Wind And Non – Liner Dynamic Analysis And Design of Steel Transmission 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. In this research work, study and analysis of the behavior of self–supporting Telecommunication tower for wind zones V and VI for Indian code practice IS 875 (part 3):2015 is done. With that analysis of the dynamic response of telecommunication tower for three ground motions occurred during earthquakes of 1940 Imperial Valley, 1957 San Francisco, and 1992 Landers is studied. Comparison of the results of analysis of telecommunication towers with different configurations is observed. 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 results 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

India has a large population residing all over the country and the electricity supply need of this population creates a requirement of a large transmission and distribution system. The use of electric power has become an increasingly important part of the economy of industrial countries. The advancement in electrical engineering shows needs for supporting heavy conductors which led to existence of towers. Towers are tall structures, their height being much more than their lateral dimensions. These are space frames built with steel sections having generally an independent foundation under each leg. The height of the tower is fixed by the user and the structural designer has the task of designing the general configuration, member and the joint details. Electric power generated at power plants is transmitted through Transmission lines supported by transmission line towers. The transmission Lines towers cost about 35 – 45 percent of the total cost of the transmission System. Hence utmost economy has to be exercised in their design and installation. A transmission line tower is a space –frame and a high order indeterminate structure. Its cost is influenced by its weight. The weight in turn Is influenced by the designer's diligence and his efficient application of the governing specifications. Given the same code in respect of material, ruling Dimension loads, unit stresses, etc., any two competent engineers could produce Designs resulting in structures which are strikingly similar in weight. This similarity is only possible if designers aim at selecting the most economical configuration for the tower and the choice of the various sections is done with the uppermost thought of conserving every kg of steel possible, within the limitations of the specifications consistent with reliability.

The main supporting unit of overhead transmission line is transmission tower. Transmission towers have to carry the heavy transmission conductor at a sufficient, safe height from ground. In addition to that, all towers have to sustain all kinds of natural calamities. So transmission tower designing is an important engineering job where all three basic engineering concepts, civil, mechanical and electrical engineering concepts are equally applicable

Transmission towers are mainly of three types depending structural action as follows;

i. Self-Supporting towers
ii. Guyed towers

iii. Monopoles

1.1.1 Self-Supporting towers

A self-supporting tower (freestanding tower) is constructed without guy wires. Self-supporting towers have a larger footprint than monopoles, but still requires a much smaller area than guyed masts.

Due to its relatively small footprint, this kind of tower is commonly seen in cities or other places where it is short of free space. The wider the base of the tower is, the larger antenna load is acceptable. Self-supporting towers are square, rectangular or triangular in plan. Though the weight of these towers is more they require less base area and are suitable in many situations. Most of the TV, MW, Power transmission, and flood light towers are self-supporting towers.

Self-supporting towers does not have limitation of height for construction and hence use widely. Based on the location of tower where it is installed, Self-supporting towers can further classified as ground base towers and rooftop tower.

a. Ground Base towers

As the name implies these type of towers are installed on plain ground or in hilly region. As ground base towers are self-supporting towers and height is more, the base width of these type of tower is greater than top width.

Depending on the number of supporting legs, these types of towers are further classified as follows:

i. 3 legged Self-supporting towers
ii. 4 legged Self-supporting towers.

3-legged self-supporting towers are triangular in plan whereas 4 legged self-supporting towers are either square or rectangular in plan. 3-legged are generally preferred for tower with less height whereas 4-Legged towers are used where more height of tower is required.

1.1.2 Guyed Towers

Guyed towers are hinged to the base, and are supported by guy wires attached to it at various levels, to transmit the wind forces to the ground. A guyed mast is a tall thin vertical structure that depends on guy lines for stability. The mast itself has the compressive strength to support its own weight, but usually does not have the shear strength to stand unsupported, and requires guy lines, diagonal tensioned cables attached to the ground, usually spaced at equal angles about its base, to resist lateral forces such as wind loads and keep it upright. Guyed towers provide height at much lower material cost than self-supporting towers due to efficient use of high strength steel in guy. Guyed towers are normally guyed in three directions over an anchor radius of typically 2/3rd of the tower height and have a triangular lattice section for central mat. Tubular masts are also used, especially where icing is very heavy and lattice sections would ice up fully. These towers are much lighter than self-supporting type but require a large free space to anchor guy wires. There are other restrictions to mount dish antennae on these towers and requires large anchor blocks to hold the ropes.

1.1.3 Monopole

Monopole towers are self-supporting pole developed for the Transmission business as an alternative to the lattice tower. Its characteristics are a slim design without visible assembling between the sections and a high load capacity with a small deflection in the top. The monopole towers are designed for up to four operators without making the deflection exceed more than 1 degree. The monopole towers can be delivered with extra equipment such as a combined ladder and safety device system as well as an anti-climb device in the bottom. Monopole is generally placed on roof of the building or on ground when the size and no of antenna required is less or height of tower required is up to 20 meters.

1.2 Configuration of Transmission 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 figure no1.6 different types of bracing and horizontal combinations are normally adopted in towers.

II. LITERATURE REVIEW

1. Khedr and McClure (1999), studied, earthquake amplification factors for the base shear and the total vertical reaction of self-supporting latticed Transmission towers were suggested based on modal superposition analysis performed on 10 existing towers, each being subjected to a set of strong-motion accelerograms acting in the horizontal and the vertical directions separately. Results were calculated displayed for two towers of height 61m and 121m respectively. Simple regression analyses are performed on the results from which the base shear and vertical reaction amplification factors were found. After studying results it may concluded that Self-supporting Transmission towers are not usually designed to account for earthquake effects. As taller towers are built, there is a need to establish a practical tool for assessing whether or not seismic analysis of such towers is necessary.

2. Venkateswarlu et al. (1993), performed a numerical study on the response of lattice microware towers subjected to random wind loadings. The dynamic response could be estimated by the use of a stochastic approach. A spectral analysis method for evaluating the along-wind response and the corresponding gust response factor were introduced. The gust response factor defined as the ratio of the expected maximum wind load effect in a specified time period to the corresponding mean value in the same time period. A 4-legged 101-m self-supporting tower was considered in their study. The gust response factor along the tower height was calculated with and without the contributions of second and higher modes of vibration. The results showed a maximum of 2 % change in the gust factor when employing higher modes of vibration.

[1] 3.Ghyslaine McClure et al. (2004), studied the seismic response of two different lattice towers mounted on the rooftop of two medium-rise buildings (Burnside Hall and 2020 University, located in Montreal, Canada). The aim was to find whether simple linear relations could represent the variation of the tower response as a function of the peak roof acceleration. In this study, time history analysis is used to explore the correlation between the building accelerations and the maximum seismic base shear as well as the base overturning moment of towers mounted on building rooftops. The models include two medium-rise buildings combined with two self-supporting lattice steel towers subjected to 45 horizontal accelerograms with varied frequency content. The tower base shear results are compared with the predictions based on a simplified formula proposed in building codes for secondary structures.

3. J.G.S. da Silva.et al. (2005), presented paper on an alternative structural analysis modelling strategy for the steel tower design considering all the actual structural forces and moments combining three dimensional beam and truss finite elements. Comparisons of the two above-mentioned design methods with a third method based on the use of spatial beam finite elements to model the main structure and the bracing system on two actually built steel Transmission towers (40 and 75 m high steel towers) have been described. Generally in all the cases studied the maximum stress values for the structural tower modelling based on the three investigated methodologies were significantly modified. The lateral displacement values were not significantly changed when the usual truss model, the beam model or the combined beam and truss model were considered. After studying results it may be concluded that the finite element modelling strategy can somehow affect the nominal values of the tower natural frequencies for the initial vibration modes.

4. Amiri and Massah (2007), studied the seismic sensitivity of 4-legged Transmission towers is investigated based on modal superposition analysis. For this purpose ten existing 4- legged self-supporting Transmission towers in Iran were studied under the effects of wind and earthquake loadings. To consider the earthquake effects on the models, the standard design spectrum based on the Iranian seismic code of practice and the normalized spectra of Manjil, Tabas and Naghan earthquakes have been applied. They observed that in the case of towers with rectangular cross section, the effect of simultaneous earthquake loading in two orthogonal directions is important. At the end, a number of empirical relations are presented that can help designers to approximate the dynamic response of towers under seismic loadings. From the results obtained it can be concluded that the wind loading is prevailing with respect to seismic loading, but, since the results from these two loadings are close to each other, more investigation for seismic forces is necessary.

5. A. Jesumi.et al. (2013), modelled five steel lattice towers with different bracing configurations such as the X-B, single diagonal, X-X, K and Y bracings for a given range of height. The heights of the towers are 40m and 50m with a base width of 2m and 5m respectively. The tower of height 40m has 13 panels and the tower of height 50m has 16 panels. 70-72% of the height is provided for the tapered part and 28-30% of the height is provided for the straight part of the tower. The towers have been analyzed for wind loads with STAAD Pro.V8i. To compare the maximum joint displacement of each tower. Optimized design has been carried out to estimate and to compare the

weight of each tower. From the results obtained, Y bracing has been found to be the most economical bracing system up to a height of 50m.

[2] 7.Richa Bhatt et al. (2013), have carried out study on the influence of modelling in lattice mobile towers under wind loading where in the towers are analysed for gust factor wind. Displacements, Member forces and maximum stress have been compared to find out the effect on towers. In this paper concluded that the wind analysis results showed that irrespective of the tower height modelling strategy does not significantly affect the displacement pattern, particularly maximum lateral displacement at the top of the tower. Truss model, in general, reflects the lower bound on stresses, irrespective of height, due to dominance of the axial stresses. The bending components normal to the plane of the element are of a lower order. The prototype as fabricated has members which are likely to be subjected to in-plane and out of plane moments.The frame idealization, hence, provides a better estimate of the design forces. Deviations, if any, are easily accounted for by the conventionally adopted factor of safety. The combined model involves more rigorous analysis, whereas the frame model is the safest to adopt due to highest stresses. As the tower height increases, the difference in the stresses among the different idealizations do change, but the generic trend remains the same.

[3] 8. Shad et al. (2014), analysed seismic performances of ten existing 4-legged Transmission towers with heights ranging from 18 to 67 meter installed in Iran. For this purpose, three different vertical distributions of lateral load had been utilized. Target displacement approach and design spectrum approach was considered to calculate the seismic performance of towers. It was exhibited that all towers had satisfied immediate occupancy level for both design base earthquake hazard level and maximum probable earthquake hazard level. Also, three equations was presented to estimate towers yield base shear and base shear that corresponds to immediate occupancy level for 4-legged self-supporting Transmission towers.

[4] 9.JitheshRajasekharan et al. (2014), designed the lattice tower for three heights of 30m, 40m and 50m with different types of bracings to study the effect of wind load on 4- legged lattice tower for wind zone V and VI using gust factor method. They also studied the seismic effect on the tower structures by carrying out the modal analysis and response spectrum analysis for zone II to zone V and concluded that the member stresses in bottom leg of XX braced tower are higher as compared to other tower models. The frequency of the tower with Y bracing displayed the least natural frequency since its stiffness was found to be higher due to more weight of the structure as compared to other models. It was observed that from 30m to 40m tower height, the increase in displacement is nearly linear but as the height increases from 40m to 50m there is a steep increase in the displacement in all the zones.

[5] 10.Hemal J shah &Dr.Atul K Desai (2014), studied Radio and Transmission signals by constructing a Television tower to transmit the television signals on the wider areas and this television towers are also used for the purpose of transmitting the radio as well as Transmission signals. These towers must be properly designed so that they will not fail during the natural disasters such as earthquakes. In past researchers had studied the effect of different earthquakes on 3 legged tall Transmission towers. In the present study earthquake response of 4 towers of different height are studied considering different bracing system of the tower. The towers of different height are modeled in SAP 2000 software and static and dynamic analysis of the tower has been carried out. In addition to this time history of the bhuj earthquake is applied on all tower and the response of the tower is studied.

[6] 11.Keshav Kr. Sharma et al (2015), comparatively analysed different three heights of towers i.e. 25m, 35m, 45m using different bracing patterns for Wind zones I to VI and Earthquake zones II to V of India. Gust factor method is used for wind load analysis, modal analysis and response spectrum analysis are used for earthquake loading. In this paper concluded that the wind is the predominate factor in the tower modelling than the seismic forces but the seismic effect cannot be fully neglected as observed from the results and V-Bracing gives satisfactory result in wind analysis, modal analysis and response spectrum analysis for all considered wind and earthquake zones mentioned in IS code. The results of displacement at the top of the towers and stresses in the bottom leg of the towers are compared.

III. OBJECTIVES

1) To study and analyse the behaviour of self – supporting Transmission tower for wind zones V and VI for Indian code practice IS 875 (part 3):1987.
2) To analyse the dynamic response of Transmission tower for three ground motions 1940 Imperial Valley (El Centro),1957 San Francisco (Golden Gate Park), and 1992 Landers (Fort Irwin).

3) To compare the results of analysis of Transmission towers with different configurations.

IV. THEORETICAL CONTENTS

Wind Analysis

- **Design Wind Speed**

Wind load is function of several parameters. Wind speed at any location can be expressed as per Indian Standard (IS: 875 part 3 1987) is as follows:

As per clause 5.3, IS:875 - Part 3, 1987
$V_Z = k_1.k_2.k_3.V_b$
where,
V_b= basic wind speed
Vz = basic wind speed of the place
k_1= probability factor or risk coefficient
= 1.05 for all important towers
= 1.0 for sign posts
k_2= terrain, height and structure size factor
k_3= Topography factor it varies from 1 to 1.4 depending on the topography.

- **Design Wind Pressure**

The design wind pressure as per Indian Standard (IS 875:1987) is as follows is obtained as;
$P_Z = 0.6.V_Z^2$……………………... (Ref. IS: 875 part 3 1987-clause 5.4)

where,

P_z = design wind pressure in N/m^2
Vz = design wind speed in m/s
According to Indian standard (IS 875:1987) six different zones are defined based on the wind speed and basic wind pressure. The wind force for specified zone is given by;

- **Design Wind Force**

$F = A\ C_f\ P_Z$
where,
A = obstruction area
C_F = net wind force coefficient which depends on the solidity ratio of the panel or structure.

Seismic Analysis

The two most important element of concern to structural engineer are calculation of seismic design forces and the means for providing sufficient ductility. The loads or the forces which a structure sustains during an earthquake results directly from the distortion induced in the structure by the motion of the ground on which it rests. Earthquake loads are inertia forces related to mass, stiffness and energy absorbing characteristic of structure.

Seismic Analysis of Structures

Determination of seismic response of steel structure is an important but challenging job. Structural response to earthquakes is a dynamic phenomenon that depends on dynamic characteristic of structures and the intensity, duration and frequency content of ground motion. Although the seismic action is dynamic in nature, building codes often recommend equivalent static load analysis for design of earthquake resistant buildings due to simplicity.

Equivalent Static Analysis

The linear static method also known as Equivalent Static Method is used to estimate the demand for the buildings whose response is particularly dominated by the first mode and expected to behave in elastic range. In this method the lateral loads are calculated based on the fundamental period of the structural and applied on the design centre of mass at every floor level and the demands are estimated. The magnitude of these pseudo lateral loads has been selected with the intention that when applied to the linearly elastic model of the building, it will result in design displacement expected during the design earthquake.

Response Spectrum Analysis

In this method the load vectors are calculated corresponding to predefined number of modes. These load vectors are applied at the design centre of mass to calculate the respective modal responses. These modal responses are then combined according to SRSS or CQC rule to get the total response.

Pushover Analysis

Pushover analysis is a simplified, static, nonlinear analysis under a predefined pattern of permanent vertical loads and gradually increasing lateral loads. Typically the first pushover load case is used to apply gravity load and then subsequent lateral pushover load cases are specified to start from the final conditions of the gravity pushover.

Time History Analysis

This is the most accurate method to determine the seismic responses of structures. In this method the structure is subjected to actual ground motion which is the representation of the ground acceleration vs. time. The ground acceleration is determined at small time step to give the ground motion record

V. METHODOLOGY AND PROBLEM STATEMENT

The methodology includes analysis of 3D modelling of Transmission towers of different height of 30m, 45m and 60mand different bracing systems such as K, V, W, XBX and XX considered. Forwind analysis zone V and VI is considered and for dynamicanalysisthree 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:

1. 1940 Imperial Valley (El Centro) elcentro_EW component
2.1992 Landers (Fort Irwin) FTI000 component
3. 1957 San Francisco (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.Transmission 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. Then the ground motions are introduced to the software and non-linear time history analysis is performed.

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. The results of the Transmission towers are compared.

VI. 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 , Y-Bracing

5.2.2 Loads on tower:-

A platform load 0.82 kN/$m^2$and live load on platform 0.75kN/m^2 is applied at 28.5m.

Antenna loading for the towers

Sr N o.	Item	Quant ity	Diameter (m)	Weight/ant enna (kg)	Locati on from base (30m)
1.	CDMA	6	0.26 x2.5	20	27
2.	Microw ave 1	1	1.2	77	24
3.	Microw ave 2	1	0.6	45	24
4.	Microw ave 3	2	0.3	25	24

Shaking Table Testing

The use of shaking tables for the assessment of the dynamic and seismic behaviour of civil engineering structures is effective since the sixties. At the beginning, shaking tables had important limitations concerning the power available and they have been used to study the dynamic characteristics (natural frequencies and mode shapes) of small models behaving essentially in the linear range. Meanwhile, bigger and more powerful shaking tables have been put in operation allowing for the adoption of lower scaling factors and therefore involving very important dynamic forces.

Model of K-bracing

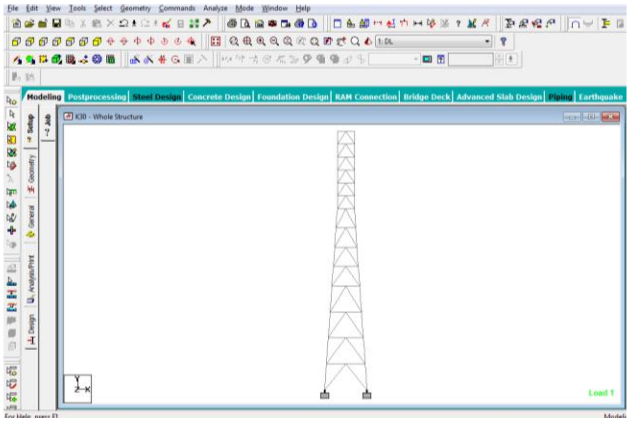


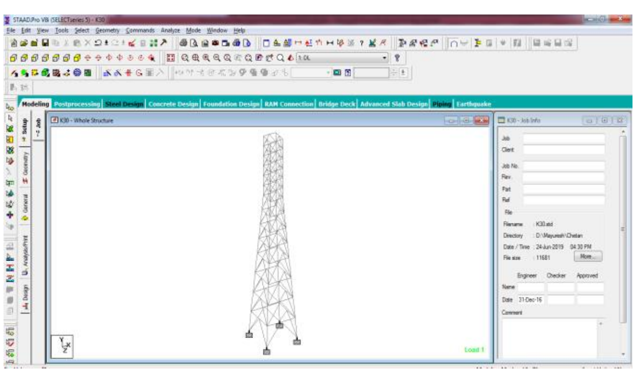
Fig 6.1:Snapshot of 3D model from Staad Pro

VII. MODELLING AND ANALYSIS OF TRANSMISSION TOWER

Structural Analysis and Design Computer Program

STAAD Pro V8i is a structural analysis and design computer program. It is used for 3D model generation, analysis and multi-material design. It includes a state of the art user interface, visualization tools and international design codes. It provides a rich graphics environment, which is used to display results of analysis that performed.

Staad Pro will eliminate the countless man-hours required to properly load your structure by automating the forces caused by wind, earthquakes and moving load etc. In addition, no matter what material you are using or what country you are designing your structure. It can easily accommodate your design and loading requirements, including U.S., European (including the Euro codes), and Nordic, Indian, and Asian codes.



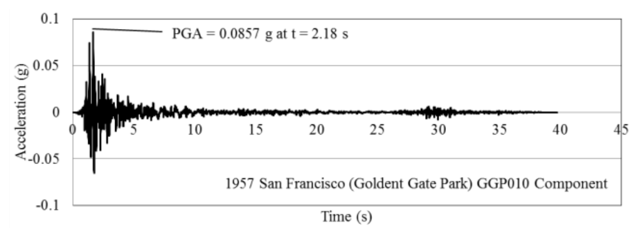
VIII. TIME HISTORY ANALYSIS

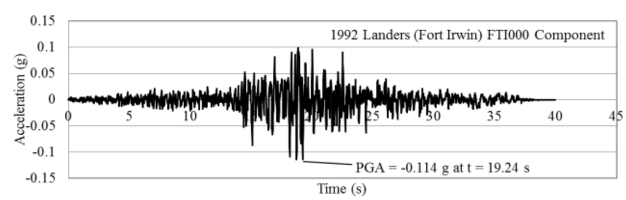
An earthquake is hysteria of ground quaking caused by a sudden discharge of energy in the earth’s lithosphere. This energy may come mainly from stresses formed during tectonic processes, which involves interaction between the crust and the inner side of the earth’s crust. Strain energy stored inside the earth will be released and maximum of it changes to heat, sound and remaining as seismic waves.

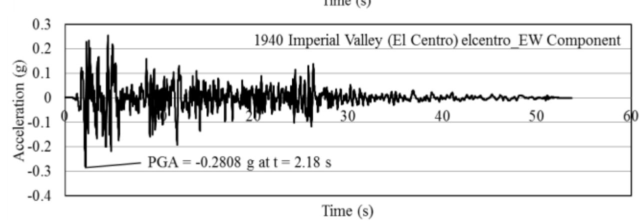
There are mainly four principle plate boundaries such as divergent boundary (inner side of the earth adds new plate material), sub deduction boundary (plates converge and the beneath thrust one is consumed), collision boundary (previous sub deduction zone where continents resting on plates are smashing), and transform boundary (two plates are sliding one another).

Ground Motion Records

The ground motion has dynamic characteristics, which are peak ground acceleration (PGA), peak ground velocity (PGV), peak ground displacement (PGD), frequency content, and duration. These dynamic characteristics play predominant rule in studying the behaviour of tower under seismic loads.





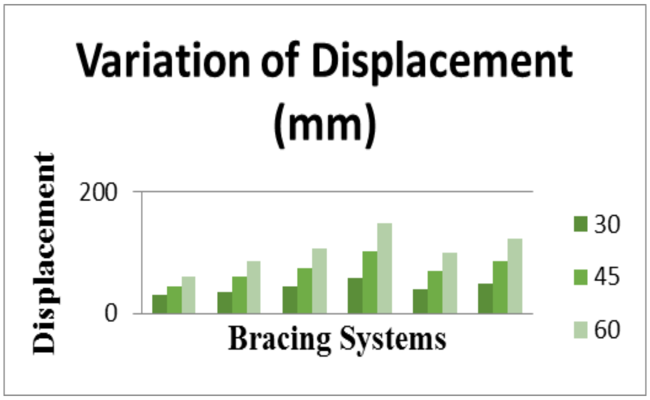


IX. RESULT AND DISCUSSION

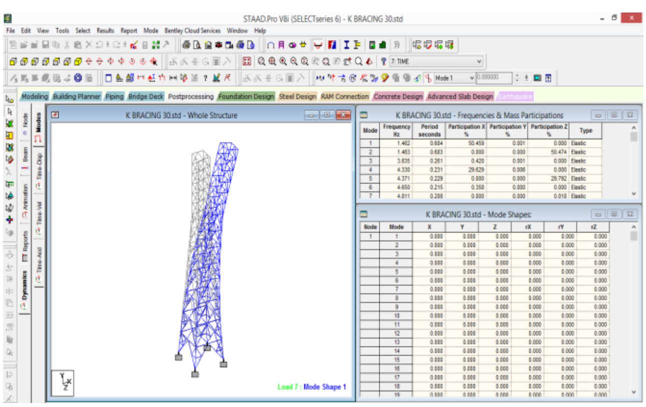
Wind Analysis Results

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

Tower height (m)	Wind zone (m/s)	Displacement (mm)					
		K-bracing	V-bracing	W-bracing	Y-bracing	XBX-bracing	XX-bracing
30.00	Zone-V (50 m/s)	35.45	43.90	58.23	58.81	39.37	48.43
45.00		60.55	75.49	102.85	103.88	69.01	85.04
60.00		85.99	107.43	147.84	149.32	98.92	121.65
30.00	Zone-VI (55 m/s)	38.65	47.95	62.81	63.44	42.36	50.79
45.00		83.38	105.51	136.29	137.65	94.79	104.42
60.00		115.79	137.41	185.65	187.51	138.05	162.12

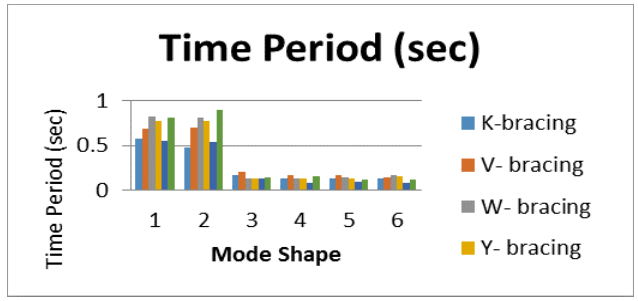


Mode shape and Time period Results

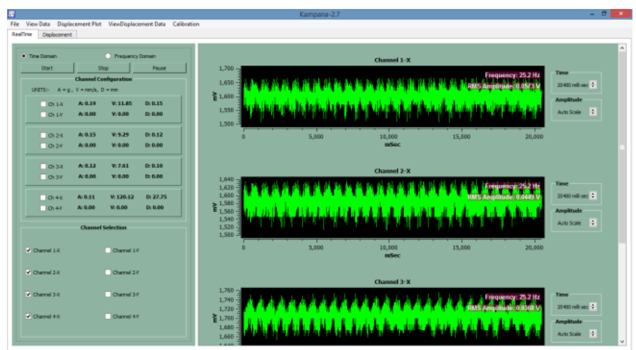


- **Time period Results**

Mode shape no.	Time Period (sec)					
	K-bracing	V-bracing	W-bracing	Y-bracing	XBX-bracing	XX-bracing
1	0.5726	0.682	0.817	0.78	0.5521	0.814
2	0.4721	0.6952	0.8156	0.77	0.5435	0.8946
3	0.1604	0.2026	0.132	0.13	0.1312	0.1424
4	0.1308	0.1655	0.1312	0.12	0.0834	0.1532
5	0.1267	0.1654	0.1398	0.13	0.0882	0.1177
6	0.125	0.1456	0.1625	0.15	0.0819	0.1126



X. RESULTS FOR K BRACING



In Above graph it Shows that the frequency given to the K Bracing Tower is 25.2 Hz andresult of RMS Amplitude is 0.0573 ,0.0449 ,And 0.0368V Simultaneously for Channel 1 ,2,3

K-BRACING					
EXPERIMENTAL			STAAD PRO		
ACCLERATION m/s2	VELOCITY m/s	DISPLACEMENT mm	ACCLERATION m/s2	VELOCITY m/s	DISPLACEMENT mm
11.5	1.96	11.6	14.4	2.56	13.7

XI. CONCLUSION

The study to know the performance of the Transmission tower under wind and dynamic load from above results and discussion, conclusion made as follows.

- For wind zone V and VI tower height up to 30m having Y & W-Bracing gives maximum value of displacement and XBX -Bracing gives minimum value of displacement. For difference between the XBX and W-bracing is about 56.82%.
- For wind zone V and VI tower height of 45m and 60m having Y & W-Bracing gives maximum value of displacement and K-Bracing or XBX -Bracing gives minimum value of displacement. For K-bracing and XBX-bracing difference gives displacement is more about 41.20%.
- Stresses in the bottom leg members of tower with tower height for a particular bracing pattern in V and VI wind zones It was concluded from table that stress increases with variation of wind zone from V to VI and found to be maximum for Y , V and W-bracing and minimum for K-bracing.
- Stresses in leg members of V-bracing are 45.40% more than K-bracing.
- Top Displacement and member stresses point view up to 30m tower use XBX-bracing and height of 45m and 60m use K and XBX-bracing gives satisfactory results.
- For time period of the structure is increasing as the height of the structure increases. As the tower height increase the weight and stiffness of the tower increases. For comparison of time period for different height of tower for different bracing systems XBX-bracings gives lesser results and Y & W-bracings gives more time period.
- For the dynamic analysis the displacement is maximum for low frequency content and minimum for high frequency content ground motions.
- For the dynamic analysis the displacement is maximum for Y & W-bracing and minimum for XBX-bracing due to ground motion 1sti.e.El-Centro ground motion of low frequency content.
- The story velocity as well as story acceleration gives different results get as compared to displacement maximum for V-bracing and minimum for XX-bracing.
- From the above analysis it can be concluded that the wind is the predominate load factor in the tower modelling than the seismic forces but the seismic effect cannot be fully neglected as observed from the results.
- From the above analysis it can be concluded that K-bracing and XBX-bracing gives satisfactory result in wind analysis and time history analysis for considered wind zones and ground motions.

XII. FUTURE SCOPE

In this study Wind and Non-linear dynamic analysis of Transmission tower is performed on the structure. There is a scope for future work in this area of study.

1. Study on effect of soil structure interaction on same structures.
2. Study can be done by considering other configurations of bracing system.
3. Study on the comparison of ground base tower and rooftop tower with various frequency content of ground motion.

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