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Seismic Analysis of Four Legged Telecommunication Towers using Fluid Viscous Dampers.

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Abstract - *The telecommunication masts are considered today as one of the basic infrastructures in the human societies. Due to their vital role, the preservation of these structures during natural disasters, such as a severe earthquake, is of utmost priority and hence their seismic performance should be properly evaluated. The researchers in their studies have considered the effects of wind and earthquake-induced loads mostly on the trussed steel masts of triangular cross sections.*

The telecommunication towers exposed to special loadings such as longitudinal loads, construction, and maintenance loads, line galloping, and structure vibration, for which it need to be designed. Longitudinal loadings may be the result of weather – related events, failure of an adjacent structure and must be resisted to prevent cascading failures of the support structures in the line. For this reason, longitudinal loadings are sometimes referred to as "Anti cascading" failure containment" or "Security" loads.

Key Words: **Telecommunication tower, self-supporting tower, Damper, Fluid viscous damper, angle section, chords, bracings.**

1. INTRODUCTION

Radio masts and communication towers are typically tall constructions specially designed to carry antennas for radio communication. Such radio communication includes television, radio, GSM and Internet traffic. Towers and masts are used in numerous applications in wireless networks from broadband point to point systems to LMR1 networks. Towers and masts are often required to raise antennas above tree lines and roof tops for line of sight connections.

The telecommunication masts are considered today as one of the basic infrastructures in the" Human societies. Due to their vital role, the preservation of these structures during natural disasters, such as a severe earthquake, is of utmost priority and hence their seismic performance should be properly evaluated. The researchers in their studies have considered the effects of wind and earthquake-induced loads mostly on the trussed steel masts of triangular cross sections.

At the start of telecommunication tower design, due to lightness and height of such structures, much of the efforts of researchers were focused on the wind loading. Nevertheless, in recent years, more attention is being paid to earthquake loading due to adding the number of antennas mounted on the telecommunication towers and also due to the high seismicity level of the regions where the towers are installed. In the latest editions of world's most accredited design codes, the topic of earthquake loading on such structures has been included.

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1.1TYPES OF TOWERS

There are three types of telecommunication towers mainly known to engineers as

1. Monopole.
2. Self-supporting towers.
3. Guyed type

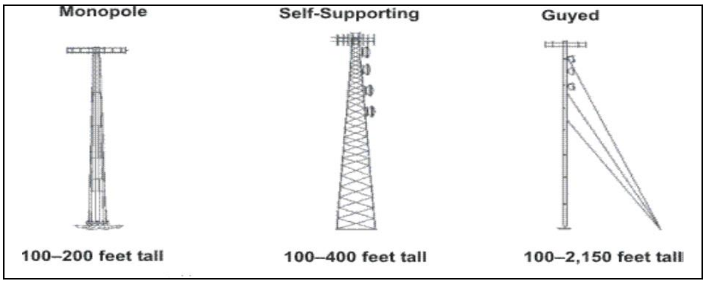

Fig 1: Types of towers.

1.2.1 Monopole towers

Monopoles are hollow tapered poles made of galvanized steel . They are constructed of slip jointed welded tubes and can be up to 200 feet (60m). Due to its construction, they are expensive to manufacture but simple to erect. Monopoles are primarily used in urban environments where limited space available for the footprint of the tower base. The maximum footprint of a 200 feet monopole is approx. 6x6 feet (2x2 m).

1.2.2 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. Self- supporting towers can be built with three or four sided structures. They are assembled in sections with a lattice work of cross braces bolted to three four sloping vertical tower legs. The wider the base of the tower is, the larger antenna load is acceptable.

The self-supporting towers are categorized into two groups

1. 4-legged towers and
2. 3-leggedtowers.

Most researches to date have been performed on 3-legged self-supporting towers and very limited attention has been paid to the dynamic behaviour of 4-legged self-supporting telecommunication towers.

1.2 Dampers

Damping is the process by which physical systems such as structure dissipate and absorb the energy input from external excitations. Therefore damping reduces the build-up of the strain energy and the system response, especially for near resonance conditions, where damping controls the response. In the other words, damping is utilized to characterize the ability of structures to dissipate energy during dynamic response. Unlike the mass and the stiffness of the structure, damping does not relate to a unique physical process but rather relates to a number of possible processes. Damping values depend on several factors, such as, vibration amplitude, material of construction, fundamental periods of vibration, mode shapes and structural configurations

1.3 USES OF DAMPERS

Generally dampers were used to.

- Reducing story drifts of tall building structures.
- Reducing accidental torsional motions of tall building structures.
- Increasing dissipation of input energy due to earthquake.
- Reducing vibration amplitude of tall building structures.

1.3 BREIF DESCRIPTION OF FLUID VISCOUS DAMPERS

Fluid viscous dampers operate on the principle of fluid flow through orifices. A stainless steel piston travels through chambers that are filled with silicone oil. The silicone oil is inert, non-flammable, non-toxic and stable for extremely long periods of time. The pressure difference between the two chambers cause silicone oil to flow through an orifice in the piston head and seismic energy is transformed into heat, which dissipates into the atmosphere. The force/velocity relationship for this kind of damper can be characterized as $F = CV^{\alpha}$ where F is the output force, V the relative velocity across the damper, C is the damping coefficient and α is a constant exponent which is usually a value between 0.3 and 1.0. Fluid viscous dampers can operate over temperature fluctuations ranging from –40°C to +70°C. Fluid viscous dampers have the unique ability to simultaneously reduce both stress and deflection within a structure subjected to a transient. This is because a fluid viscous damper varies its force only with velocity, which provides a response that is inherently out-of-phase with stresses due to flexing of the structure

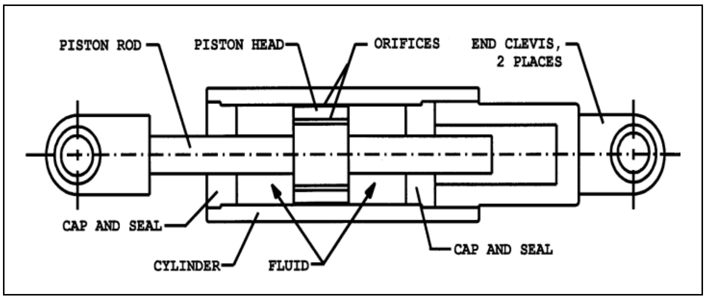

Fig 2: Fluid viscous Damper

2. LITERATURE REVIEW

This chapter provides a review of literature on telecommunication towers with different configurations. SAP2000 is an powerful tool for analysis of towers addition to this it is much faster and will be cost effective as compared with conducting the experiments.

Akbas.et.al.(2003): Conducted a push over analysis on steel frames to estimate the seismic demands at different performance levels, which requires the consideration of inelastic behaviour of the structure.

G. Ghodrati Amir et al. (2004): Investigated the overall seismic response of 4-legged self-supporting telecommunication towers. For this purpose, ten existing 4-legged self-supporting telecommunication towers in Iran are studied under the effects of the design spectrum from the Iranian seismic code of practice and the normalized spectra earthquakes. As part of some of the results, it was observed that the first three flexural modes are sufficient for the dynamic analysis of such towers, even though in the case of taller towers, considering the first five modes would enhance the analysis precision and he finally concluded that the lowest three flexural modes of vibration are sufficient for the dynamic analysis of self-supporting telecommunication towers .Although, considering the lowest five modes, especially in the case of taller towers, would enhance the analysis precision.

Marcel Isandro R. de Oliveira et al. (2007): The usual structural analysis models for telecommunication and transmission steel tower design tend to assume a simple truss behavior where all the steel connections are considered hinged. Despite this fact, the most commonly used tower geometries possess structural mechanisms that could compromise the assumed structural behavior. A possible explanation for the structure stability is related to the connections semi-rigid response instead of the initially assumed pinned behavior. This paper proposes an alternative structural analysis modelling strategy for guyed steel towers design, considering all the actual structural forces and moments, by using three-dimensional beam and truss finite elements. Comparisons of the above mentioned design models with a third alternative, that models the main structure and the bracing system with 3D beam finite elements, are made for three existing guyed steel telecommunication towers (50m, 70mand 90m high). The comparisons are initially based on the towers static and dynamic structural behaviour later to be followed by a linear buckling analysis to determine the influence of the various modelling strategies on the tower stability behaviour. Finally, based on the obtained results for the investigated tower geometries, the authors would like to suggest the adoption of the third mixed strategy in which the bracing systems are modelled by truss elements.

3. OBJECTIVES

1. To analyze a four legged telecommunication tower for lateral analysis particularly for earthquake using equivalent static analysis.
2. Also tower is analyzed for dynamic analysis using time history method.
3. Both the above 2 methods are done with and without dampers.
4. Top displacements are extracted and compared for both the methods
5. Response from both type of analysis are extracted and plotted.
6. Finally the effect and significance of the damper is discussed.

4. METHODS OF SEISMIC EVALUATION

Once the structural model has been selected, it is possible to perform analysis to determine the seismically induced forces in the structures. There are different methods of analysis provides different degrees of accuracy. Currently seismic evaluation of buildings can be divided into two categories

- Qualitative method
- Analytical method

The qualitative methods are based on the available background information of the structures, which involves the visual inspection report, some non-destructive test results etc. Whereas analytical methods involves the estimation of forces and behaviour of the structures during the earthquakes depending on the available data

Analytical method includes

1. Equivalent static analysis
2. Time history analysis
3. Response spectrum analysis
4 Nonlinear dynamic analysis
In our study of work I will comparison only with equivalent static and time history method.

5. MODELLING AND ANALYSIS

5.1 MODEL DESCRIPTION

One of the major objectives of this work was to test a real- life structure under Seismic loads and also only when wind load is considered without seismic loads.

Two framed Telecommunication Towers are modelled, with and Without Dampers were used in the analysis to know the realistic behaviour of Tower during earthquake, using SAP14. and all the analysis is done by considering medium soil for zone 5.

5.2 Model geometry

One of the major objectives of this work was to test a real-life structure under Seismic loads and also only when wind load is considered without seismic loads. In order to keep the structure as close to reality as possible, no special design for the Model as such was performed and instead a portion of a real life framed structure was selected.

The details of the model are given as:

Tower height = 56.0 m.
Bottom Dimension =10 mx10 m.
Top Dimension =2.0mx 2.0m.
Bracings Type = Concentric and Eccentric Type

MEMBER	SPECIFICATION
ANGLE	ISA 100X100X12 ISA 200X200X25

The plan of the Tele Communication tower is shown in the fig below

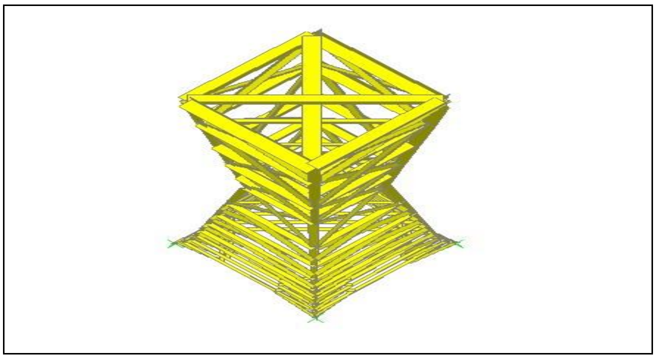

Fig3: Plan of Render View of the Tower

The elevation of tele-Communication tower is shown in the fig

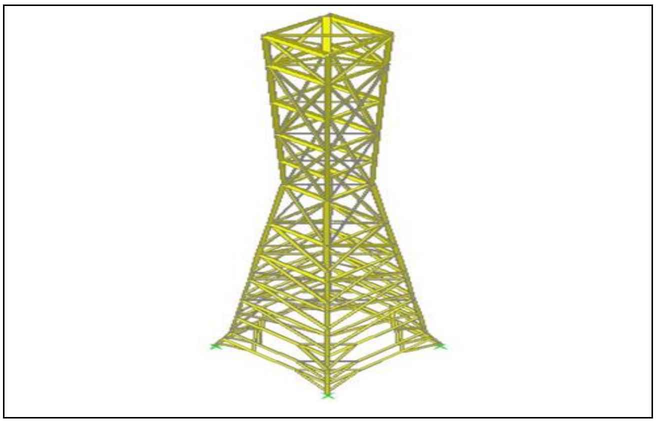

Fig 4:Elevation of the tower

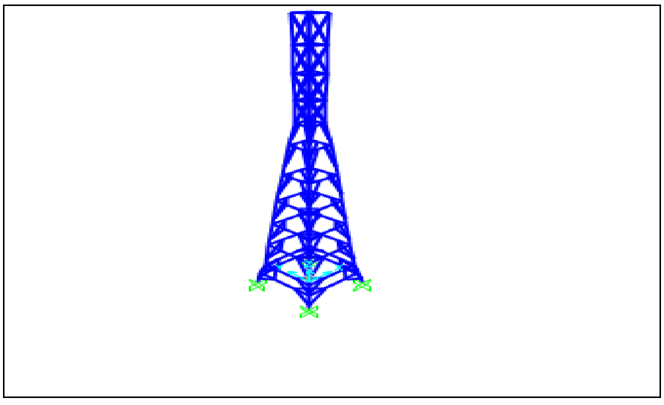

Fig 5 : Telecommunication tower without damper.

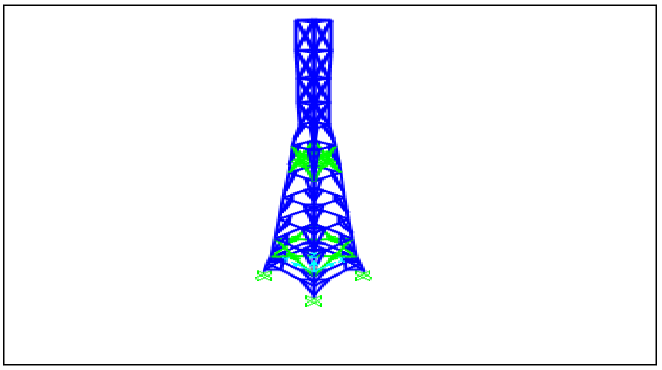

Fig 6: Telecommunication tower with dampers

6 RESULTS AND DISCUSSION

6.1Wind Loads

On a lattice structure like tower downward thrust and drag force are two wind force effects that were measured. Based on configuration of tower 0 and 90 degree are considered. Dead load +0 degree direction basic wind speed and dead load +90 degree direction basic wind speed combination is used for analysis.

The wind load on tower is computed according to Indian standard angles IS 875 1987.The basic wind speed depending on location of tower is selected as 50m/s .Other parameters for instance terrain category is taken as 4 and class B

Table: 1 Comparative values for tower height versus displacement

TOWER HEIGHT	WITHOUT DAMPERS	WITH DAMPERS
0	0	0
3.25	3.56	3.24
6	10.34	7.28
12	25.48	15.34
18	44.7	22.67
24	64.76	32.11
30	86.76	44.34
36	103.65	57.77
40	118.7	65.32
44	149.56	82.76
48	175.77	97.97
52	199.34	109.77
56	232.67	123.34

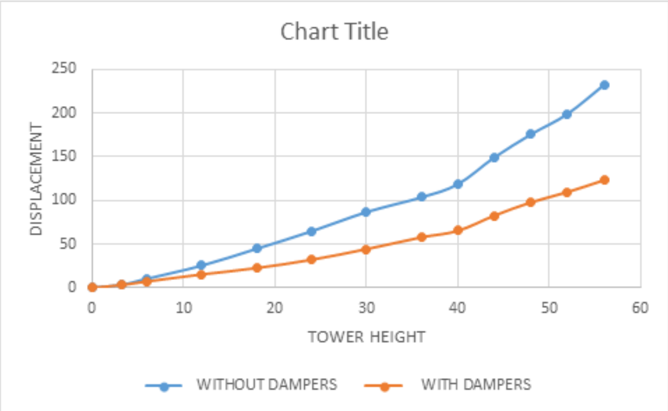

Chart-1: Graph showing Comparative values for tower height versus displacement

The above table shows the comparison of displacement of with and without damper with respect to tower height.From the table 1 we can conclude that the displacement of the tower reduces after the provision of the damper.

6.2 Equivalent static analysis

Here the total design lateral force or design base shear along any principal direction is given in terms of design horizontal seismic coefficient and seismic weight of the structure. Design horizontal seismic coefficient depends on the zone factor of the site, importance of the structure, response reduction factor of the lateral load resisting elements and the fundamental period of the structure.

The procedure generally used for the equivalent static analysis is explained below:

(i) Determination of fundamental natural period (T_a) of the buildings

$$T_a = 0.075h^{0.75}$$

Moment resisting RC frame building without brick infill wall.

$$T_a = 0.085h^{0.75}$$

Moment resisting steel frame building without brick infill walls

$$T_a = 0.09h/\sqrt{d}$$

All other buildings including moment resisting RC frame building with brick infill walls.

Where,

h - is the height of building in m

d - is the base dimension of building at plinth level in m, along the considered direction of lateral force.

(ii) Determination of base shear (V_B)n of the building

$$V_B = A_h \times W$$

Where,

$$Ah = \frac{Z}{2}\frac{I}{R}\frac{Sa}{g}$$

is the design horizontal seismic coefficient, which depends on the seismic zone factor (Z), importance factor (I), response reduction factor (R) and the average response acceleration coefficients (Sa/g). Sa/g in turn depends on the nature of foundation soil (rock, medium or soft soil sites), natural period and the damping of the structure.

(iii) Distribution of design base shear

The design base shear V_B thus obtained shall be distributed along the height of the building as per the following expression:

$$Q_i = V_B \frac{W_i h_i^2}{\sum_{i=1}^{n} W_i h_i^2}$$

Where, Q_i is the design lateral force, W_i is the seismic weight, h_i is the height of the i^{th} floor measured from base and n is the number of stories in the building.

Table:2 Comparative values for tower height versus displacement

TOWER HEIGHT	WITHOUT DAMPERS	WITH DAMPERS
0	0	0
3.25	2.36	0.78
6	7.34	1.98
12	13.56	6.76
18	22.93	10.96
24	33.77	16.87
30	43.12	21.22
36	53.76	25.89
40	63.75	30.38
44	82.89	40.53
48	102.34	54.97
52	120.22	68.88
56	140.23	83.78

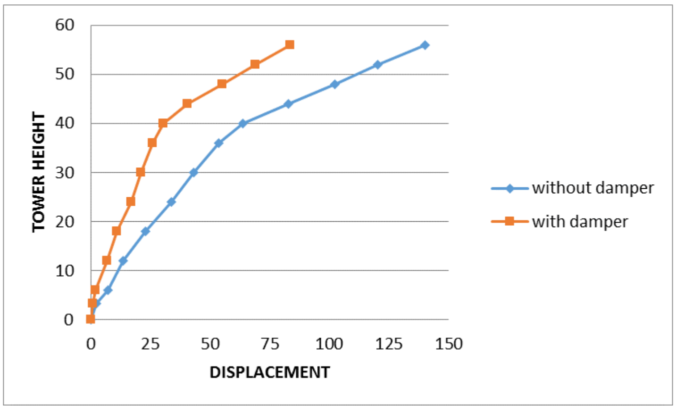

Chart-2: Graph showing Comparative values for tower height versus displacement

The above table shows the comparison of displacement of with and without damper with respect to tower height.From the table 2 we can conclude that the displacement of the tower reduces after the provision of the damper

6.3: Time history analysis

The Time History analyses technique represents the most sophisticated method of dynamic analyses for buildings. In this method the mathematical model of a building is subjected to accelerations from earthquake records that represent the expected earthquake at the base of the structure.

This method consists of direct step by step direct integration over a time interval. Equations of motions are solved with the displacements, Velocities and acceleration of the previous step serving as initial functions. The Time History Method is applicable to both elastic and inelastic analyses. In elastic analyses the stiffness characteristics are assumed to be constant for whole duration of earthquake. In the inelastic analysis, however the stiffness is assumed to be constant through the incremental time only. Modifications to structural stiffness caused by cracking, formation of plastic hinges, etc. are incorporated between the incremental solutions.

The earthquake motions are applied directly to the base of the model of a given structure. The procedure usually includes the following steps:

1. An Earthquake records representing the design earthquake is selected.
2. The record is digitized as a series of small time intervals of about 1/40 to 1/25 of second.
3. A mathematical model of the building is setup, usually consisting of a lumped mass at each floor.
4. The digitized record is applied to the model as acceleration at the base of the structure.
5. The equations of motions are then integrated with the help of a software program

Table: 3 Comparative values for tower height versus displacement

TOWER HEIGHT	WITHOUT DAMPERS	WITH DAMPERS
0	0	0
3.25	1.68	1.13
6	5.43	2.57
12	10.11	5.13
18	15.65	8.67
24	22.89	13.76
30	30.34	18.9
36	40.11	24.33
40	48.66	28.85
44	64.79	36.39
48	81.97	44.7
52	102.33	55.59
56	122.46	68.67

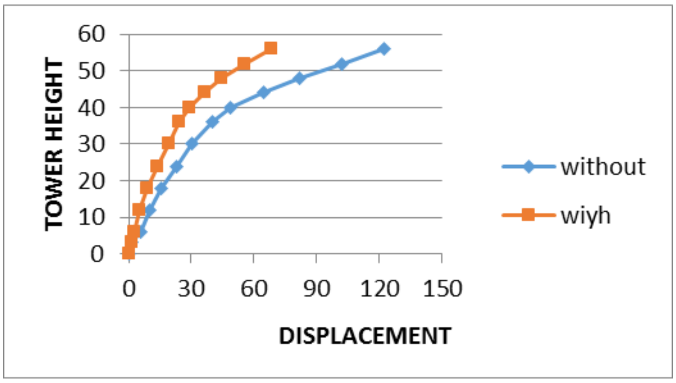

Chart-3: Graph showing Comparative values for tower height versus displacement

The above table shows the comparison of displacement of with and without damper with respect to tower height.From the table 3 we can conclude that the displacement of the tower reduces after the provision of the damper

7. CONCLUSIONS

- As per the objective of the this research, performance of the existing tower were analyzed considering different Earth quake methods as per equivalent static method and time history method

- From the wind analysis it can be observed that the joint displacement decreases with the provision of damper.
- In wind analysis the joint displacement is more for the tower without damper and the tower with damper, and displacement reduces for about 35%.
- In equistatic analysis the displacement reduces about 83%
- In time history analysis the displacement reduces about 85%

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BIOGRAPHIES

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