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Analysis of Transmission Tower

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Abstract – *In this study, a typical type of transmission line towers (suspension tower) carrying 400kV double circuit conductors are modelled and analyzed using Staad.Pro V8i SS5 considering forces like wind load as per IS 802 (part I/Sec 1):1995, dead load of the structure and earthquake load as per IS 1893(part 1):2015. The height of transmission tower is 50m which includes the ground clearance and base width is 10m. The towers are designed into two wind zones i.e. 2 and 6 and it is located in the seismic region Zones i.e. II and V. K and X bracing systems are considered. From the whole analysis, it is found that X bracing is safer in cost as compare to K bracing. Comparison between the bracing systems, Wind zones and Seismic zones of the Towers is done.*

Keywords: Transmission tower, Bracing systems, Wind Load, Seismic Load, Double circuits, square base tower.

1. INTRODUCTION

Transmission line towers are one of most important life-line structures. Transmission towers are necessary for the purpose of supplying electricity to various regions of the nation. They are designed and constructed in wide, variety of shapes, types, sizes, configuration and materials. Transmission towers of square base self-supporting with different bracing systems are considered in this study. Transmission line should be stable and carefully designed so that they do not fail during natural disaster. In the planning and design of a transmission line, a number of requirements have to be met from both structural and electrical point of view. From the electrical point of view, the most important requirement is insulation and safe clearances of the power carrying conductors from the ground. From Structural point of view, Steel angle sections of different grades are generally used for towers.

(a)

(b)

Figure 1.1 Transmission tower (a) Double Circuit (b) Single Circuit

2. LITERATURE SURVEY

Anshu Kumar Pal, M. Suneel, P V Rambabu (2019), in this study, 220 KV suspension type, and square based self supporting transmission tower having double circuits. Two bracing systems viz. XX and XBX are being compared in all the six wind zones of India as per IS 802 (Part-1/Sec-I):1995. The towers are modelled and analyzed in STAAD Pro V8i. The XBX bracing was concluded to be more economical in comparison with XX bracing in all wind zones of India.

Deepali Patel, Dr. Dipti Singh, Dr. Shilpa Pal and Sachin Tiwari (2018), an attempt has been made to make a 400kV double circuit's tension tower having deviation angle of 2-15° with X, K and mixed both bracings using STAAD.PRO. A mixed combination of K and X bracing is to be applied for least cost. Rectangular base configuration cost is lesser than the Square configuration by 1.17%, but Rectangular base configuration is difficult to carry in practice and hence, practically Square Configuration is adopted.

3. OBJECTIVES7OF THE STUDY

1. To determine the Weight of Steel require for the Structures.
2. To find the deflection and axial forces of the towers.
3. To determine the Base Shear of the towers for various Seismic zones.

4. To study the behaviour of the towers in different Wind zones and bracing systems.
5. To compare the Seismic behaviour of the towers under various Seismic zones and Wind zones with different types of bracing systems.
6. To compare the amount of Steel use under different bracings.

4. METHODOLOGY

STAAD.Pro V8i has been used for the analysis of Transmission Tower. The models are modelled in the software with different bracing systems (X and K bracings). In the following flow chart (figure 4.1), step by step procedures are shown according to which the study has been carried out.

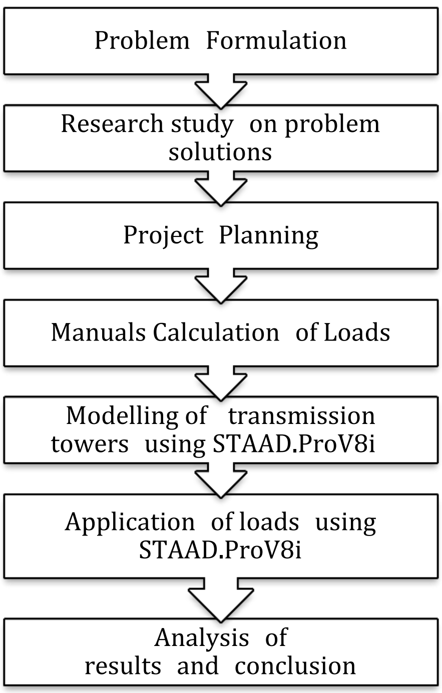


Figure 4.1 Methodology

After modelling, the models are divided in seven panels for both the bracings. The models of the Transmission Tower which had modelled in the software are shown in the below figure 4.2(a) and 4.2(b). Now based on the validation of results through STAAD.Pro V8i, the important conclusions are made.

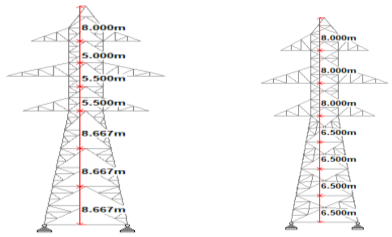


Figure 4.2 Tower with divided panels

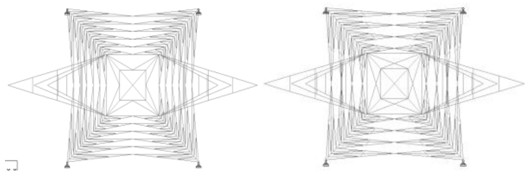


Figure 4.3 Top views of Tower

4.1. Specifications of the Tower

Angle Sections (ST ISA) are used for all the sections of Structure.

Table No. 4.1 Specifications of the Sections

Wind zones		Types of Bracings	
		K	X
6	Seismic zone II	200x200x25 120x120x18 75x75x10	200x200x25 110x110x16 75x75x10
	Seismic zone VI	200x200x25 120x120x18 75x75x10	200x200x25 110x110x16 75x75x10
2	Seismic zone II	150x150x18 100x100x15 75x75x10	150x150x18 90x90x12 75x75x10
	Seismic zone VI	150x150x18 100x100x15 75x75x10	150x150x18 90x90x12 75x75x10

Table No.4.2 Specifications of Conductor8and Ground Wire

Properties	Conductor wire	Ground wire
Material	ACSR	Galvanised steel Earth wire
Strand (mm)	7/3.53	7/3.66
Diameter (mm)	31.77	11
Sectional area (mm^2)	597	57.8
Weight (kg/mm)	2	0.7363
Ultimate tensile strength (kg)	16280	6950

Table No.4.3 Specifications of Insulators

Insulator type	Suspension type
Size of2insulator1disc	280x170 mm
Length6of insulator6string	3850 mm
Minimum4wind load on insulators	1 kN
Area of Insulator	1.814 m^2

4.2. Wind Loads

Table No.4.4 Wind Load on Tower, F_{wt}

Panels	F_{wt} in kN (K bracing)		F_{wt} in kN (X bracing)	
	Wind zone 2	Wind zone 6	Wind zone 2	Wind zone 6
1	30.39	68.87	16.74	46.08
2	29.61	66.86	20.53	46.29
3	25.57	57.67	18.96	42.72
4	44.37	99.63	17.31	38.74
5	36.2	79.75	38.83	87.55
6	15.33	34.22	44.90	102.46
7	28.51	63.57	41.92	96.46

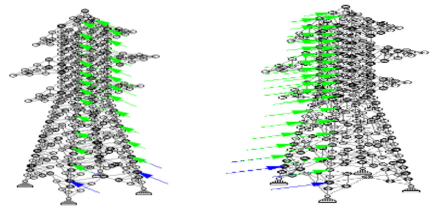


Figure 4.6 Wind Loadings on the Transmission Towers

Table No. 4.5 Wind Load on Conductor8and Ground wire, F_{wc} (For both the bracing systems)

Wind zones	F_{wc} in kN (Conductor)			F_{wc} in kN (Ground wire)
	Bottom	Mid	Top	
2	13.46	13.94	14.74	6.124
6	26.77	27.74	29.32	12.18

Table No.4.6 Wind Load on Insulator Strings, F_{wi} (For both the bracing systems)

Wind zones	F_{wi} in kN		
	Bottom String	Mid String	Top String
2	3.35	2.46	2.55
6	4.67	4.89	5.076

4.3. Response Spectrum Analysis

The Response Spectrum analysis is a linear dynamic process, in which the response of the structure is assumed from the design Spectrum specified in the IS code. The analysis is carried out as per IS 1893 (part 4):2015. The Response Spectra specified in IS 1893 (part 4):2015 is for a damping ratio of 5%. The soft soil sites are used in this study.

4.4. Temperature Load

1. Max. temperature: 75°c (Ref. IS 802 (part I/Sec 1):1995)
2. Min. temperature : 0° (Ref. IS 802 (part I/Sec 1):1995)
3. Average temperature : 32° (Ref. IS 802 (part I/Sec 1):1995)

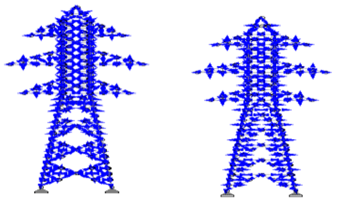


Figure 4.9 Temperature load on the Transmission Tower

5. RESULTS AND DISCUSSIONS

I. WEIGHT OF STEEL

Table No.5.1 Weight of Steel

Wind zones	Weight of steel (kN)	
	K bracing	X bracing
2	312.213	302.629
6	461.011	451.014

II. MAXIMUM AXIAL FORCES

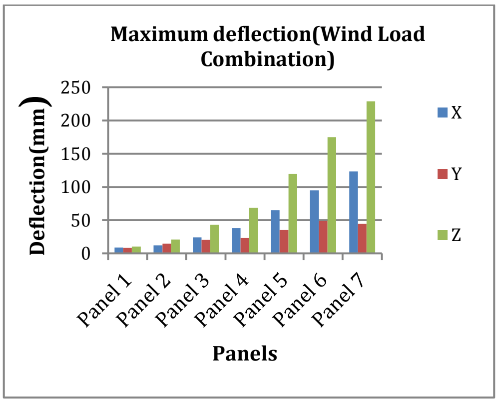
The Maximum Axial Forces for Wind Load Combination and Seismic Load Combination is more in Main leg when compare to Main bracing and Secondary bracing in all types of bracing systems under different Wind zones and Seismic zones.

III. BASE SHEAR

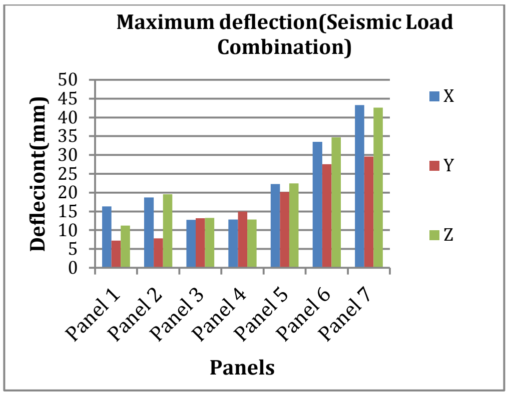
In all the Seismic zones with different bracing systems, the Base Shear is same in all the x and z directions.

IV. MAXIMUM DEFLECTION OF X BRACING

- For Wind Zone 6 and Seismic Zone V

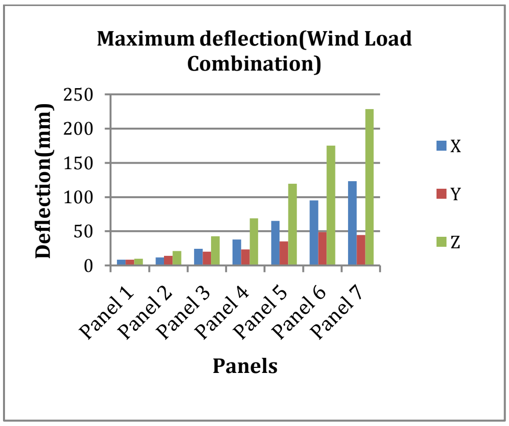


- For Wind Zone 6 and Seismic Zone V

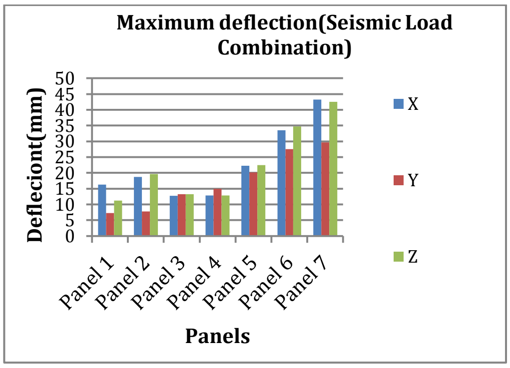


V. MAXIMUM DEFLECTION OF X BRACING

- For Wind Zone 6 and Seismic Zone V



- For Wind Zone 6 and Seismic Zone V

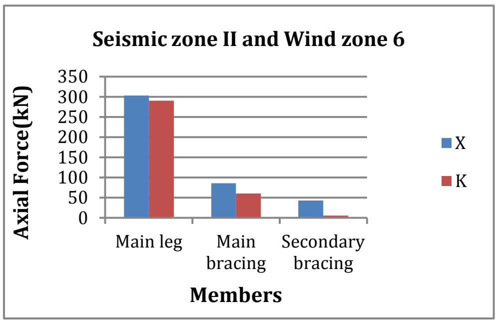


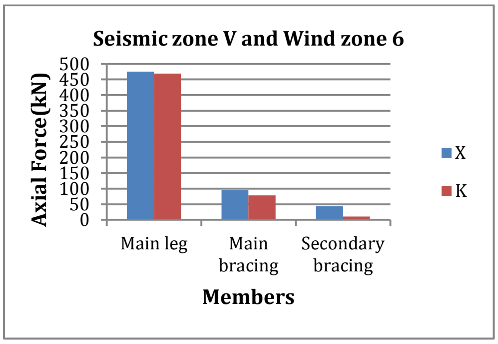
From the above graphs, it is observed that the deflection of the tower is increases as the height of the tower increases. For the remaining Wind zones and Seismic zones, the same results are seen in both the bracing systems.

VI. COMPARATIVES STUDIES

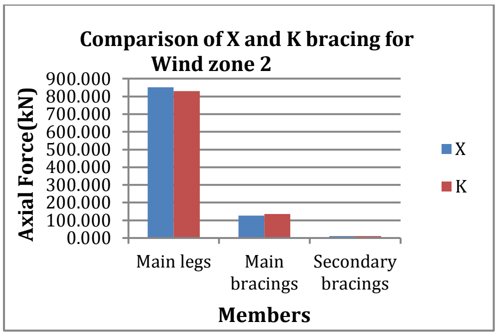
a) **The total weight of Steel**: The total weight of Steel used for towers is more in K bracing compare to X bracing in both the wind zones.

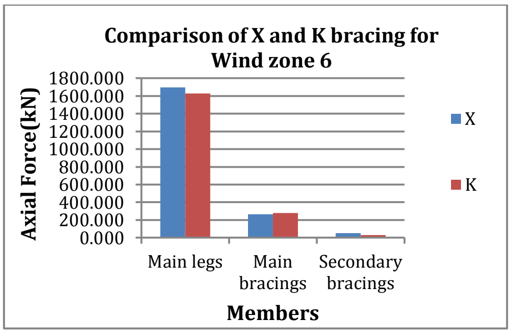
b) Seismic behaviour of Axial Force:



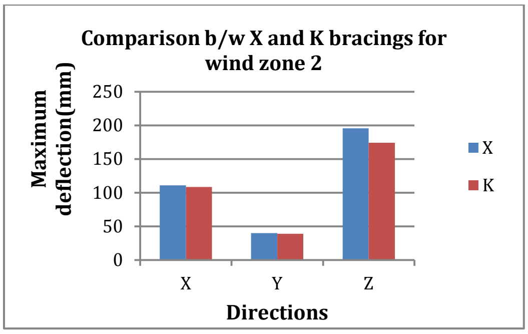


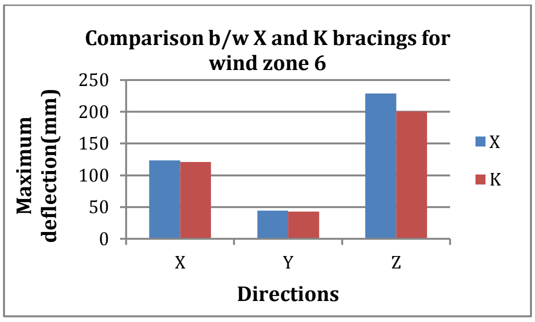
c) Wind behaviour of Axial Force:



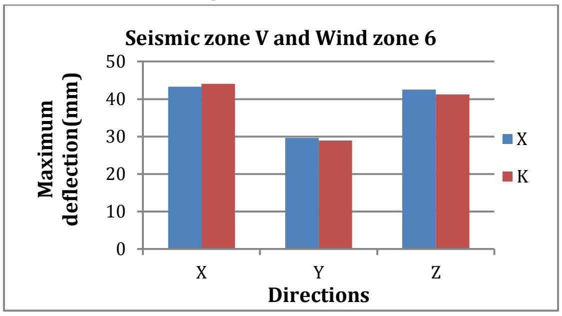


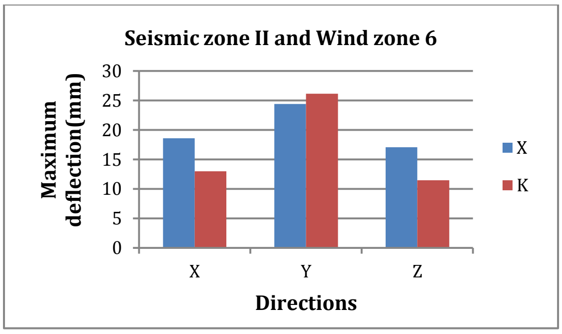
d) Maximum deflection of X and K bracing for Wind Loading:





e) Maximum deflection of X and K bracing for Seismic Loading:





6. CONCLUSIONS

a) A saving in steel weight of 3.07% resulted when using X bracing tower as compared with K bracing. It is concludes that X bracing is more economical in costs than K bracing.

b) The Base Shear of the Towers for Wind zones 2 and 6 of Seismic zone V is 72.2% higher than the Seismic zone II for both the bracing systems.

c) All the bracing systems do not show much differ in deflections under all types of loadings. Hence, it can be recommended in practice.
d) All the deflections for Earthquake loading are in permissible limits is less than D_{max} =0.005*H, where H is the height of the structure above the base and D_{max} is the maximum lateral deflection.
e) All the deflections for Wind loading are in permissible limits is less than H/100.

7. FUTURE SCOPE OF THE STUDY

a) Analysis of Transmission Tower Line Systems with Broken conditions of the Earth Wire, Conductors, and Insulators is recommended.
b) Different types of bracing systems which mean mixed both X and K bracing and W bracing systems can carry for further study.
c) Collapse Analysis of Transmission Tower should be investigated in the further research.

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