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Behavior of Self-Supporting Communication Tower under Horizontal Loads

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Abstract: Communication towers have been traditionally designed for wind load. The earthquake load has not been observed in the analysis of the communication tower. Recent earthquakes, there have been indications of collapse to the communication tower. Due to the complex nature of the problem, there is a lack of research work in the area of analysis of the communication tower. The purpose of this research is to test the communication tower's response to earthquake ground movement to determine the current design software methodology. The effect of earthquake ground motion spatial variation on multi-support structures dynamic response may be necessary. The aim of this project is to use the traveling wave assumption to investigate the seismic response of high antenna-supporting guyed towers. The horizontal component of the Bhuj earthquake is considered as excitation. Elements of response analyzed are cable tension, base shear, mast axial force and lateral displacement of the tower tip. Parametric analyses show that the structural response tends to increase as the amplitude of the wave decreases and can become much larger than the reaction from synchronous excitation.

Keywords: Towers, Earthquake Load, Axial Force,Deflection.

I. INTRODUCTION

The telecommunications industry plays a vital role in human societies in the modern period. Applications Telecommunications towers have the crucial task of transmitting information from the affected areas to the rescue centers at times of natural disasters. In addition, infrastructure quality such as dams, electrical, oil, and fuel transmission stations is mainly dependent on the data being transmitted through these telecommunications towers. Specific fields of use for such towers are the military and defense industries in addition to the media, radio, and telecommunications industries, thereby generating the need for further work on telecommunications towers. Three types of steel telecommunication tower mainly known to engineers as guyed towers, self-supporting towers, and monopoles. Guyed towers regularly provide an economical and efficient solution for tall towers of 150 m and above, compared to self-supporting towers [1]. Self-supporting towers are classified into two classes of four-legged and three-legged lattice towers. The monopoles are designed for use with cellular, microwave, broadcast, and other applications.

Monopoles are most economical for heights under 55 m and are a viable solution for space limitation problems and rigid zoning codes. Industry separates monopoles from self-supporting towers, with the latter being latticed. Most research to date has been performed on 3-legged self-supporting towers, and minimal attention has been paid to the seismic behavior of 4-legged self-supporting telecommunication towers. Since almost all of the self-supporting towers built in Iran are 4-legged, therefore, in this paper, these types of towers are investigated based on the detailed dynamic analyses of ten existing towers erected in high seismic risk regions of Iran. Tower responses to seismic excitations are evaluated and then compared with those under the effect of statically applied wind forces.

The design concepts of 3-legged towers are different from that of 4-legged towers, and the results from this study could be useful for countries where the use of 4-legged towers is predominant. The transversal cross-section of such towers tapers down along the tower elevation. The member sections used are light equal-legged angles. All the members and the connection components, such as bolts and nuts, are galvanized.

SAP2000 is an independent, finite-element-based structural program for civil structure analysis and design. It provides an intuitive yet powerful user interface with many tools to help you create models quickly and accurately, along with the advanced analytical techniques you need to do the most complex projects.

SAP2000 is object-based, which means the models are generated using members representing the physical reality. A beam with more members framing into it is made as a single object, just as it happens in the real world, and the software performs the meshing needed to ensure communication occurs with the other members internally. For the overall object, tests of analysis and design are recorded, not for each sub-element that comprises the purpose, providing information that is both easier to understand and more compatible with the physical structure.

With many features and functions, SAP2000 is an extremely versatile and powerful application. Not all of these skills are protected by this guide. Instead, we're explaining quickly how to work with the software, making some suggestions along the way. SAP2000/Bridge is a bridge structure research and development program. The simplicity with which complex bridge systems can be modeled has made the bridge analysis and development software SAP2000/Bridge the most effective in the industry.

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II. SCOPE OF THE PROJECT

Modeling of different parts of the communication tower to analyze its seismic response, comparison between the forces generated in the transmission tower members by wind and earthquake loads, and Analyzing the probabilistic characteristics of the tower response to earthquake ground motion in order to establish a seismic design procedure for a communication tower.

III. TYPES OF ANALYSIS OF OMMUNICATION TOWERS

A. Dynamic analysis

Dynamic modeling provides a precise measure of the predicted structural response to a particular earthquake occurrence or earthquake group. If you can develop an accurate structural model, it is possible to directly use the measured global displacements to determine seat widths, separations, local deformations and ductility specifications to determine the required details. Such models must be built with the assumption that the fundamental uncertainty in seismic loading cannot be resolved by any level of sophistication in structural modeling.

The dynamic analysis can be used to provide a marginal measure of predicted responses that will protect the structure's adequate actions (if it falls within certain defined boundaries). The third aim of the study is to ensure that each frame has a simple and direct load direction. In addition to ensuring that each frame can sustain its own earthquake behavior without unnecessarily relying on neighboring frames, a secondary motive for this type of analysis may be to test a design based on more complex analytical models.

B. Static elastic analysis

It is possible to perform static analysis by hand or using a computer program. The bridge design community generally has the tools and skills at its disposal. Unfortunately, for only a limited class (but a significant number) of bridges, static elastic analysis is appropriate. This class includes monolithic bridges and short bridges.

C. Dynamic elastic analysis

Dynamic analysis of multimode is usually performed using a computer program. There are various programs available, and many engineers have the skills needed to operate and interpret them. Many programs allow input motions along with three orthogonal directions and combine responses according to an effective modal combination rule; others allow only one input movement part at a time and involve the combination of orthogonal input motions responses using an algebraic rule (e.g., 1.0L + 0.3 T). There is both the choice of time-history response and the option of modal spectral response. The latter is recommended for routine analysis. Response time-history analysis requires the selection of ground motions that envelop the expected input motions.

D. Linear analysis

Recent earthquakes in various part of the world points out the importance of seismic analysis and design of the buildings. Once external loading is applied, any functional with mass and elasticity appears to vibrate. Structure analysis is performed to determine the distribution of forces and deformation induced by ground shaking in the structure. The linear technique refers to elastic response structures. Any practical structure having mass and elasticity tends to vibrate on the application of external loading. Ground motion due to earthquakes may be causing the structure to vibrate. The vibration behavior of a structure can be understood with the idealization of a one-story structure consisting of mass "m" lumped on a massless spring of stiffness "k" and a viscous damper having a damping coefficient "c" that dissipates vibration energy of the system. The system considered is shown in Figure. Any function of a structure

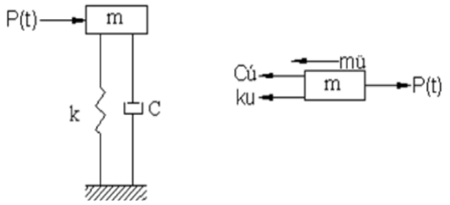

FIG. 1 IDEALIZED SDOF SYSTEM FIG.1(B) FREE BODY DIAGRAM OF MASS "M"

Consider an external force P(t) acting on the mass, m. The external force is resisted by the spring force fs, the damping force fd and inertia force fi. Applying Alembert's principle, the equation of dynamic equilibrium for the above system is given by:

$fi + fd + fs = P(t)$

Where,

fi = mü, is the inertia force
fd = cú, is the damping force
fs = ku, is the spring force
P(t) = external force.
ü = acceleration
ú = velocity
u = displacement

Therefore, the Equation becomes

$m\ddot{u} + c\acute{u} + ku = P(t)$

When the structure is subjected to earthquake induced motion, equation becomes

$m\ddot{u} + c\acute{u} + ku = - m\ddot{u}g$

Where,

üg = ground acceleration

The solution of the equation of motion gives the response of the structure.

The linear analysis includes:

IV. ANALYSIS UNDER SEISMIC LOADING

SAP is a system of static and dynamic structural analysis that provides capabilities for linear and non-linear analysis. Seismic analysis can be performed using SAP, and the ground motion can be modeled using spectrum or time history functions of particular interest for this project were the dynamic modeling capabilities, which can be performed using response spectrum analysis, time history analysis, and combinations of loading scenarios. Modal analysis was performed using Eigenvector analysis for response spectrum function and Ritz vector for time history function. SAP allows the user to input the response spectrum function.

Preprocessing in SAP utilizes a graphical interface for defining the tower geometry and properties of members and for defining loads and load combinations. Post-processing provides output for internal forces and moments, displacements, mode shapes, and design checks.

Dynamic Analysis

Currently available dynamic analysis facilities include the solution of the

1. Free vibration problem (eigenproblem),
2. Response spectrum analysis
3. Forced vibration analysis.

V. MODELING AND ANALYSIS

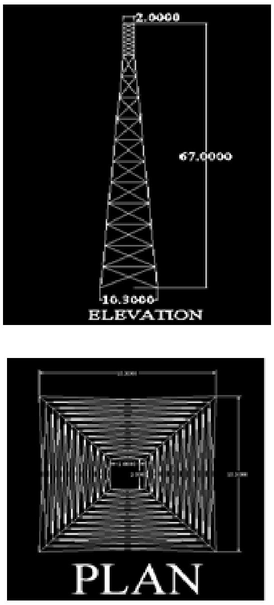

FIG 2 PLAN AND ELEVATION OF COMMUNICATION TOWER

SOFTWAREANALYSIS OF COMMUNICATION TOWER

Dead load

1. Self weight of the structure =374.532kn

Wind load as per IS 802 part I

1. Wind zone = 2
2. Wind speed=39m/s
3. Area of tower facing wind load =262.5m2
4. Gust Response Factor for Towers (GT) = 2.13
5. Wind pressure (Pd) =563N/m2(table 4)
6. Wind load on tower = 0.912KN

SEISMIC DATA

1. Zone = v(0.36)
2. Response reduction factor = 5
3. Importance factor = 1
4. Soil type = medium
5. Structure type = steel structure

SEISMIC ANALYSIS OF TRANSMISSION LINE TOWER AS PER IS 1893: 2002

Seismic data for tower

1. Zone factor = 0.36(zone V)
2. Types of Soil = Medium soil
3. Response reduction factor (R) = 5 (steel frame with Eccentric bracing)
4. Importance factor (I) = 1.5
5. Damping = 2 %

ANGLE SECTION

WIND AND SEISMIC ANALYSIS OF TOWERS

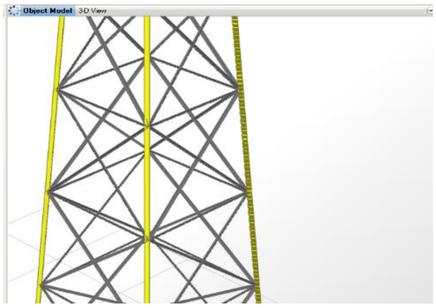

FIG 3 3D VIEW OF TOWER ANGLE SECTION

TABLE 1: AXIAL FORCES DUE TO SL

MEMBER	AXIAL FORCE (KN)
F2	6283.168
F19	-4676.565
F20	-3507.321
F21	-5285.089
F22	4569.038
F23	3553.216
F24	5233.683
25	4255.076
F26	4601.826
F27	4859.463
F28	5003.668

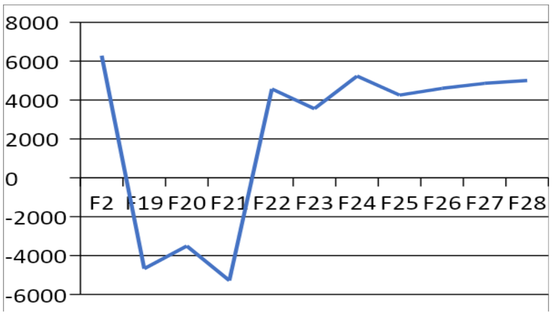

FIG 4 AXIAL FORCE DUE TO SL

TABLE 2: DEFLECTION DUE TO SL

JOINT	MODE	DISPLACEMENT (In mm)
J8	4	-329.359465
J12	2	-621.033967
J23	11	505.298481
J24	6	-466.366488
J25	11	-426.688963
J26	4	439.756484
J27	4	471.694158
J28	4	448.977374

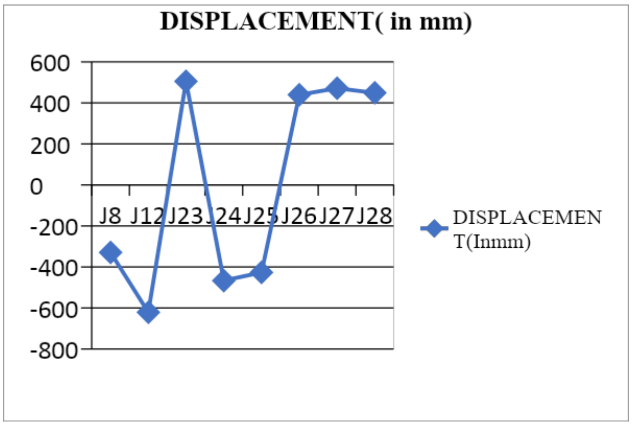

FIG 5 DISPLACEMENT DUE TO SEISMIC LOAD

TABLE 3: AXIAL FORCE DUE TO WIND

JOINT	AXIAL FORCE (In mm)
J2	90.428
J19	41.28
J20	-6.029
J21	-57.501
J22	-113.35
J23	-175.085
J24	-242.728
J25	-315.885
26	-393.958
J27	-476.167
J28	-561.991

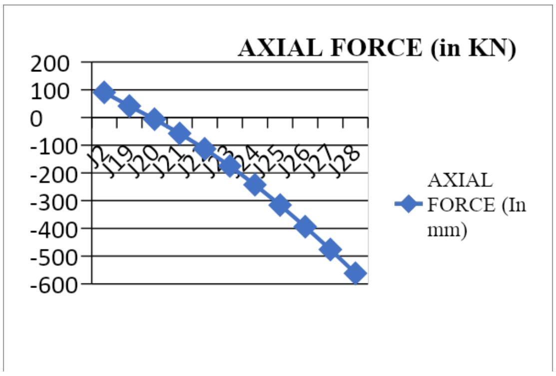

FIG 6 AXIAL FORCE DUE TO WIND

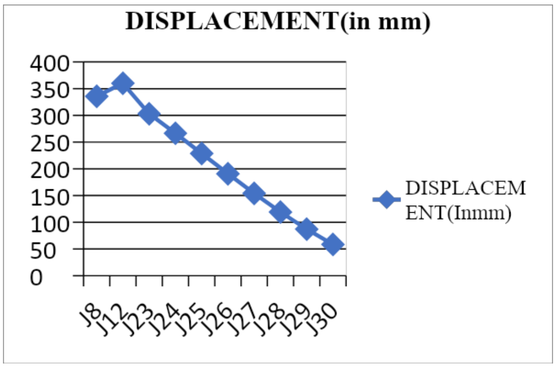

FIG 7 DISPLACEMENT DUE TO WIND

TABLE 4: BASE REACTION IN (KN)

STEP TYPE	STEP NO	GLOBAL FX	GLOBAL FY	GLOBAL FZ
Text	Unitless	KN	KN	KN
Mode	1	-38.314	-183.173	0.006936
Mode	2	-183.569	38.396	0.01
Mode	3	4.429	6.725	0.22
Mode	4	-201.795	-1627.281	-0.675
Mode	5	1630.126	-201.882	1.724
Mode	6	2.585	0.384	-7266.313

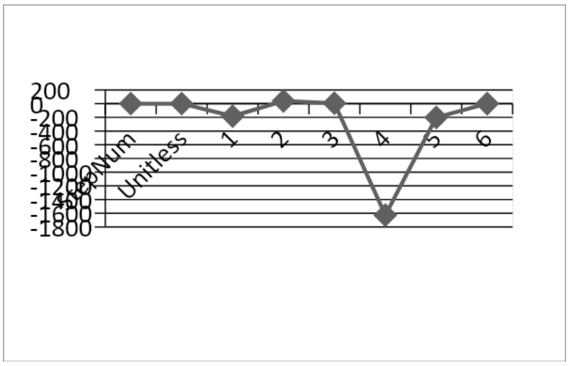

FIG 8 BASE REACTION

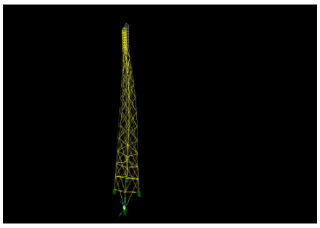

FIG 9 MODE SHAPE 1

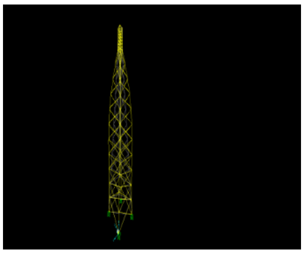

FIG 10 MODE SHAPE3

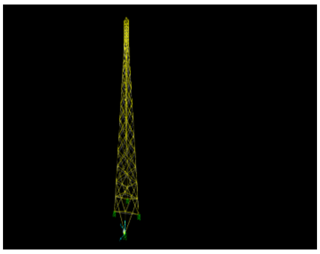

FIG 11 MODE SHAPE 6

PIPE SECTION

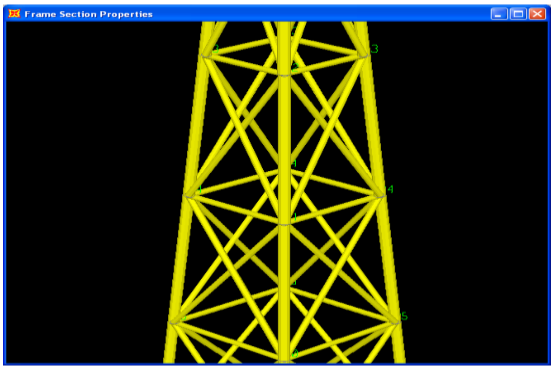

TABLE 5: DEFLECTION DUE TO WIND

JOINT	DISPLACEMENT (IN mm)
J8	70.651791
J12	72.330789
J23	65.640629
J24	59.137135
J26	43.72582
J27	35.594396

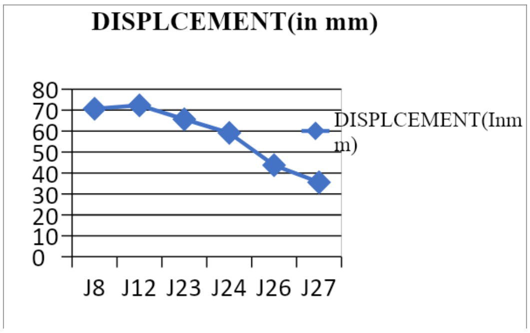

FIG 12 DISPLACEMENT DUE TO WIND

TABLE 6: AXIAL FORCE DUE TO WIND

MEMBER	AXIAL FORCE (In mm)
F2	95.05
F20	31.707
F21	-7.836
F22	-56.151
F23	-113.79
F24	-180.583
F25	-255.909
F26	-338.934
F27	-428.652
F28	-523.658

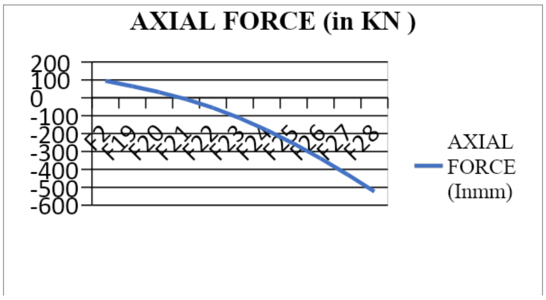

FIG 13 AXIAL FORCE DUE TO WIND

TABLE 7: DEFLECTION DUE TO SL

JOINT	MODE	DISPLACEMENT (In mm)
J24	9	238.86965
J23	9	229.752806
J27	4	217.079504
J26	11	214.984449
J12	7	203.160269
J8	7	108.540394

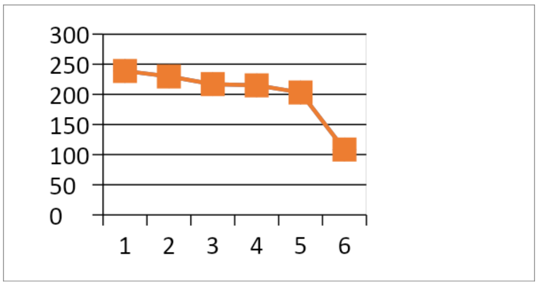

FIG 14 DEFLECTION DUE TO SL

TABLE 8: AXIAL FORCE DUE TO SEISMIC

Member	Mode	Axial force (in mm)
f21	12	17886.703
f22	12	17206.691
f20	12	16333.274
f23	12	13733.024
f19	12	13376.59
f2	12	9826.908
f24	10	8819.767
f28	5	7835.647
f27	5	7535.679
f26	5	7041.024

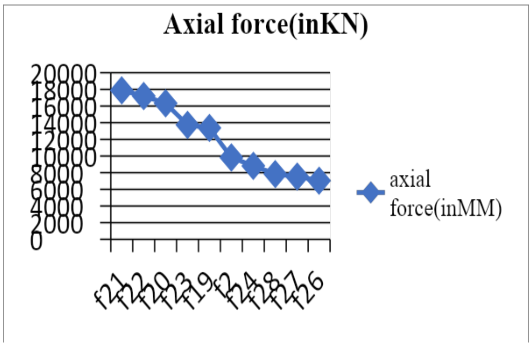

FIG 15 AXIAL FORCE DUE TO SEISMIC

TABLE 9: BACE REACTION DUE TO SEISMIC

STEP TYPE	STEP NO	GLOBAL FX	GLOBAL FY
Text	Unitless	KN	KN
Mode	1	-302.923	-860.293
Mode	2	861.48	-303.341
Mode	3	1999.036	6021.528
Mode	4	-6025.044	1999.956
Mode	5	6.368	-0.187
Mode	6	-1712.757	-15877.119

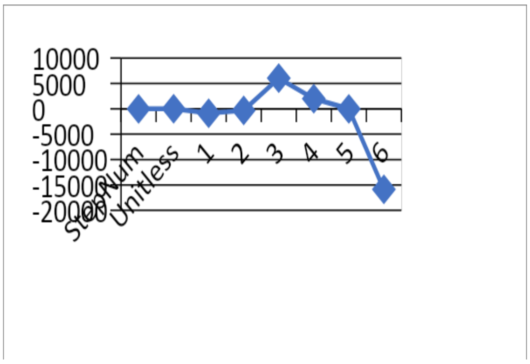

FIG 16 BASE REACTION DUE TO SL

JOINT	DISPLACEMENT (In mm)
J8	61.519162
J12	63.228001
J23	57.107401
J24	51.317198
J25	44.652003
J26	37.493674
J27	30.177437
J28	23.019042

TABLE 10: DISPLACEMENT DUE TO WIND

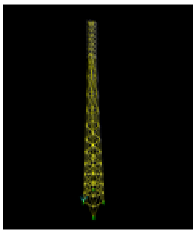

FIG 17 MODE SHAPE

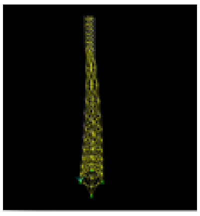

FIG 18 MODE SHAPE 6

COMBINATION OF ANGLE AND PIPE SECTION

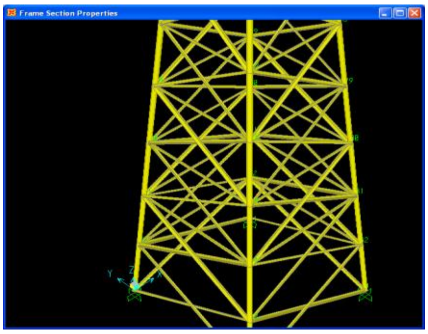

FIG 19 COMBINED SECTION

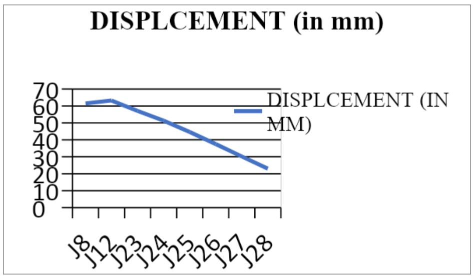

FIG 20 DISPLACEMENT DUE TO WIND

TABLE 11: AXIAL FORCE DUE TO WIND LOAD

MEMBER	AXIAL FORCE (In KN)
F2	83.319
F19	59.021
F20	30.801
F21	-5.156
F22	-51.25
F23	-108.337
F24	-176.4
F25	-254.826
F26	-342.678
F27	-438.794
F28	-540.848

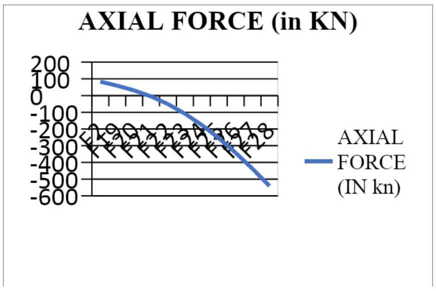

FIG 21 AXIAL FORCE DUE TO WIND

TABLE 12: DISPLACEMENT DUE TO SL

JOINT	MODE	DISPLACEMENT (In mm)
J8	2	194.516466
J12	2	202.214263
J23	2	175.971889
J24	2	153.230643
J25	2	128.685089
J26	4	149.351686
J27	4	164.817386
J28	4	156.8715

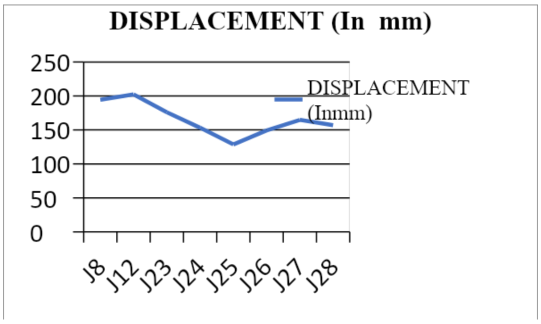

FIG 22 DISPLACEMENT DUE TO SL

TABLE 13: AXIAL FORCE DUE TO SL

MEMBER	MODE	AXIAL FORCE (In KN)
F28	12	-18275.536
F24	11	-16319.877
F27	12	-12289.704
F2	11	-11238.119
F23	11	-10577.276
F19	11	-10244.492
F22	9	-8379.965
F21	10	-7249.546
F26	8	-6789.179
F20	7	-5669.483
F25	2	-938.221

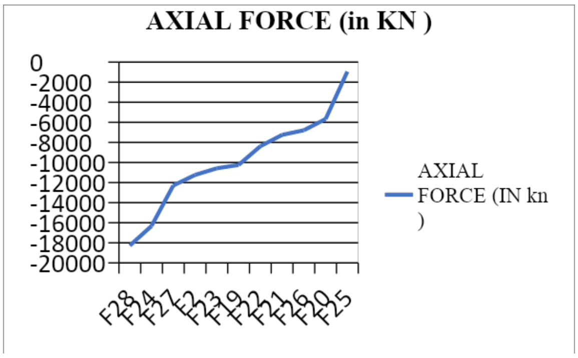

FIG 23 AXIAL FORCE DUE TO SL

TABLE 14: BASE REACTION IN KN

GLOBAL FX	GLOBAL FY	GLOBAL FZ
KN	KN	KN
383.974	723.8	-0.413
-724.941	384.573	0.143
2493.679	5861.381	-13.109
-5866.407	2494.859	2.789
6.334	-0.98	-31268.729
-934.41	-18671.794	28.518

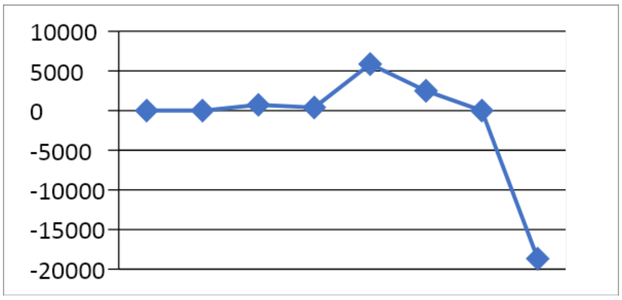

FIG 24 AXIAL FORCE DUE TO SL

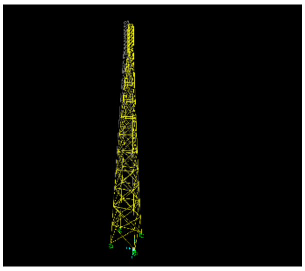

FIG 25 Mode shape 1(T=0.54s)

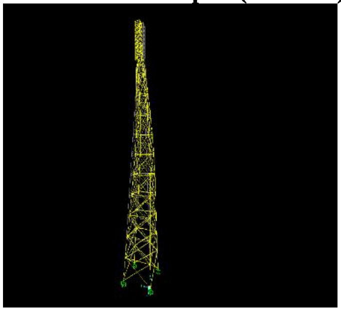

FIG 26 Mode shape 3 (T=0.14s)

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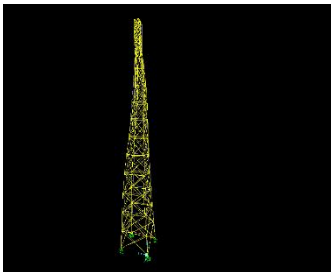

FIG 27 mode shape 6 (T=0.09s)

V.RESULTS AND DISCUSSION

The Results Of The Angle, Pipe, And Combination Of Angle And Pipe Sections Are Analyzed And Compared In The Below Table.

SECTION	AXIAL FORCE DUE TO WIND (KN)	DEFLECTION DUE TO WIND(MM)	AXIAL FORCE DUE TO SEISMIC(KN)	DEFLECTION DUE TO SEISMIC (mm)
Angle section	561.99	335.66	6283.168	621.033
Pipe section	523.658	72.33	17886.703	229.75
Combined section	540.848	63.228	18275.536	202.214

VI. CONCLUSION

The communication system mainly consists of transferring communication all over the universe, and the signals can be supplied when all the towers are stable. Therefore, constructing a communication tower without toppling is a critical matter. Telecommunications towers vulnerability damaged in past earthquakes, as well as current requirements and technology to protect such provision from earthquake damage to be checked. No evidence was found of conditions to preserve telecommunication towers in the seismic zone. In this work, communication tower analysis for seismic and wind by Sap 2000, for different sections (Angle, pipe, and combination of both), the results indicate that in combination section, the deflection occurred is comparatively less and the failure of the part is avoidable. Also, the region is economical.

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