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# Seismic Analysis of Self Supporting Telecommunication Tower

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**Abstract—***In this age of communication and networking telecommunication towers plays important role in human society. So the analysis and design of telecommunication towers for earthquake are the major issues which are playing significant role in recent decades in the designing. Telecommunication towers with different configurations behaves differently for lateral loadings. Lot of literature is available which proposes different formulas to determine seismic parameters. Also previously, designers considered safety of towers only against overturning. During the seismic event some members of towers reach its ultimate strength causing failure. However, performance of the different configurations of telecommunication tower against earthquake is not much discussed in the literatures. So there is need of in-depth study of behavior of telecommunication tower for different configurations and its analysis for earthquake effect. This paper deals with designing and modelling of telecommunication towers for different configuration such as different bracing systems using Structural Analysis Program (SAP2000) software. Linear and non-linear analysis is carried out of different modelled towers and the results are compared based on the pushover curve to find the best suitable configuration of towers.*

**Keywords***: Telecommunication towers, bracing systems, seismic analysis, base shear, Pushover curve, SAP200.*

## 1. INTRODUCTION

The television and telecommunication industry plays a great role in human societies and thus communication industries have seen a tremendous increase in last few years which have resulted in installation of large number of towers to increase the coverage area and network consistency. In wireless communication network these towers play a significant role thus much more attention is now being paid to telecommunication towers than it was in the past.

Besides the need of telecommunication towers in day to day life, during the events of the earthquake telecommunication and TV towers have the crucial task of instant transmission of information from the affected areas to the rescue centers so that help could reach the needed as early as possible. Therefore utmost importance should be given in considering all possible extreme conditions for analysis and designing of these towers.

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.

In some of the first studies conducted on performance of telecommunication tower, Konno and kimura studied the effect of earthquake loading on roof top telecommunication tower to obtain the mode shapes, natural frequencies and damping properties of structure. Also Mikus investigated the seismic behavior of six three legged self-supporting telecommunication tower using accelogram.

AS a part of study, initially efforts have been made to study amplication factor for base shear and total vertical reaction of self-supporting tower based on modal superposition analysis performed on 10 existing towers [1}. And leter on the study was extended to investigated seismic behavior of 4-legged self-supporting telecommunication tower under Tabas and Manjhil earthquake spectra and offered relationship for estimating fundamental time period and base shear [2]. Also on seismic sensitivity of 4-legged telecommunication tower based on modal superposition analysis shows that in case of rectangular crossection earthquake loading in two orthogonal direction is important [3]. The other efforts study related to towers, also calculated seismic amplification factor, and offered relation for estimating the vertical response of tower [4]. The other researcher attempted to study both rooftop tower and ground base towers and compared based on axial forces. In another study conducted, seismic response of ten 4 legged telecommunication tower, the study presented three equations to estimate tower yield base shear and base shear that corresponds to immediate occupancy level of tower [6]. The earthquake response of four towers was also conducted with different height considering different bracing system based on base shear and the displacement for time history of Bhuj earthquake [7].

Most of these previous studies were carried out to provide various formulae to find out various seismic parameters. Also previously the interest of designers was in safety against overturning of tower. But during the event of earthquake some of the members of tower reaches yield strength and causes failure. Due to this, nonlinear pushover analysis should be carried out to study the actual behavior of telecommunication tower.

Keeping this in view, in this paper, an attempt is made to study the nonlinear seismic analysis of different telecommunication towers with different configurations of bracing systems.

**1.1. Configuration of telecommunication towers**

Telecommunication towers are mostly square or triangular in plan, made of standard steel angles and connected together by means of bolts and nuts.

There are mainly five types of bracing and horizontal combinations that are normally adopted in towers as follows;

1) X-Bracing without horizontals, call it XX-Bracing and it is statically determinate for each panel.
2) XB-bracing: X-bracing with horizontals is called XB-bracing and it is statically indeterminate. The horizontal are the redundant members and carry only nominal forces.
3) K-bracing: K-bracing is statically determinate and gives larger head room. Therefore, it is used in the panels next to ground.
4) Y-bracing: The bracing type is statically determinate and provides better head room space and so could be used at ground or lower panels.
5) W-bracing: it is a kind of overlapping panels and statically determinate. It is suitable for small panels.
6) Arch-bracing: An arch bracing can be adopted in wide panels.

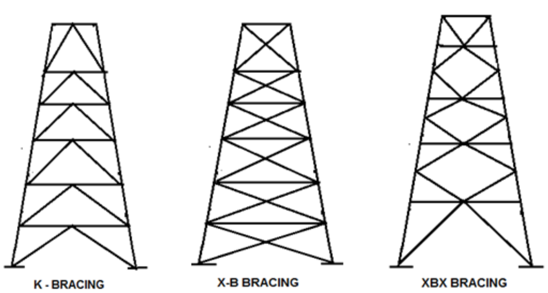



**Fig. 1.1: Different configuration of bracing system**

**1.2. Analysis of telecommunication tower**

Due to ductile behaviour of steel, analysis and design of steel telecommunication tower is difficult task. Different sections of leg members, bracing members and horizontal members are to be designed considering loads on it. In this study bare telecommunication towers are designed and checked for gravity loading.

Nonlinear dynamic analysis which is also known as time history analysis, of telecommunication towers is time consuming process and requires special inputs whereas nonlinear static analysis is a simplified analysis under a predefined pattern of permanent vertical loads and gradually increasing lateral loads. This is also known as pushover analysis. This type of analysis enables weakness in the structure to be identified. The decision to retrofit can be taken in such studies

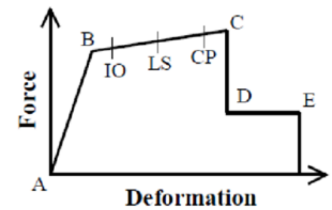



**Fig. 1.2 Nonlinear static analysis curve (ASCE 41, 2007)**

The range AB is elastic range, IO, LS and CP stand for Immediate Occupancy, Life Safety and Collapse Prevention respectively.

## 2. SCOPE AND OBJECTIVES

In this paper, an attempt is made to study and compare the effects of earthquake on a 4 legged self-supporting telecommunication towers with different configuration using SAP2000. The methodology includes analysis of 3D modelling of telecommunication towers of different bracing systems. The non-linear analysis is carried out for the different towers to compare the effect of earthquake on it.

## 3. PROBLEM DISCUSSION AND MODELLING OF STRUCTURE

In order to evaluate the seismic response of telecommunication towers dynamic analysis is adopted. The details of this towers is mentioned in following table.

**Details of Models:**

In this study, the towers of 50 meter height is considered. This tower is considered to be situated seismic zone IV and designed in compliance to the Indian Code of Practice for Earthquake Resistant Design of Structures[8]. The tower is considered to be fixed at the base. The tower is modelled using software SAP2000. Pushover analysis is carried out on the same model to obtain pushover curve.

| | |
|---|---|
| **Model I** | Telecommunication tower with X-B bracing system. |
| **Model II** | Telecommunication tower with X-B-X bracing system. |
| **Model III** | Telecommunication tower with K bracing system. |
| **Model IV** | Telecommunication tower with K bracings with additional bracing system. |

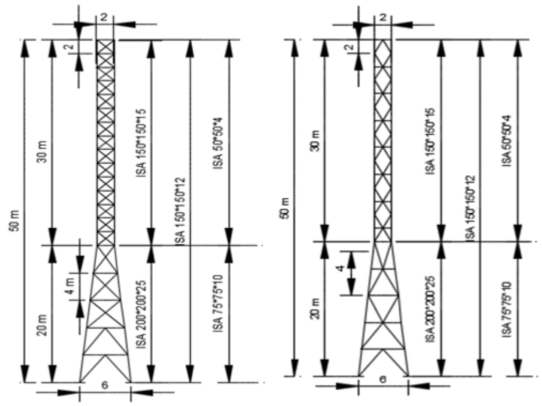


**Fig. 3.1. Schematic drawing of Mode I and Model II**

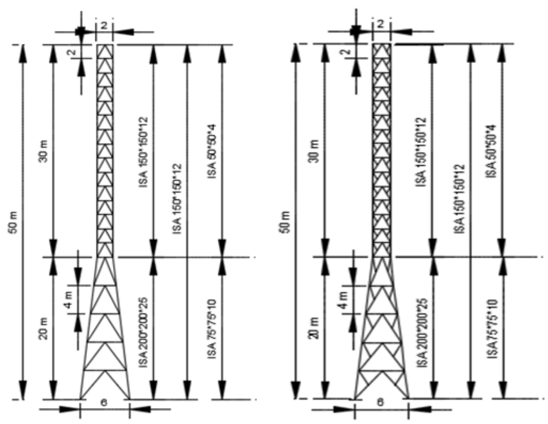
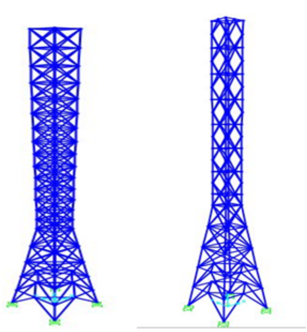
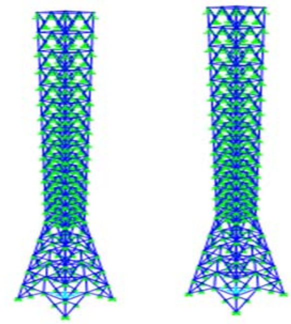


**Fig. 3.2.Schematic drawing of Mode III and Model IV**



**Model I Model II**



**Model III Model IV**

**Fig. 3.3 Snapshots of 3-Dimensional models of towers from SAP2000**

## 4. RESULT AND DISCUSSION:

The fundamental time period and base shear values using Uniform building code and from SAP2000 are tabulated below.

**Table 4.1. Comparison of analytical and software results for Model I**

| Parameters | Uniform Building Code (1997) | SAP2000 |
|---|---|---|
| Fundamental Time period (sec) | 0.658 | 0.622 |
| Base shear (kN) | 10.8 | 8.724 |

From Table 4.1 it can be seen that the result obtained from software and that obtained from Uniform building code 1997 are nearly same. The base shear is decreasing and time period is increasing in case of software results.

The results of fundamental time period and base shear for different type of bracings is tabulated below

**Table 4.2. Comparison of seismic parameters for different bracing systems**

| | XB Bracing | XBX Bracing |
|---|---|---|
| Base Shear (kN) | 8.724 | 12.667 |
| Fundamental time period (sec) | 0.66 | 0.599 |

**Table 4.2. Comparison of seismic parameters for different bracing systems**

| | K Bracing | *K-Add |
|---|---|---|
| Base Shear (kN) | 8.328 | 10.26 |
| Fundamental time period (sec) | 0.647 | 0.648 |

*Additional bracing with K bracing

From pushover analysis, displacement for constant base shear for different bracing system is shown below:

**Table 4.3. Variation of displacement for constant base shear for different bracing systems**

| Type of bracing system | Base Shear (kN) | Displacement (mm) |
|---|---|---|
| XB Bracing | 575 | 1.85 |
| XBX Bracing | 575 | 1.55 |
| K Bracing | 575 | 0.9 |
| *K-Add | 575 | 0.8 |

*Additional bracing with K bracing

The above table shows the variation of displacement of towers with different configurations for constant base shear. It is observed that tower having K bracing system with additional bracing system shows minimum displacement whereas XB bracing tower shows maximum displacement.

For comparison purpose the pushover curve has been converted to its equivalent bilinear form as shown below;

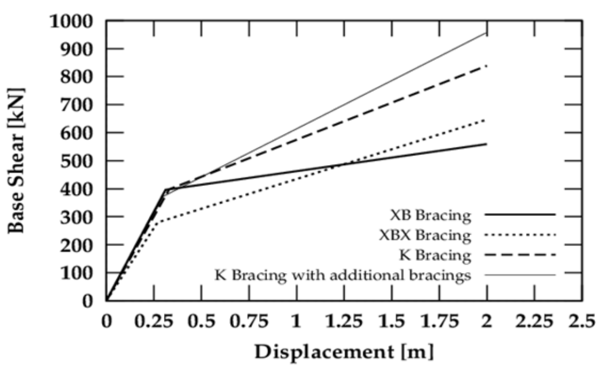



**Fig. 4.1 Comparison of bilineared nonlinear static pushover curves of different bracing systems**

## 5. CONCLUSION

The telecommunication tower is designed and checked under gravity loading and depending upon observations following conclusions are drawn;

- From linear analysis, the time period for tower with X-B-X bracing system is minimum and respective base shear is maximum over other towers with different bracing system.
- At yield point during pushover analysis the tower with K bracing (Model III) shows better results than other three models with XB, XBX and K bracing with additional bracing system.
- Considering 2 meters as ultimate displacement, tower having K bracing with additional bracing system perform better at ultimate point than other towers with additional bracing systems.
- Additional bracing system provided with K bracing system reduces the unsupported length of bracing members thus increasing buckling strength. Hence, at ultimate point, base shear for tower with K bracing with additional bracing system is 956.19 kN which is greater than any other tower configuration.
- Telecommunication tower with K bracing system with additional bracing system is better for the tower configuration considered in this study.

## 6. ACKNOWLEDGEMENTS

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