Analytical Investigation of Communication Tower under Wind Load

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Abstract—*With the rapid and widespread expansion of long distance broadcasting and communication in last two decades, the structural engineers have been faced with the problem of support of antennas at great heights, which is necessary to broadcast signals over long distance. In addition, the field of power transmission also requires the high tension conductors to be installed at reasonable heights. Engineering design of telecommunication structure is concerned with much more than calculation and numerical analysis. The present study focus on analysis of communication towers for strength and stability to withstand the lateral force because of wind as the tower are affected by lateral force like wind as a result tower deflect laterally to maximum extent and there by it can affect the cost of the project as well as communication broad systems there fore the primary aim of investigation was to provide minimum deflection for the high communication tower. In the present analytical study, the number of towers with different bracing have been modeled and analysis with SAP 2000 computer package. The principal influencing parameter in the study where type of bracing (X, XB, K, XB K and K XB), base width and height of tower. The tower is resting on building of height 45 m and tower this as resulted the total height of tower as 55 m, 64 m and 73 m. The base width varies from 2.5 m, 3 m, 3.5 m and 4 m and height of towers varies from 9 m, 18 m and 27 m. All the towers are models in space frame with different braced systems; this has resulted into 55 models. The study reviewed that the height, base width and type of bracing are the significant influencing parameter on the strength and stability of tower. As the base width and height increases, deflection also increases significantly. However the result shows that X and XB bracing are more suitable for all height more than 55 m where as all type of bracing suitable up to 55 m.*

Keywords— Communication Tower, SAP 2000 software, Wind Load, Strength and Stability.

I. INTRODUCTION

The tall structures with relatively small cross section and with large ratio between the height and maximum width are known as towers. A tower is also known as a pylon. A is a single cantilever freely standing. The towers may be built-up with three or more legs. In general, the towers are constructed with four legs, spaced suitably. The four legs towers maintain stability of towers. The present study is limited to the analysis of communication towers. The numbers of towers with different bracing are to be modal with SAP 2000 software. The models are to be prepared in space frame with different braced systems. And analysis should be made to get the lateral deflections subjected to static loading. The present study will provide minimum deflection for the high communication towers to the working engineers. Generally tower is affected by lateral forces like wind load. Therefore, it deflects laterally to the maximum extent. The lateral deflection can affect the cost of the project as well as communication and broadcasting system. A number of towers models with different bracing system and height have been investigated with view to understand the performance of the models under wind load *i.e* lateral deflection. Antenna towers are one of the most widely used structures in the arena of telecommunication like TV transmission, air traffic control and in defense sector. Their need has been enhanced recently due to booming network of telecommunication and advent of information technology.

II. ANALYTICAL ANALYSIS

The main objective of the analysis is to study the maximum deflection of communication tower which resting on roof. The analysis is carried out in SAP2000 software. Various tables presented in this paper shows the results obtained from SAP2000. Results of communication towers with different brace systems are discussed in comparison with deflectionTowers are situated in wind zone IV other details of the towers are as below.

The lattices tower are modeled and analyzed for the different combinations of static loading. The comparison is made between two types of system for deflection. Towers are situated in wind zone IV other details of the towers are as below.

ASSUMPTIONS MADE

The following are the assumptions are made

The heights of the towers are kept as 9m, 18m, 27m from top of building.

The towers of 9 m height are divided in to three main parts like 3m, 6m and 9m from top of building.

The towers of 18 m height are divided in to six main parts like 3m, 6m, 9m, 12m, 15m and 18m from top of building.
The towers of 27 m height are divided in to nine main parts like 3m, 6m and 9m 12m, 15m, 18m, 21m, 24m and 27m from top of building.
The towers are braced by K-type, X-type, and XB-type of bracing for 9 m height from top of building and are named as 'Model A'.
The towers are braced by K-type, X-type, XB-type, XB-K type, K-XB type of bracing for 18 m height from top of building and are named as 'Model B'.
The towers are braced by XB-K type, K-XB type of bracing for 27 m height from top of building and are named as 'Model C'.
The weight of the railing plate form is considered as 1.2 kN/m^2
The weight of the ladder, cables and lighting system etc. is considered as 1.25 kN/m^2.
For the calculation of the wind load basic wind speed is considered as 44 km/h.
The tower comes into category 4 and class B of IS: 875 (Part 3) - 1987.
For the seismic analysis the tower is considered in zone IV with medium soil condition.

III. GROUP PROPERTIES

The description of properties of members are given in tabular form as below

Table 1: Group Properties

Height	Height up to 9m	Height up to 18m	Height up to 27m
Main members	ISA 100x100x10	ISA 130x130x10	ISA 150x150x10
Horizontal members	ISA 100x100x10	ISA 130x130x10	ISA 150x150x10
Main bracing	ISA 90x90x10	ISA 100x100x10	ISA 100x100x10

Description for loading
The loading on the tower is considered as per following calculations
Dead loads
Weight of railing etc = 1.2 x 2 x 2 = 4.8 kN
Weight of the accessories = 1.25 x 2 x 2 = 5 KN
Self weight of tower is automatically considered by the soft ware SAP 2000.
Live loads
The minimum live load of 1 kN/m^2 is considered on the tower

The description of geometry is given in tabular form as below Data
Type of Bracing is K type bracing
Height of Tower = 55m
Base Width = 2.5 m
Top Width = 1m
Number of Panels = 3
Force Data
Basic Wind Speed V_b = 44 m/s
Risk Coefficient k_1 = 1.05
Topography Coefficient k_3 = 1
Terrain Coefficient k_2 varies with respect to height.
Design Wind Pressure at different height are computed as Wind load is calculated as per IS: 875-1987 (Part 3). The calculation is done as below.

$$V_z = V_b\ k_1\ k_2\ k_3$$

For 55m height

$$V_z = 44 \text{ x } 1.0 \text{ x } 1.05 \text{ x } k_2$$
$$V_z = 46.2\ k_2 \text{ m/s}$$

Design Wind Pressure $Pz = 0.6 \text{ x } V_z^2$

$$= 0.6 \text{ x } (46.2 \text{ x } k_2)^2$$
$$= 1280.66 \text{ x } (k_2)^2 N/m^2$$
$$Pz = 1.280 \text{ x } (k_2)^2 \ kN/m^2$$

Table 2: Solidity Ratio of different Height for Modal 2.5 K 9

Height m	Terrain, Height and Structure Size Factor k_2	Design Wind Pressure kN/m^2	Solidity Ratio Φ	Pressure Coefficient Cp
55	1.058	1.43	0.3386	2.60
52	1.052	1.41	0.2353	3.12
49	1.038	1.37	0.1871	3.39

IV. DESCRIPTION OF LOADING FOR DIFFERENT PANELS

Wind load calculations at different height which is ranging from 49 m to 55 m are calculate for different types brace system. Solidity Ratio, Design Wind Pressure, Pressure Coefficient varies when Terrain, Height and Structure Size Factor k_2 changes, shown in Tables 3 to 8.

Table 3: Results of Wind Load for 2.5 K 9 Model

Height m	Terrain, Height and Structure Size Factor k_2	Design Wind Pressure kN/m^2	Solidity Ratio Φ	Pressure Coefficient Cp	Wind Load kN
55	1.058	1.43	0.33	2.60	0.72
52	1.052	1.41	0.23	3.12	0.89
49	1.038	1.37	0.18	3.39	1.0

Table 4: Results of Wind Load for 2.5 X 9 Model

Height m	Terrain, Height and Structure Size Factor k_2	Design Wind Pressure kN/m^2	Solidity Ratio Φ	Pressure Coefficient Cp	Wind Load kN
55	1.058	1.43	0.35	2.56	0.73
52	1.052	1.41	0.39	2.32	0.58
49	1.038	1.37	0.42	2.27	0.58

Table 5: Results of Wind Load for 2.5 XB 9 Model

Height m	Terrain, Height and Structure Size Factor k_2	Design Wind Pressure kN/m^2	Solidity Ratio Φ	Pressure Coefficient Cp	Wind Load kN
55	1.058	1.43	0.346	2.55	0.73
52	1.052	1.41	0.25	3.05	0.91
49	1.038	1.37	0.195	3.30	1.038

Table 6: Results of Wind Load for 3 K 9 Model

Height m	Terrain, Height and Structure Size Factor k_2	Design Wind Pressure kN/m^2	Solidity Ratio Φ	Pressure Coefficient Cp	Wind Load kN
55	1.058	1.43	0.34	2.60	0.72
52	1.052	1.41	0.24	3.13	0.89
49	1.038	1.37	0.18	3.38	1.01

Table 7: Analysis of Wind Load for 3 X 9 Model

Height m	Terrain, Height and Structure Size Factor k_2	Design Wind Pressure kN/m^2	Solidity Ratio Φ	Pressure Coefficient Cp	Wind Load kN
55	1.058	1.43	0.35	2.56	0.73
52	1.052	1.41	0.39	2.32	0.58
49	1.038	1.37	0.43	2.24	0.59

Table 8: Analysis of Wind Load for 3 XB 9 Model

Height m	Terrain, Height and Structure Size Factor k_2	Design Wind Pressure kN/m^2	Solidity Ratio Φ	Pressure Coefficient Cp	Wind Load kN
55	1.058	1.43	0.35	2.56	0.73
52	1.052	1.41	0.25	3.05	0.91
49	1.038	1.37	0.198	3.325	1.06

V. RESULTS OF DEFLECTIONS

The maximum deflection is calculated for different height of tower. The different bracing systems are used for the analysis of tower. The maximum deflection at top are collected in tabular form as shown in Tables 9 to 11.

Table9: Results of Maximum Deflections for Model A

Height (m)	Bottom Width (m)	Maximum Deflection (mm)				
		X Bracing	XB Bracing	K Bracing	K XB Bracing	XB K Bracing
55	2.5	13.76	13.43	13.75	13.21	13.00
	3.0	14.61	14.65	15.30	13.32	13.85
	3.5	15.27	17.89	17.07	16.53	17.34
	4.0	17.30	17.41	17.11	16.57	16.80

Table 10: Results of Maximum Deflections for Model B

Height (m)	Bottom Width (m)	Maximum Deflection (mm)				
		X Bracing	XB Bracing	K Bracing	K XB Bracing	XB K Bracing
64	2.5	14.89	16.71	17.45	17.37	16.75
	3.0	18.80	18.25	18.57	18.67	18.29
	3.5	18.90	19.12	19.25	21.93	21.41
	4.0	20.97	20.89	20.90	21.00	20.84

Table 11: Results of Maximum Deflections for Model C

Height (m)	Bottom Width (m)	Maximum Deflection (mm)				
		X Bracing	XB Bracing	K Bracing	K XB Bracing	XB K Bracing
73	3.0	19.05	18.65	32.75	36.80	22.61
	3.5	22.98	23.16	24.60	25.52	24.67
	4.0	22.25	22.95	23.31	27.40	26.67

VI. COMPARISON OF DIFFERENT BRACING BY GRAPHICAL REPRESENTATION

From the above table there is comparison between deflection and base width, shown in figure 1 to 6**.**

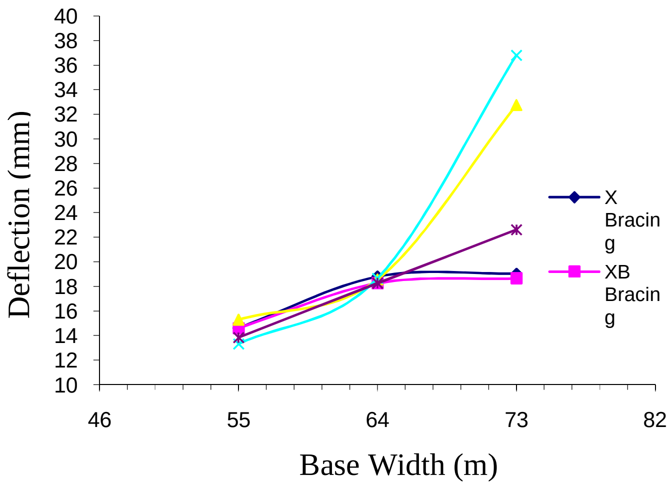

Fig.1: A graph of Variation for deflection and height for Model D with base width 3 m

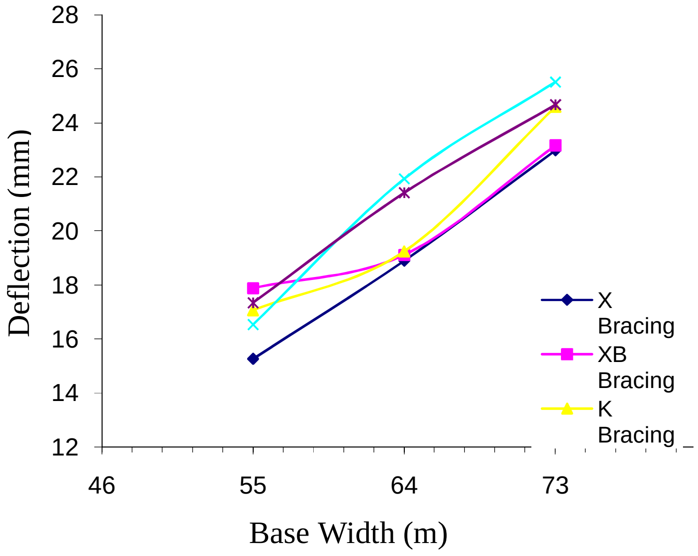

Fig.2: A graph of Variation for deflection and height for Model D with base width 3.5 m

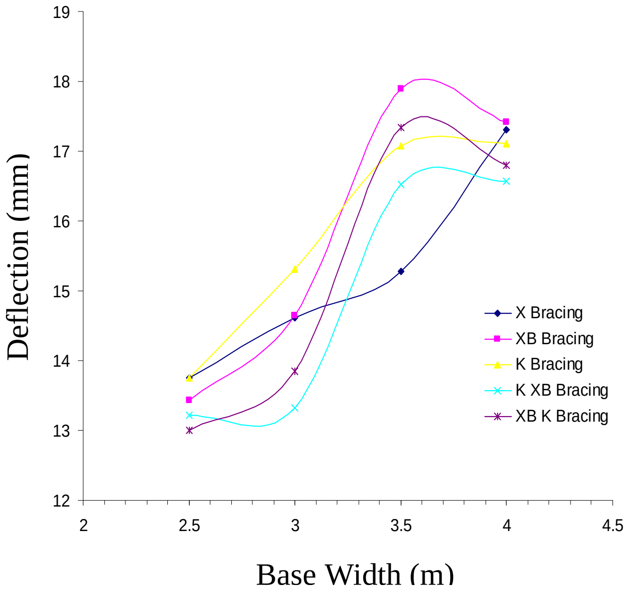

Fig.4: Comparison of Deflection by Modal A with Height 55 m

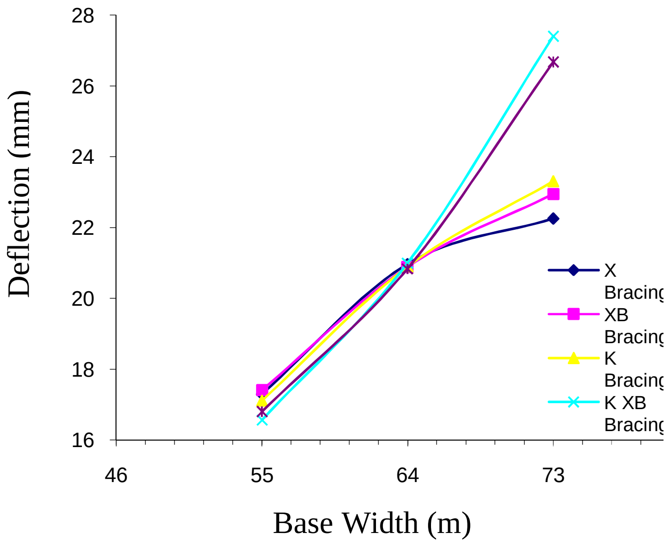

Fig.3: A graph of Variation for deflection and height for Model D with base width 4 m

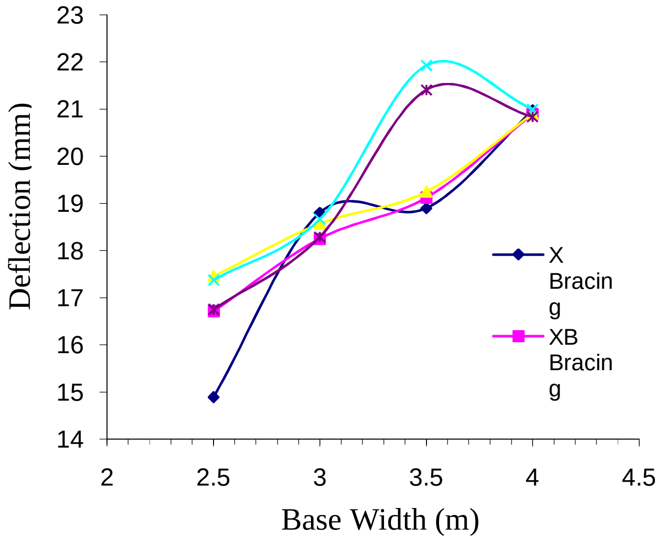

Fig.5: Comparison of Deflection by Modal B with Height 64 m

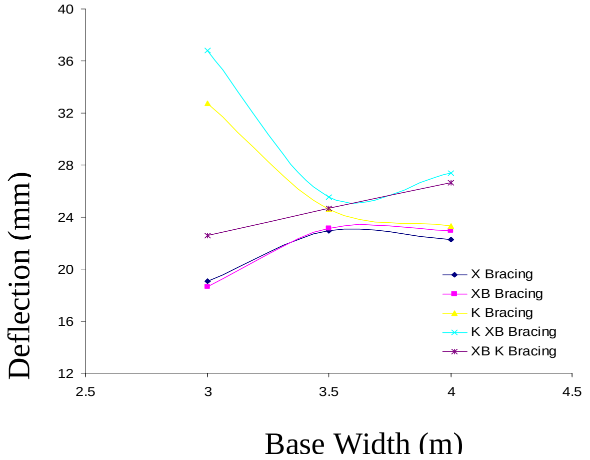

Fig.6: Comparison of Deflection by Modal C with Height 73 m

VII. CONCLUSIONS

On the basis of the results and discussions obtained in this investigation, the following conclusions have been drawn:

1. The deflection of tower is average for all type of bracing up to 55 m height in Modal D with base width 3 m. The deflection is nearly same at height 64 m and deflection for X and XB bracing is less for 73 m height when it compared to other type of bracing. There fore X and XB bracing suitable for base width 3 m at any height.
2. There is no significant change in deflection for X and XB bracing with base width 3.5 m in Model D. However the deflection of tower is gradually increases for all type of bracing, in general the deflection for X and XB bracing is nearly equal at 73 m height. As a result, the X and XB bracing is suitable for 64 m and 73 m height.
3. The deflection of tower is gradually for all type of bracing. When compared all models, it is found that the deflection is maximum when K XB bracing are use. There is significant change in deflection when K XB and XB bracing compared has with base width 4 m in Model D.
4. The X and XB bracing are suitable for 55 m, 64 m and 73 m height.
5. The deflection of tower for Modal A with base width 2.5 m then the deflection is nearly same for all type of bracing. As a result the deflection of tower with base width 3 m which contain low deflection for K XB bracing. It is found that the deflection is maximum when XB bracing for base width 3.5 m.
6. The deflection of tower is maximum for K XB bracing in Modal B. The deflection of tower is high for XB K bracing with base width 3.5 m. Whereas the deflection of tower is nearly equal at base width 4 m.
7. The deflection of tower is minimum for X bracing as compared to other type of bracing with base width 3.5 m and 4 m in Modal C. The deflection of tower is found to be maximum with base width 3 m, 3.5 m and 4 m for K XB bracing. However the deflection of tower occurs for K XB bracing is maximum for all base width.

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