Case C
CASE B	1584.55		
CASE C	1572.20		
CASE D	1583.71		
CASE E	1586.28		

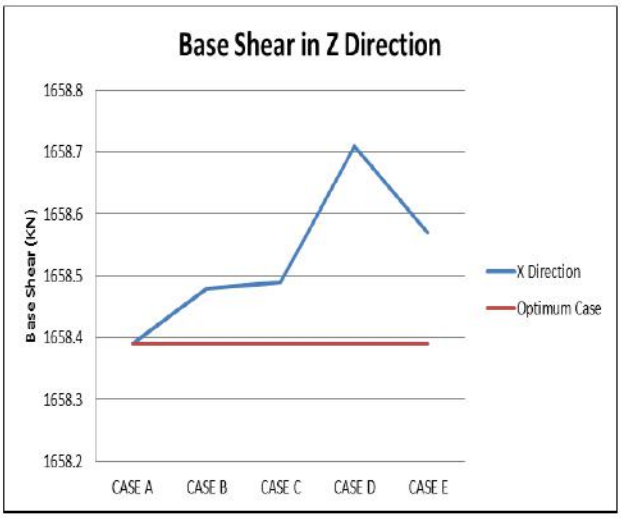


Graph 1: Graphical representation of Base Shear in X direction for all 5 cases under seismic Zone IV

Table.7: Base Shear in Z direction for all 5 cases under seismic Zone IV

Tower Location Cases	Base Shear Z – direction (KN)	Optimum Case	Remarks
CASE A	1658.39	Case A	Whenever telecommunication tower used in G+12 story building, optimum location case for base shear parameter in Z direction will be Case A
CASE B	1658.48		
CASE C	1658.49		
CASE D	1658.71		
CASE E	1658.57		

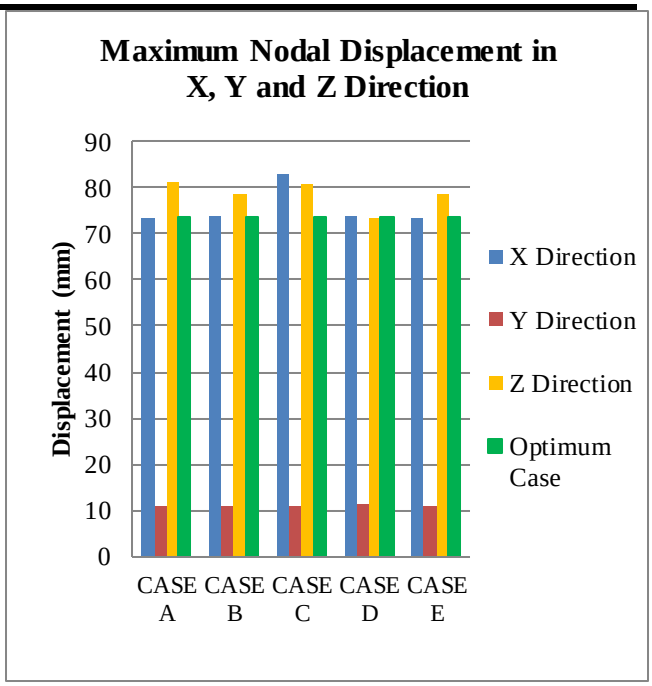
https://dx.doi.org/10.22161/ijaers.6.2.9 SSN: 2349-6495(P) | 2456-1908(O)



Graph 2: Graphical representation of Base Shear in Z direction for all 5 cases under seismic Zone IV

Table.8: Maximum nodal displacement in X, Y and Z direction for all 5 cases under seismic Zone IV

Tower Location Cases	Maximum Displacement			Optimum Case	Remarks
	X direction (mm)	Y direction (mm)	Z direction (mm)		
CASE A	73.501	10.862	81.328	Case D	Whenever telecommunication tower used in G+12 story building, optimum location case for Maximum nodal displacement will be Case D
CASE B	73.774	10.865	78.838		
CASE C	83.216	10.857	80.720		
CASE D	73.853	11.136	73.381		
CASE E	73.585	10.869	78.554		

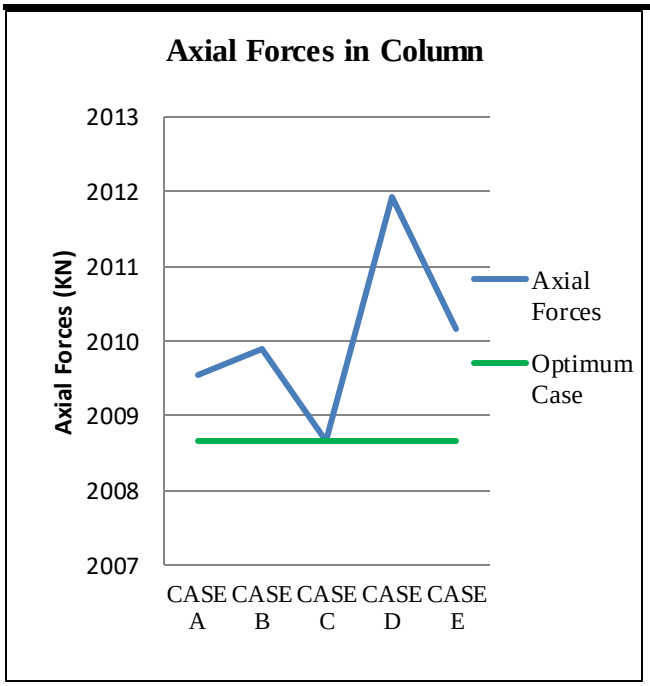


Graph 3: Graphical representation of maximum nodal displacement in X, Y and Z direction for all 5 cases under seismic Zone IV

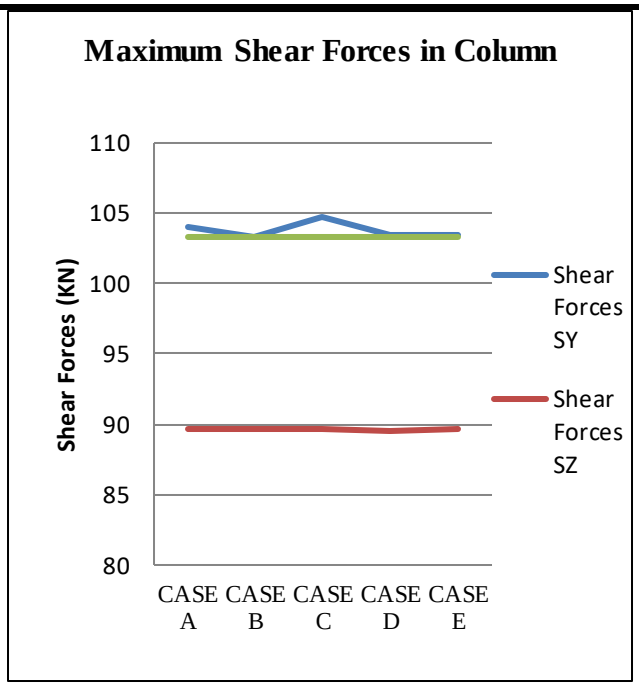
Table.9: Axial Forces in Column at ground story for all 5 cases under seismic Zone IV

Tower Location Cases	Axial Forces in Column (KN)	Optimum Case	Remarks
CASE A	2009.533	Case C	Whenever telecommunication tower used in G+12 story building, optimum location case for Axial forces in Column will be Case C
CASE B	2009.888		
CASE C	2008.655		
CASE D	2011.922		
CASE E	2010.164		

https://dx.doi.org/10.22161/ijaers.6.2.9 SSN: 2349-6495(P) | 2456-1908(O)



Graph 4: Graphical representation of Axial forces in Column at ground story for all 5 cases under seismic Zone IV



Graph 5: Graphical representation of Maximum Shear Forces in Column for all 5 cases under seismic Zone IV

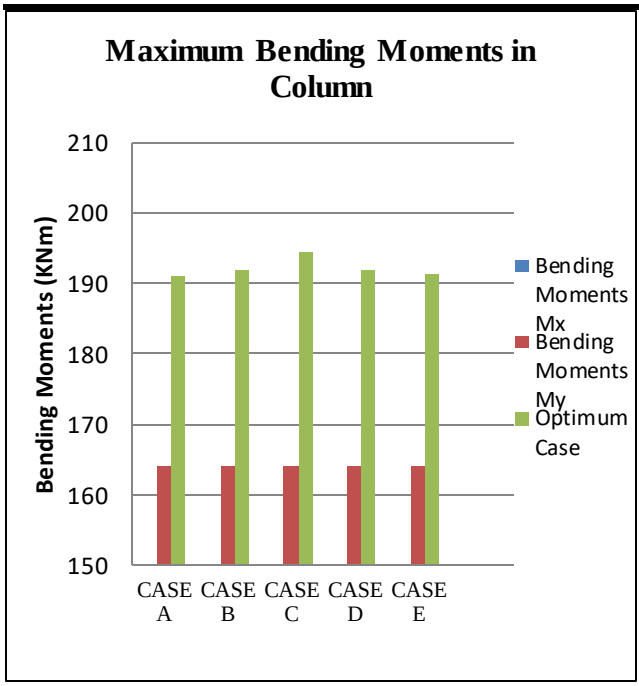
Table.10: Maximum Shear Forces in Column for all 5 cases under seismic Zone IV

Tower Location Cases	Shear Forces in Column (KN)		Optimum Case	Remarks
	SY	SZ		
CASE A	103.960	89.659	Case D	Whenever telecommunication tower used in G+12 story building, optimum location case for Shear forces Sy and Sz in Column will be Case D
CASE B	103.273	89.673		
CASE C	104.691	89.630		
CASE D	103.395	89.562		
CASE E	103.453	89.651		

Table.11: Maximum Bending Moments in Column for all 5 cases under seismic Zone IV

Tower Location Cases	Bending Moments in Column (KNm)		Optimum Case	Remarks
	My	Mz		
CASE A	164.180	191.152	Case D	Whenever telecommunication tower used in G+12 story building, optimum location case for Bending Moments My and Mz in Column will be Case D
CASE B	164.205	191.754		
CASE C	164.127	194.380		
CASE D	164.005	191.982		
CASE E	164.165	191.354		

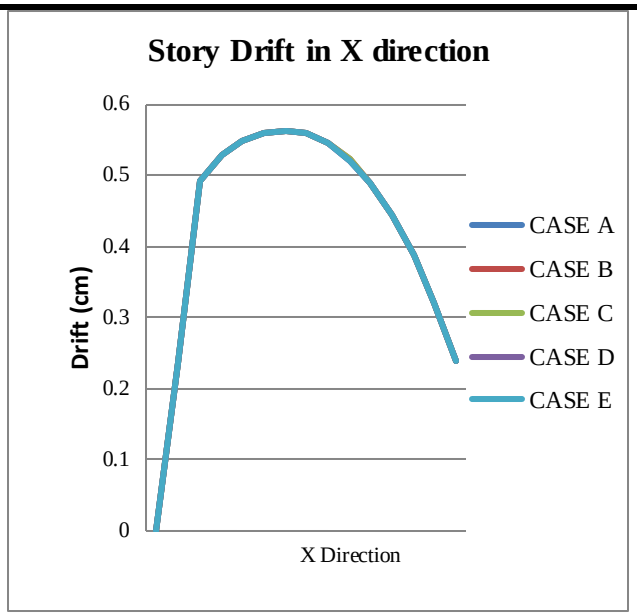
https://dx.doi.org/10.22161/ijaers.6.2.9 *SSN: 2349-6495(P) | 2456-1908(O)*



Graph 6: Graphical representation of Maximum Bending Moments in Column for all 5 cases under seismic Zone IV

Table.12: Story drift in X direction for all 5 cases under seismic Zone IV

Height (m)	Story Drift For X Direction (cm)				
	CASE A	CASE B	CASE C	CASE D	CASE E
0	0	0	0	0	0
3.3	0.2366	0.2366	0.2366	0.2366	0.2366
6.66	0.4931	0.4932	0.4932	0.4932	0.4931
10.32	0.5295	0.5295	0.5296	0.5295	0.5295
13.98	0.5481	0.5482	0.5483	0.5482	0.5482
17.64	0.5594	0.5595	0.5596	0.5595	0.5594
21.30	0.5631	0.5632	0.5633	0.5632	0.5631
24.96	0.5585	0.5586	0.5587	0.5586	0.5585
28.62	0.5449	0.5450	0.5451	0.5450	0.5449
32.28	0.5217	0.5218	0.5218	0.5217	0.5217
35.94	0.4881	0.4882	0.4882	0.4881	0.4881
39.60	0.4436	0.4437	0.4437	0.4436	0.4436
43.26	0.3876	0.3877	0.3876	0.3876	0.3876
46.92	0.3193	0.3194	0.3193	0.3193	0.3193
50.58	0.2386	0.2388	0.2385	0.2386	0.2386
Optimum Case	Case A and Case E				
Remarks	Whenever telecommunication tower used in G+12 story building, optimum location case for Story drift in Z direction will be Case A and E with lesser values				

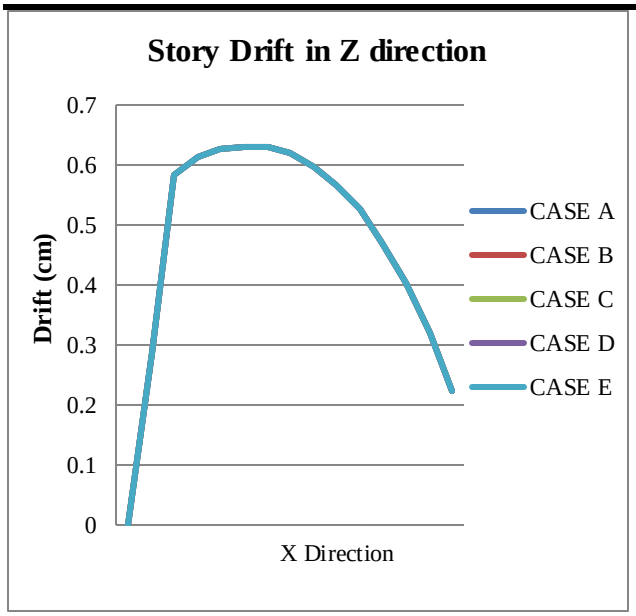


Graph 7: Graphical representation of story drift in X direction for all 5 cases under seismic Zone IV

Table.13: Story drift in Z direction for all 5 cases under seismic Zone IV

Height (m)	Story Drift For Z Direction (cm)				
	CASE A	CASE B	CASE C	CASE D	CASE E
0	0	0	0	0	0
3.3	0.2871	0.2871	0.2871	0.2871	0.2871
6.66	0.5814	0.5814	0.5814	0.5814	0.5814
10.32	0.6114	0.6114	0.6114	0.6114	0.6114
13.98	0.6244	0.6243	0.6244	0.6243	0.6244
17.64	0.6302	0.6302	0.6302	0.6301	0.6302
21.30	0.6283	0.6282	0.6283	0.6282	0.6283
24.96	0.6177	0.6176	0.6177	0.6176	0.6176
28.62	0.5974	0.5973	0.5974	0.5973	0.5974
32.28	0.5666	0.5665	0.5666	0.5665	0.5666
35.94	0.5243	0.5242	0.5243	0.5242	0.5242
39.60	0.4696	0.4694	0.4696	0.4694	0.4695
43.26	0.4017	0.4015	0.4017	0.4015	0.4016
46.92	0.3194	0.3192	0.3194	0.3192	0.3193
50.58	0.2213	0.2210	0.2213	0.2210	0.2211
Optimum Case	Case B and Case D				
Remarks	Whenever telecommunication tower used in G+12 story building, optimum location case for Story drift in Z direction will be Case B and Case D with lesser values				

https://dx.doi.org/10.22161/ijaers.6.2.9 *SSN: 2349-6495(P) | 2456-1908(O)*



Graph 8: Graphical representation of story drift in Z direction for all 5 cases under seismic Zone IV

VI. CONCLUSION

It has been concluded from the above study that the seismic forces when hit on any structure having a telecommunication tower over it, all location cases considered shows their own values in different parameters under seismic Zone IV are as follows:-

1. In case of base shear in X direction, Case C emerges out to be the best optimal case among all five cases. Since the values keep on decreasing from case A to C and then it again increases. For Z direction, the values are same for all the five different cases.
2. Parametric results achieved in case of maximum nodal displacement shows minimum values in Case D. Comparing nodal displacements in all directions in G+12 story building, optimum location case for Maximum nodal displacement will be Case D.
3. Axial forces in column seems to be increasing first and then its values keeps on decreasing to Case C and then it keeps on increasing. Hence optimum location case for Axial forces in Column at ground story will be Case C.
4. Shear Forces in column in Y direction as Sy seems to be lower in Case D and this case shows again less in Sz i.e. shear forces in Z direction. Concluding the optimum case in this, Case D attains more in this parameter.
5. Again Case D among all location cases seems to be lower in Maximum Bending Moment parameter. Since the values are same in My and Mz, getting into minute values after the decimal place, Case D shows optimal values in columns.
6. Story drift seems to be minimum in Case A and E, showing almost same values under seismic zone IV. On the other hand Case B and Case D show minimum values. Since there was a minute difference between them, at a height of 17.64 m to 21.30 m, the values of story drift keeps on decreasing.

ACKNOWLEDGEMENTS

I would like to thank ***Mr. Sagar Jamle***, Assistant Professor, Department of Civil Engineering, Oriental University, Indore, for his involvement and dedication in my topic and continuous support throughout this work.

REFERENCES

[1] Arpit Chawda, Vijay Baradiya (2007), "Earthquake Amplification Factors for Self-supporting 4-legged Telecommunication Towers", World Applied Sciences Journal, ISSN 1818-4952, Vol. 2, Issue 6, pp. 635-643.

[2] C. Preeti and K. Jagan Mohan (2013), "Analysis of Transmission Towers with Different Configurations", Jordan Journal of Civil Engineering, Vol. 7, Issue 4, pp. 450-460.

[3] G. Ghodrati Amiri, M A. Barkhordari, S.R. Massah (2004), "Seismic Behavior of 4-Legged Self-Supporting Telecommunication Towers", 13th World Conference on Earthquake Engineering Vancouver, B.C., Canada, Paper no. 215, pp. 1-11.

[4] G. Ghodrati Amiri, M A. Barkhordari, S.R. Massah and M.R. Vafaei (2007), "Earthquake Amplification Factors for Self-supporting 4-legged Telecommunication Towers", World Applied Sciences Journal, ISSN 1818-4952, Vol. 2, Issue 6, pp. 635-643.

[5] Gholamreza Soltanzadeh, Hossein Shad, Mohammadreza Vafaei, Azlan Adnan (2014), "Seismic Performance of 4-Legged Self-supporting Telecommunication Towers", International Journal of Applied Sciences and Engineering Research, ISSN 2277-9442, Vol. 3, Issue 2, pp. 319-332.

[6] Ghyslaine Mcclure, Laura Georgi, Rola Assi (2004), "Seismic Considerations for Telecommunication Towers Mounted on Building Rooftops", 13th World Conference on Earthquake Engineering Vancouver, B.C., Canada, Paper no. 1988, pp. 1-14.

[7] Hemal J shah, Dr. Atul K Desai (2014), "Seismic Analysis of Tall TV Tower Considering Different Bracing Systems", International Journal of Engineering, Business and Enterprise Applications, ISSN 2279-0039, Vol. 14, Issue 178, pp. 113-119.

[8] Jithesh Rajasekharan, S Vijaya (2014), "Analysis of Telecommunication Tower Subjected to Seismic & Wind Loading", International Journal of Advancement in Engineering Technology,

https://dx.doi.org/10.22161/ijaers.6.2.9 *SSN: 2349-6495(P) | 2456-1908(O)*

Management & Applied Science, ISSN 2349-3224, Vol. 1, Issue 2, pp. 68-79.

[9] Nitin Bhosale, Prabhat Kumar, Pandey A. D. (2012), "Influence of Host Structure Characteristics on Response of Rooftop Telecommunication Towers", International Journal of Civil and Structural Engineering, ISSN 0976-4399, Vol. 2, Issue 3, pp. 737-748.

[10] Patil Vidya M., Lande Abhijeet C., "Structural Response of Lattice Steel Masts for Seismic Loading", IOSR Journal of Mechanical and Civil Engineering, ISSN 2278-1684, pp. 36-42.

[11] Richa Bhatt, A. D. Pandey, Vipul Prakash (2013), "Influence of modeling in the response of steel lattice mobile tower under wind loading", International Journal of Scientific Engineering and Technology, ISSN 2277-1581, Vol. 2, Issue 3, pp. 137-144.

[12] Shailesh S. Goral, Prof. S. M. Barelikar (2015), "Influence of Structure Characteristics on Earthquake Response Under Different Position of Rooftop Telecommunication Towers", International Journal of Engineering Sciences & Research Technology, ISSN 2277-9655, Vol. 4, Issue 10, pp. 73-78.

[13] Siddesha. H (2010), "Wind Analysis of Microwave Antenna Towers", International Journal of Applied Engineering Research, ISSN 0976-4259, Vol. 1, Issue 3, pp. 574-584.

[14] Sourabh Rajoriya, K.K. Pathak, Vivekanand Vyas (2016), "Analysis of Transmission Tower for Seismic Loading Considering Different Height and Bracing System", International Journal for Research in Applied Science & Engineering Technology, ISSN 2321-9653, Vol. 4, Issue 9, pp. 108-118.