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WIND AND NON LINEAR DYNAMIC ANALYSIS OF SELF SUPPORTING TELECOMMUNICATION TOWER

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Abstract: ***The increasing trend of mobile communications has seen exponential growth in the last three years. Increased competitions among mobile operators also have contributed to the installation of many towers to enhance both coverage area and network reliability. The tower locations as specified in terms of latitudes and longitudes with the height of mounted antenna dictated by functional requirements of the network. Communication towers are playing vital role in this generation and in next. The main objectives of the present research work are i) To study and analyze the behavior of self–supporting Telecommunication tower for wind zones V and VI for Indian code practice IS 875 (part 3):2015. ii) To analyze the dynamic response of telecommunication tower for three ground motions occurred during earthquakes of 1940 Imperial Valley, 1957 San Francisco, and 1992 Landers. iii) To compare the results of analysis of telecommunication towers with different configurations. The experimental investigation consists of various tower like K-Bracing, V-Bracing, W-Bracing, XBX-Bracing, XX-Bracing of varies height 30m, 45m, 60m and also varies zone like Zone-V (50 m/s), and Zone-VI (55 m/s). In this study it is found that for wind zone V and VI, tower height up to 30m, the displacement difference between XBX and W bracing is found to 56.82%. Also for wind zone V and VI, tower height 45m and 60m, the displacement difference between K and XBX bracing is found to 41.20%. The analytical values are compared with experimental values, it is observed that analytical result are almost similar to experimental result. Further the present research investigation it was confirmed that K-bracing and XBX-bracing gives satisfactory result in wind analysis and time history analysis for considered wind zones and ground motions.***

Keywords: *Telecommunication Tower, Seismic Analysis, Time History Analysis, Staad Pro.*

I INTRODUCTION

The telecommunication industry plays a great role in human societies. At the times of occurrence of natural disasters, telecommunication towers have the crucial task of instant transmission of information from the affected areas to the rescue centres. In addition, performance of infrastructure such as dams, electric, gas, and fuel transmission stations, depends extensively on the information being transmitted via these telecommunication towers. Military and defence industries in addition to television, radio, and telecommunication industries are other areas of application for such towers and thus create the necessity for further research on telecommunication towers. Telecommunication towers are tall structure usually designed for supporting parabolic antennas which are normally used for microwave transmission for communication, also used for sending radio, television signals to remote places and they are installed at a specific height. These towers are self-supporting structures and categorized as three-legged and four-legged space trussed structures. The self-supporting towers are normally square or triangular in plan and are supported on ground or on buildings. They act as cantilever trusses and are designed to carry wind and seismic loads. These towers even though demand more steel but cover less base area, due to which they are suitable in many situations.

Previously due to the height of telecommunication tower only wind was considered for analysis but from the past experiences seismic effect should also be considered in analysis so that the towers could resist the seismic forces. Also in early year telecommunication towers are designed considering mainly the stability against overturning. But during the event such as earthquake, some members of the towers reach their ultimate strength causing failure of the tower. This type of failure of members should also be considered during seismic analysis of tower. Thus the purpose of this study is to investigate the seismic response of the self-supporting telecommunication towers using nonlinear dynamic analysis method.

A. Configuration of Telecommunication Tower

The self-supporting towers, subjected predominantly to wind loads, are called lattice towers. These towers are mostly square in plan, made of standard steel angles and connected together by means of bolts and nuts. The members are bolted together, either directly or through gusset plates. Triangular towers attract lesser wind loads compared with square towers. However they are used only for smaller heights of tower due to difficulties in joint detailing and fabrication using angle sections. In order to reduce the unsupported length and thus increase their buckling strength, the main legs and the bracing members are laterally supported at intervals in between their end nodes, using secondary bracings or redundant. These secondary bracings increase the buckling strength of the main compression members, K and X bracing with secondary bracings were commonly using in microwave towers shown in fig 1. different types of bracing and horizontal combinations are normally adopted in towers.

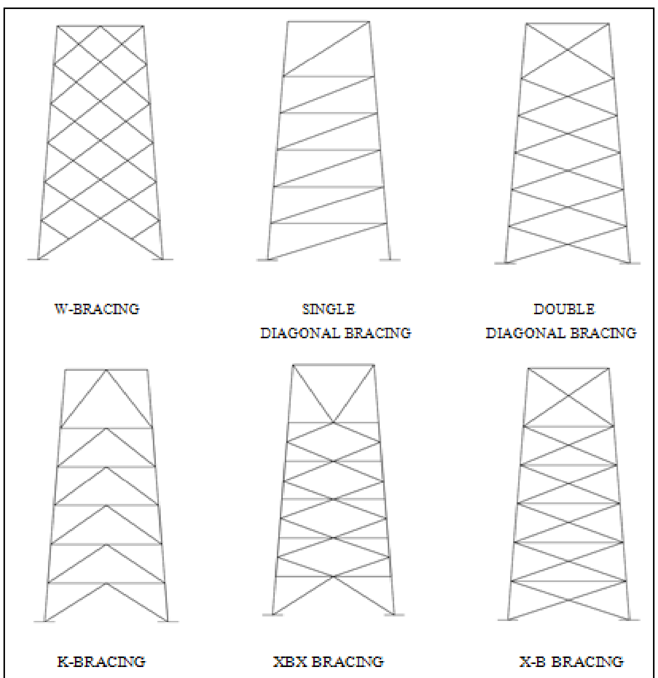

Fig.1 Different types of Bracing Systems

B. Problem Statement

Configuration of the tower

The towers lies in wind zones V and VI.

The height of the tower is 30m.

The base width of the tower is 5 m.

The top width of the tower is 2 m.

The bracing systems used K, V, W, XBX, XX-Bracing.

C. Aim

- To Study Structural Behaviour of Self-Supporting Telecommunication Tower under wind and seismic forces.

D. Objectives

- To study and analyses the behavior of self – supporting Telecommunication tower for wind zones V and VI for Indian code practice IS 875 (part 3):2015.
- To analyses the dynamic response of telecommunication tower for three ground motions 1940 Imperial Valley, 1957 San Francisco, and 1992 Landers.
- To compare the results of analysis of telecommunication towers with different configurations.

II MATERIALS & METHODOLOGY

A. *General*

The methodology includes analysis of 3D modelling of telecommunication towers of different height of 30 m, 45 m and 60 m and different bracing systems such as K, V, W, XBX and XX considered. For wind analysis zone V and VI is considered and for dynamic analysis three different ground motions is considered compare results with different tower models. The following three ground motion records, which have low, intermediate, and high-frequency content, have been considered for the analysis:

I. 1940 Imperial Valley Earthquake (El Centro) elcentro_EW component

II. 1992 Landers Earthquake (Fort Irwin) FTI000 component

III. 1957 San Francisco Earthquake (Golden Gate Park) GGP010 component

The ground motion (1) is the 1940 El Centro east west component. Ground motion record (2), (3) are selected from Pacific Earthquake Engineering Research Centre (PEER) Next Generation Attenuation (NGA) database. Telecommunication towers of different height of 30m, 45m and 60m and different bracing systems such as K, V, W, XBX and XX are modelled as three-dimension towers in

STAAD Pro. The basis of the present work is to study the behaviour of telecommunication tower under low, intermediate, and high-frequency content ground motions. Here, the displacement, velocity, acceleration, and base shear of telecommunication tower models due to the three ground motions of low, intermediate and high-frequency content are obtained.

The methodology, which is conducted, is briefly described as below:

1. Preparation of Model as per geometry adopted in Staad Pro.
2. Calculation of wind pressure intensity at various levels for zone V and VI and ground motion records are collected.
3. Wind and Non-Linear time history analysis is performed in STAAD Pro.
4. Tower response such as joint displacement, member stresses are found due to wind load and displacement, velocity and acceleration are found due to the ground motions.
5. Preparation of same fabricated model.
6. Testing of fabricated model on shake table.
7. The results of the telecommunication towers are compared.

B. Materials Used

The analysis of 3D modelling of telecommunication towers of different height of 30m, 45m and 60m and different bracing systems such as K, V, W, XBX and XX considered.

Table.1 Details of members considered for 30m height models

Panel	Height	Tower member	Sections
1-4	Up to 12m	Leg members	ISA150X150X15
		Horizontal members	ISA100X100X12
		Bracing members	ISA80X80X10
5-8	12m – 21m	Leg members	ISA120X120X12
		Horizontal members	ISA90X90X12
		Bracing members	ISA70X70X10
9-14	21m – 30m	Leg members	ISA90X90X12
		Horizontal members	ISA80X80X12
		Bracing members	ISA65X65X10

Table .2: Details of members considered for 45m height models

Panel	Height	Tower member	Sections
1-4	Up to 16m	Leg members	ISA180X180X20
		Horizontal members	ISA150X150X20
		Bracing members	ISA100X100X15
5-9	16m – 28m	Leg members	ISA150X150X18
		Horizontal members	ISA120X120X15
		Bracing members	ISA80X80X10
10-13	28m – 36m	Leg members	ISA120X120X15
		Horizontal members	ISA100X100X15
		Bracing members	ISA70X70X10
14-19	36m – 45m	Leg members	ISA90X90X12
		Horizontal members	ISA80X80X12
		Bracing members	ISA65X65X10

Table.3: Details of members considered for 60m height models

Panel	Height	Tower member	Sections
1-4	Up to 18m	Leg members	2 ISA200X200X20
		Bracing members	ISA200X200X12
		Horizontal members	ISA150X150X20
5-9	18m – 33m	Leg members	ISA180X180X20
		Bracing members	ISA180X180X15
		Horizontal members	ISA100X100X12
10-15	33m – 48m	Leg members	ISA150X150X20
		Bracing members	ISA130X130X12
		Horizontal members	ISA90X90X12
16-21	48m – 60m	Leg members	ISA100X100X12
		Bracing members	ISA90X90X12
		Horizontal members	ISA80X80X12

III• RESULTS AND OBSERVATIONS

A. General

The result obtained from experimental and software analysis of self-supporting telecommunication tower in wind zone V and VI and dynamic load are as follows.

B. Wind Analysis Results

Joint displacement at the top of the tower were obtained for towers of height 30m, 45m and 60m with different bracing arrangements for wind zones V and VI are tabulated in Table 4.

Table 4: Comparison of Displacement at Top with Different Bracing

Tower height (m)	Wind zone (m/s)	Displacement (mm)				
		K-bracing	V-bracing	W-bracing	XBX-bracing	XX-bracing
30	Zone-V (50m/s)	42.44	50.84	65.11	41.52	59.83
45		109.33	126.08	158.71	115.89	139.29
60		152.84	179.25	215.91	191.06	197.11
30	Zone-VI (55m/s)	45.86	54.95	69.81	44.37	61.79
45		132.35	152.61	192.19	140.29	168.62
60		184.67	216.51	260.75	231.05	238..02

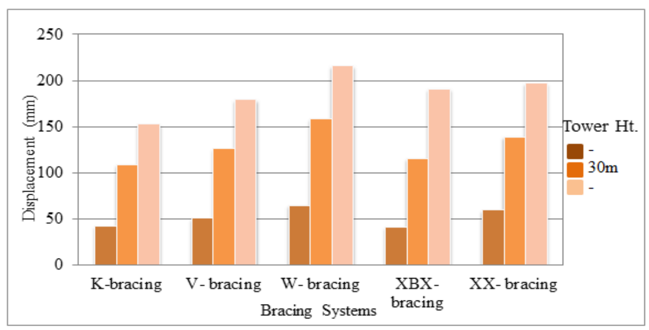

Fig 2: Variation of Displacement (mm) at Top for Different Tower for Zone-V

For Fig 2 shows that wind zone V tower height of 30m and 45m having K, V and XBX-bracing gives minimum value of displacement and W-bracing gives maximum value of displacement. For tower height of 60m having K and XBX-Bracing gives minimum value of displacement and W-Bracing gives maximum value of displacement. For tower height changing form 30m to 45m the values of top displacement changes abruptly for all bracings as compared to 60m height tower.

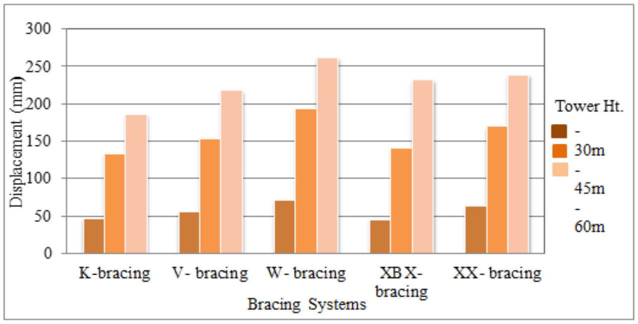

Fig 3: Variation of Displacement (mm) at Top for Different Tower for Zone-VI

For Fig 3 shows that wind zone VI tower height of 30m, 45m and 60m having top displacement W-Bracing gives maximum value of displacement and K-Bracing or XBX -Bracing gives minimum value of displacement similar results like wind zone V. For tower height from 30m to 45m for V-bracing changes top displacement abruptly but for tower height 45m to 60m lesser the top displacement for wind zone V and VI.

C. Seismic Analysis Results

The results of tower height of 30m, 45m and 60m and bracing systems of K, V, W, XBX and XX bracing in terms top displacement, top velocity, and top acceleration for each tower due to each ground motion is illustrated in (x) transverse direction. The responses of the structures due to the ground motions are found. The responses due to1940 Imperial Valley (El Centro) elcentro_EW component (GM1), 1992 Landers (Fort Irwin) FTI000 (GM2) and 1957 San Francisco (Golden Gate Park) GGP010 (GM3) component ground motions are shown. The responses due to the above three ground motions are displayed.

30 m Telecommunication tower

The 30m telecommunication tower responses of due to three ground motions are displayed for different bracing systems.

Table 5: Comparison of Displacement at Top with 30m tower Different Bracing for ground motions

Ground Motion	Tower height (m)	Displacement (mm)				
		K-bracing	V-bracing	W-bracing	XBX-bracing	XX-bracing
GM1	30	11.4	12.60	18.00	11.2	17.01
GM2		2.79	2.51	3.18	2.47	3.21
GM3		0.77	0.72	0.78	0.57	0.76

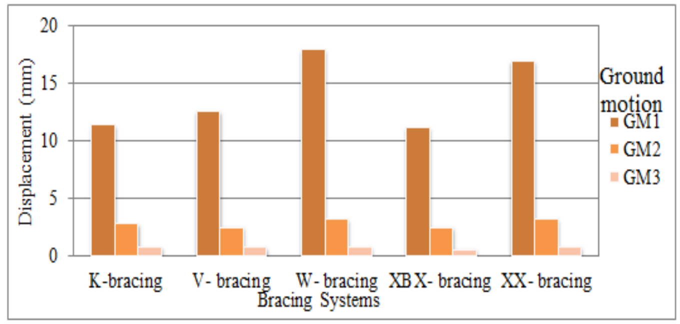

Fig 4.Variation of Displacement (mm) at Top with 30m tower Different Bracing for ground motions in x-direction

Fig 4 shows top displacement of 30m telecommunication tower due to ground motion GM1, GM2, and GM3. The top displacement is maximum due to ground motion GM1 and minimum due to ground motion GM3.It indicates that the tower undergoes high top displacement due to low-frequency content ground motion low top displacement due to high-frequency content ground motion. For top displacement is minimum for XBX-bracing and maximum for W-bracing for all ground motions.

45m Telecommunication tower

The 45m telecommunication tower responses of due to three ground motions are displayed for different bracing systems.

Table 6. Comparison of Displacement at Top with 45m tower Different Bracing for Different ground motion

Ground Motion	Tower height (m)	Displacement (mm)				
		K-bracing	V-bracing	W-bracing	XBX-bracing	XX-bracing
GM1	45	19.1	18.6	18.9	18.2	14.5
GM2		3.04	2.79	3.54	3.01	3.5
GM3		0.68	0.69	0.79	0.65	0.78

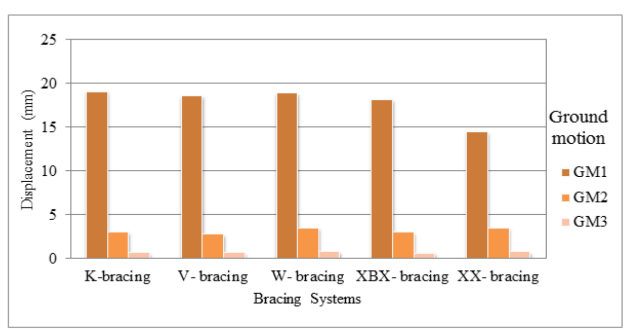

Fig 5: Variation of Displacement (mm) at Top with 45m tower Different Bracing for ground motions in x-direction

Fig 5. Shows top displacement of 45m telecommunication tower due to ground motion GM1, GM2, and GM3. The top displacement is maximum due to ground motion GM1 and minimum due to ground motion GM3.It indicates that the tower undergoes high top displacement due to low-frequency content ground motion low top displacement due to high-frequency content ground motion. For top displacement is minimum for XBX-bracing and maximum for W-bracing for all ground motions.

60m Telecommunication tower

The 60m telecommunication tower responses of due to three ground motions are displayed for different bracing systems.

Table 6: Comparison of Displacement at Top with 60m tower Different Bracing for Different ground motion

Ground Motion	Tower height (m)	Displacement (mm)				
		K-bracing	V-bracing	W-bracing	XBX-bracing	XX-bracing
GM1	60	24.01	24.4	26.3	24.5	27.1
GM2		6.57	6.80	7.64	6.47	7.42
GM3		2.48	3.05	3.32	2.68	3.12

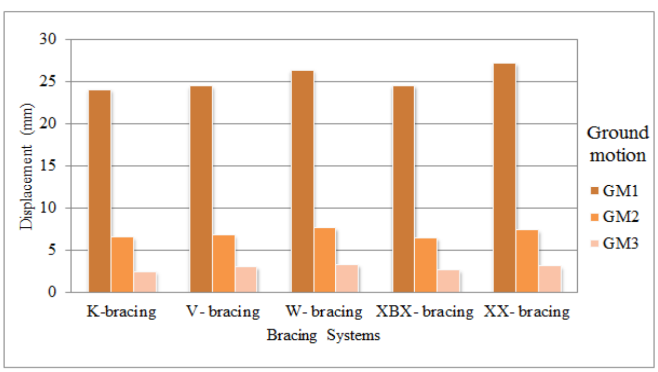

Fig 6: Variation of Displacement (mm) at Top with 60m tower Different Bracing ground motion in x-direction

Fig 6. Shows top displacement of 60m telecommunication tower due to ground motion GM1, GM2, and GM3. The top displacement is maximum due to ground motion GM1 and minimum due to ground motion GM3.It indicates that the tower undergoes high top displacement due to low-frequency content ground motion low top displacement due to high-frequency content ground motion. For top displacement is minimum for XBX-bracing and maximum for XX and W-bracing for all ground motions.

IV CONCLUSION

1. For wind zone V and VI, tower height up to 30m, having W-Bracing gives maximum value of displacement and XBX -Bracing gives minimum value of displacement. Displacement difference between the XBX and W-bracing is about 56.82%.
2. For wind zone V and VI, tower height of 45m and 60m, having W-Bracing gives maximum value of displacement and K-Bracing and XBX -Bracing gives minimum value of displacement. For K-bracing and XBX-bracing difference gives displacement is more about 41.20%.
3. Stresses in leg members of V-bracing are 45.40% more than K-bracing.
4. From Top Displacement and member stresses point of view, use of XBX-bracing up to 30m tower height and use of K and XBX-bracing for height of 45m and 60m gives satisfactory results.
5. As the height of tower increases, the time period of structure also increases, also the weight and stiffness of the tower increases along with height. The comparison of time period for different height of tower with different bracing systems XBX-bracings gives lesser results and W-bracings gives more time period.
6. The displacement is maximum for low frequency content and minimum for high frequency content ground motions.
7. The displacement is maximum for W-bracing and minimum for XBX-bracing due to ground motion of low frequency content.

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