

# Reverse Engineering of Telecom Towers

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**Abstract**— The Indian Telecom industries have witnessed a tremendous growth in network services and data utilization from the last few years which have resulted in installation of large number of towers to increase the coverage area and network consistency. But the construction of new towers takes long time and needs huge initial capital investment. The time delay during construction of new towers and installation of new antennas causes a great interruption for customers in their network services. To avoid these congestions the existing towers should be utilized to their full capacities instead of constructing new towers. The geometrical details of the existing towers can be availed using the mapped data done by the tower climbers and this process of climbing the tower, measuring the dimensions of members and mapping that data is called Reverse Engineering.

In this present study, a case study of 3-Legged Triangular Ground Based Tower of elevation 280 ft (85.344m) has done and the tower is analyzed for the newly proposed and installed LTE antennas loads by removing the old GSM/CDMA antennas and checked whether the tower can safely carry the newly proposed loads or not. The analysis has been done using TIA-222-G standard and brief data regarding analysis and results obtained has mentioned below.

**Keywords**— Reverse Engineering, 3-Legged Steel Lattice Tower, Gust Effect Factor, Tele-Density, Tower mapping, Ground Based Triangular tower, Optimal Design

## INTRODUCTION

### *Reverse Engineering – The need of the hour in Telecom Industry:*

The Indian telecom industry has witnessed significant growth in subscriber base over the last decade, with increasing network coverage and a competition-induced decline in tariffs playing facilitators. The growth story and the potential have also served to attract newer players in the industry, with the result that the intensity of competition has kept increasing, forcing the Telecom Operators (TELCOs) to look for cost-cutting measures. One such measure has been the hive-off of telecom tower related operations into separate companies to allow for greater operating efficiencies and tower sharing. The attractiveness of the telecom tower industry, given the aggressive network rollout plans of the TELCOs, has led to the entry of several companies in the fray.

Telecom tower companies with a relatively large portfolio of towers offer certain clear advantages to Telcos, including rapid rollout over a large area, and tenancy driven discounts. Further, large tower companies can access capital markets better to fund growth. These advantages make it somewhat difficult for the smaller tower companies to grow; thereby paving the path for consolidation in the industry. The exponential growth in the telecom industry resulted in the huge demand for telecom carriers. As a result of this the telecom carriers are experiencing huge demand from customers to provide network coverage along with quality service. In order to meet this huge demand the telecom carriers have two options:

#### **A. To build the new Tower sites**

- i. To build a new cell site (GBT) it costs about 25 Lacs and for a new rooftop site it costs around 15 Lacs. This is a huge capital investment and please note that India has very least revenue per call rates, this is becoming a challenge for TELCOs as the Return-On-Investment (ROI) period becomes too long. Also the telecom carriers have issues with the funding. Because of these reasons the TELCOs do not want to spend huge capital expenditure for new cell sites unless it is inevitable.
- ii. New Site takes longer time to build & commission. Since Telecom is a fast paced industry any delay may cause huge loss in the revenue for the investors.

#### **B. To utilize the existing towers for its full capacity.**

There are thousands of towers which were built by the telecom carriers decades ago. That time these towers were built for stringent condition considering the future expansion. However these towers are not utilized to its full capacity which may be instant revenue generators for the TELCOs. However there are many challenges that the TELCOs face utilizing the existing tower. Many times the

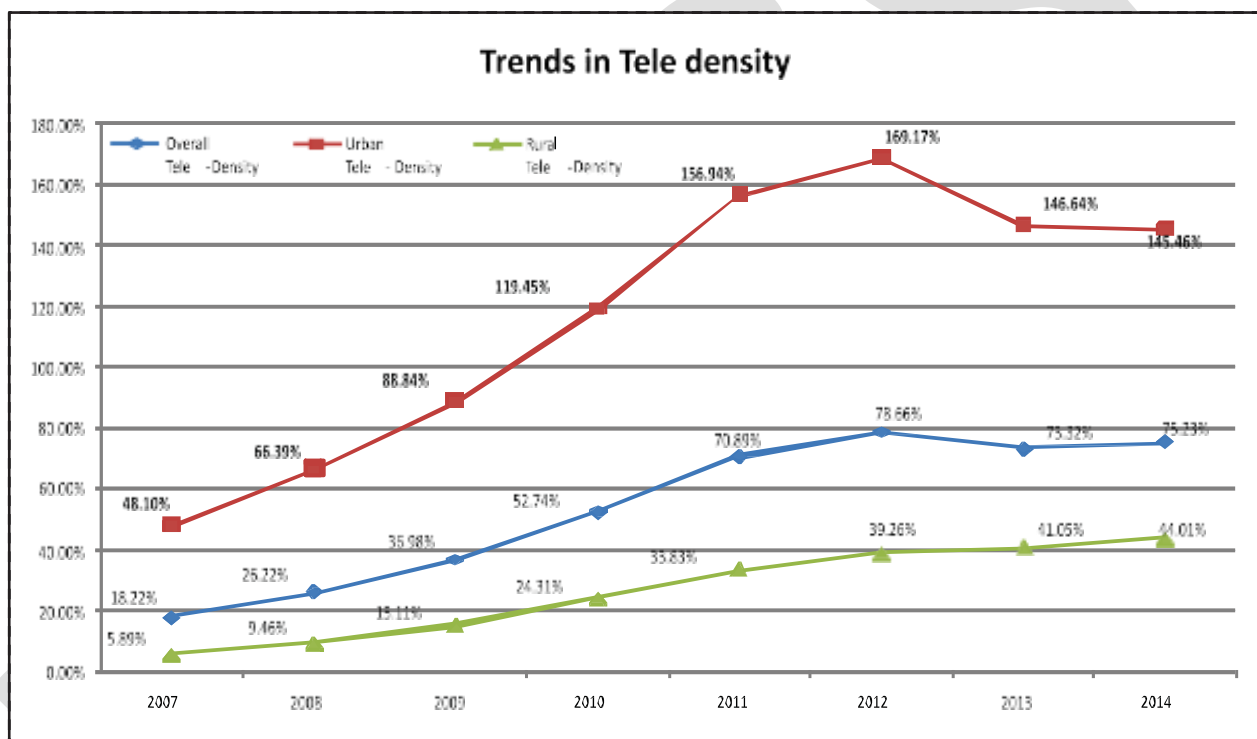
site information, structural drawings are unavailable. In such cases, the Reverse Engineering process has to be carried out in order to get the missing information, analyze the tower and check whether the tower can withstand the existing and additional loading.

## BACKGROUND

Communication has grown to be an essential infrastructure for socio-economic development in an increasingly knowledge intensive world. The reach of telecom services to all parts of the country is integral to development of an innovative and technologically driven society. Studies have shown that there is a positive correlation between the penetration of Internet and Mobile Services on the growth of GDP of a country. As a result of the measures taken by the Government over the years, the Indian Telecom Sector has grown exponentially and has become the second largest network in the world, next to China.

### Tele-density:

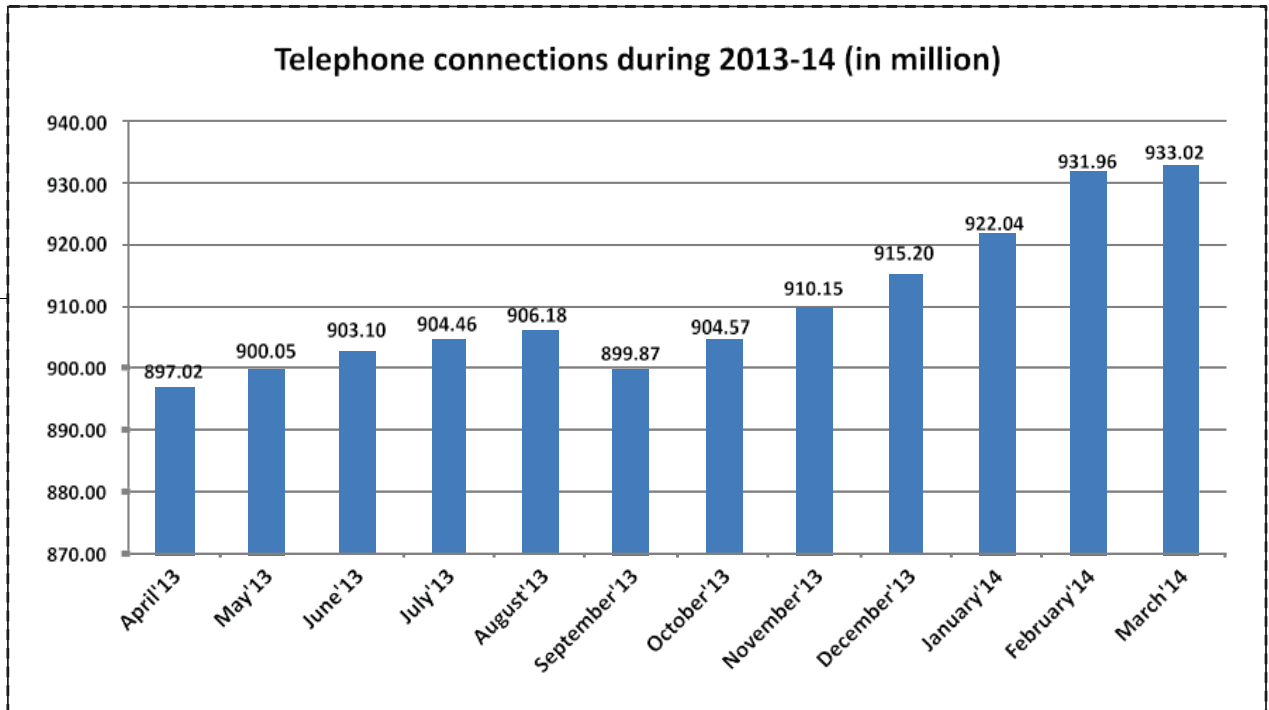
Tele-density, which denotes the number of telephones per 100 population, is an indicator of telecom penetration in the country. Tele-density in the country, which was 73.32% as on 1st April, 2013, increased to 75.23% at the end of March 2014. The rural Tele-density increased from 41.05% to 44.01% during this period urban Tele-density, however, registered a decline from 146.64% to 145.46% during this period. The chart below indicates the trend in Tele-density over the years.



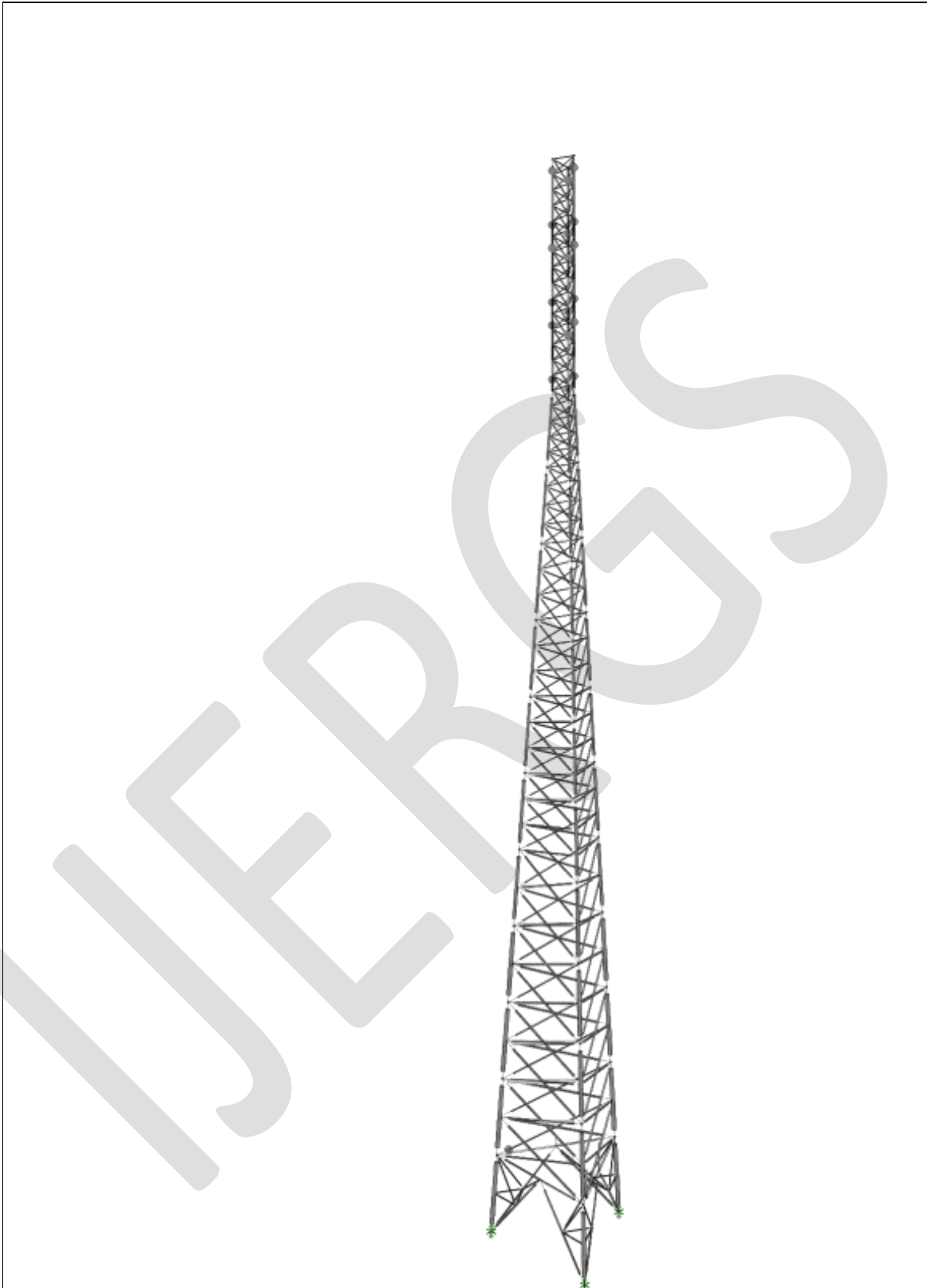
### Growth Indicators / Key Statistics:

Indian telecom network is the second largest in the world after China. Following are the recent growth indicators/statistics/trends

- **Tele-density:** Overall Tele-density in the country is 75.23%. Urban Tele-density is 145.46%, whereas rural Tele-density is 44.01%.
- **Telephony:** The country has 933.02 million telephone connections. The number of telephony connection increased from 898.02 million in the beginning of the financial year to 933.02 million at the end of March 2014.
- **Wireless Connections:** 904.52 million-96.95%.of the total Telephones
- **Fixed / Wireline Connections:** 28.5 million-3.05 %.of the total Telephones
- The share of private sector in total telephones is 87.13%.
- Number of Broadband connections is 60.87 million



#### MODELLING OF TOWER:-



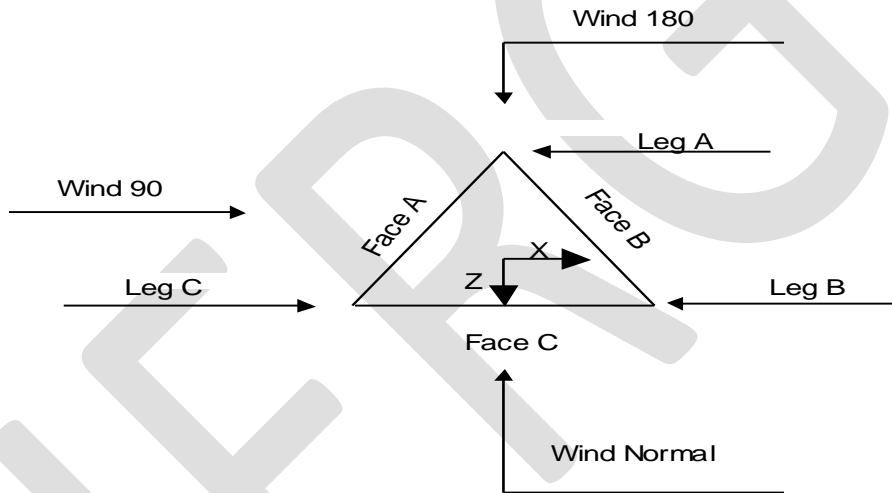
	RENDERED VIEW OF	DWG NO: 01
	280' SELF SUPORTING TOWER	REV NO: 00
		Mar 24, 2015 at 3:29PM

**ANALYSIS:-**

**Basic Tower Details:**

- Type of Tower- Simply Supported 3-Legged Triangular
- Location- Wyandotte County, Kansas, USA
- Elevation- 280 ft (85.344m)
- Face Width at top- 4.67 ft (1.423 m)
- Base width- 27.75 ft (8.458 m)
- Basic Wind Speed- 90 mph (40.23 m/s)
- Structure Class II.
- Exposure Category C
- Topographic Category 1

The Tower has 14 panels each having section height 20ft. The Wind load on each section is calculated separately using TIA-222-G standard and it is assumed to act at Centre of Gravity (CG) of that section. The Wind Load acting on CG is divided into nodal loads for analysis purpose to get force on each member.



**Triangular Tower**

**Tower Input Data**

<b>Tower Section</b>	<b>Tower Elevation (ft)</b>	<b>Section Width (ft)</b>	<b>Section Length (ft)</b>	<b>Diagonal Spacing (ft)</b>	<b>Bracing Type</b>
T1	280.00-260.00	4.67	20.00	4.00	X Brace
T2	260.00-240.00	4.67	20.00	4.00	X Brace

<b>Tower Section</b>	<b>Tower Elevation (ft)</b>	<b>Section Width (ft)</b>	<b>Section Length (ft)</b>	<b>Diagonal Spacing (ft)</b>	<b>Bracing Type</b>
T3	240.00-220.00	4.67	20.00	4.00	X Brace
T4	220.00-200.00	4.67	20.00	4.00	X Brace
T5	200.00-180.00	6.76	20.00	5.00	X Brace
T6	180.00-160.00	8.86	20.00	6.67	X Brace
T7	160.00-140.00	10.96	20.00	6.67	X Brace
T8	140.00-120.00	13.06	20.00	6.67	X Brace
T9	120.00-100.00	15.16	20.00	6.67	X Brace
T10	100.00-80.00	17.26	20.00	10.00	X Brace
T11	80.00-60.00	19.36	20.00	10.00	X Brace
T12	60.00-40.00	21.45	20.00	10.00	X Brace
T13	40.00-20.00	23.55	20.00	10.00	X Brace
T14	20.00-0.00	25.65	20.00	20.00	K1 Down

*Section capacity table*

<b>Section No.</b>	<b>Elevation (ft)</b>	<b>Component Type</b>	<b>Size (inch)</b>	<b>Developed stress P (K)</b>	<b>Allowable stress <math>\phi P_{allow}</math> (K)</b>	<b>% Capacity</b>	<b>Pass or Fail</b>
T1	280 - 260	Leg	P2x.154	-3.17	36.84	8.6	Pass
		Diagonal	L1 1/2x1 1/2x1/8	-0.55	5.51	10.1	Pass
		Top Girt	L1 1/2x1 1/2x1/8	-0.02	2.48	0.9	Pass
T2	260 - 240	Leg	P2x.154	-12.95	36.84	35.2	Pass
		Diagonal	L1 1/2x1 1/2x1/8	-1.38	5.51	25.1	Pass
T3	240 - 220	Leg	P2.5x.276	-56.06	83.25	67.3	Pass
		Diagonal	L1 1/2x1 1/2x1/8	-4.37	5.59	78.2	Pass

<b>Section No.</b>	<b>Elevation (ft)</b>	<b>Component Type</b>	<b>Size (inch)</b>	<b>Developed stress P (K)</b>	<b>Allowable stress <math>\phi P_{allow}</math> (K)</b>	<b>% Capacity</b>	<b>Pass or Fail</b>
T4	220 - 200	Leg	P3x.3	-81.80	119.06	68.7	Pass
		Diagonal	L1 1/2x1 1/2x1/8	-2.16	3.44	62.6	Pass
T5	200 - 180	Leg	P3.5x.318	-100.57	141.80	70.9	Pass
		Diagonal	L1 3/4x1 3/4x1/8	-2.50	3.27	76.6	Pass
T6	180 - 160	Leg	P4x.337	-118.00	159.90	73.8	Pass
		Diagonal	L2x2x3/16	-3.11	4.46	69.7	Pass
T7	160 - 140	Leg	P5x.375	-136.61	239.38	57.1	Pass
		Diagonal	L2 1/2x2 1/2x3/16	-3.60	6.85	52.6	Pass
T8	140 - 120	Leg	P5x.375	-155.88	239.38	65.1	Pass
		Diagonal	L3x3x3/16	-4.27	9.35	45.7	Pass
T9	120 - 100	Leg	P6x.432	-176.44	343.09	51.4	Pass
		Diagonal	L3x3x3/16	-4.87	7.53	64.7	Pass
T10	100 - 80	Leg	P6x.432	-195.67	303.73	64.4	Pass
		Diagonal	L3x3x1/4	-5.85	6.98	83.8	Pass
T11	80 - 60	Leg	P8x.322	-216.78	334.41	64.8	Pass
		Diagonal	L3 1/2x3 1/2x1/4	-6.53	9.67	67.5	Pass
T12	60 - 40	Leg	P8x.322	-238.75	334.41	71.4	Pass
		Diagonal	L4x4x3/8	-7.44	17.98	41.4	Pass
T13	40 - 20	Leg	P8x.5	-261.67	505.53	51.8	Pass
		Diagonal	L4x4x3/8	-8.16	15.48	52.7	Pass
T14	20 - 0	Leg	P8x.5	-267.96	505.53	53.0	Pass
		Diagonal	P2.5x.276	-13.46	20.37	66.1	Pass

<b>Section No.</b>	<b>Elevation (ft)</b>	<b>Component Type</b>	<b>Size (inch)</b>	<b>Developed stress P (K)</b>	<b>Allowable stress <math>\phi P_{allow}</math> (K)</b>	<b>% Capacity</b>	<b>Pass or Fail</b>
		Horizontal	P2.5x.203	-7.27	6.86	106.0	Fail <b>X</b>
		Redund.Horz 1 Bracing	P1.5x.145	-4.65	12.65	36.7	Pass
		Redund.Diag 1 Bracing	P1.5x.145	-4.21	4.09	102.8	Fail <b>X</b>
		Redund. Hip 1 Bracing	P1.5x.145	-0.03	11.59	0.3	Pass
		Redund. Hip Diagonal Bracing	P1.5x.145	-0.06	2.11	2.8	Pass
						<b>Summary</b>	
					Leg (T6)	73.8	Pass
					Diagonal (T10)	83.8	Pass
					<b>Horizontal (T14)</b>	<b>106.0</b>	<b>Fail X</b>
					Top Girt (T1)	0.9	Pass
					RedundHorz 1 Bracing (T14)	36.7	Pass
					<b>RedundDiag 1 Bracing (T14)</b>	<b>102.8</b>	<b>Fail X</b>
					Redund Hip 1 Bracing (T14)	0.3	Pass
					Redund Hip Diagonal Bracing (T14)	2.8	Pass
					<b>RATING =</b>	<b>106.0</b>	<b>Fail X</b>

**RESULTS:-**



From the above Section Capacity table, it is evident that the all the members of the tower are passing for the proposed LTE load and other loads, except two members i.e.

- T14-Horizontal member **Pipe P2.5x.203overstressed with 106.0%**
- T14-Redundant diagonal-1 bracing **Pipe P1.5x.145overstressed with 102.8%**

It is recommended to replace these members with the higher sections, in order to bring the stresses to the acceptable limit (below 100%). Since the overstress is marginal, we can increase the member thickness, without changing the overall diameter. As a result of this, there will not be any change on the tower loading as the exposed area remains the same. We just need to re-run the analysis / design in order to check the modified stress ratios of these members.

### **CASE STUDY I: OPTIMAL DESIGN OF LATTICE TOWERS MADE UP OF SOLID ROUND STEEL BARS <sup>[9]</sup>**

The rational design of lattice steel towers made up of solid round steel bars affected by the static load are discussed.

#### **Peterson, 1993**

A large portion of such construction works are towers of a low and medium height. Lattice towers are portable, can be installed on roofs of buildings. Those towers are used for telecommunication facilities and other construction purposes as well. The behaviour and calculations of typical steel towers structures are broadly analyzed in numerous studies.

#### **Smith, 2007**

The efficiency of lattice steel tower is determined by their relatively simpler construction, low production and assembling cost. Wind pressure is considered as the predominant loading on tower structures. Therefore, Chords and Bracing members in towers most often are of round cross section.

#### **Jasim, Galeb, 1998, 2002**

The designing practice often makes the use of so called multivariate analysis in order to reduce the mass of structures. The mass or volume of steel in tower structures is selected as main criterion of quality while solving optimization problem.

#### **Conclusions:**

The tower under consideration gives the calculation of optimal values of tower width and inclination of bracing members, considering the towers height, steel grade and wind load intensity.

Tower's optimal width varies between  $(1/17)H$  and  $(1/55)H$ . The increase in the towers height also causes an increase in values of tower's optimal width. Higher wind load intensity demands for the increased spacing between chords.

As strength of the Steel increases, optimal width of the tower decreases. The optimal inclination of bracing members in a tower of round solid bar is virtually independent of towers height and wind load intensity. Its average value is 35 degrees

### **CASE STUDY II: - INFLUENCE OF MODELING IN THE RESPONSE OF STEEL LATTICE MOBILE TOWER UNDER WIND LOADING <sup>[10]</sup>**

The tower under consideration in this case is Guyed Tower for radio antenna by finite element method in ANSYS using three different structural idealization of the model.

#### **Sullins Eric James**

Used ERI Tower software for wind and ice effects concluded that diagonal bracing tends to control the ability of the tower to withstand wind and ice loading.

#### **Wind Load and Analysis of Lattice Towers**

For assessing Dynamic Response of the towers, Indian code of standard and most of other countries worldwide recommends the use of GFM (Gust Factor Method) or GEFM (Gust Effectiveness Factor Method).

IS: 875 (Part 3) gives wind load on structure on a strip area  $A_e$  at a height  $z$  is,

$$F_z = C_f \times A_e \times P_z \times G$$

Where,  $C_f$  = Force co-efficient of the Structure

$A_e$  = Effective Frontal Area considered for the structure at height  $z$

$P_z$  = Design Pressure at height  $z$  due to hourly mean wind obtained as  $0.6v_z^2$

$G$  = Gust factor

Above notations are as per IS: 875 (Part3)

There are three models adopted in this study and are discussed below:

- a) Model-1 or Rigid Space Frame model in which members are considered as rigid jointed members.
- b) Model-2 or Space Truss Model in which members are considered to be hanged permitting in plane rotation.

- c) Model-3 or Combined or Hybrid models in which main leg members were rigid jointed and bracings are considered to be hinged.

**Result:**

Rigid frame model gives the least displacements exhibited by the truss model.

**Conclusions:**

The wind analysis results showed that irrespective of 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 lower order.

**CASE STUDY III: WIND ANALYSIS OF MICROWAVE ANTENNA TOWERS <sup>[11]</sup>**

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

The analysis of microwave antenna towers with Static and Gust Factor methods. The comparison is made between the towers with angle and square hollow sections. The displacement at the top of the tower is considered as the main parameter. The analysis is also done for different configuration by removing one member as present in the regular tower at lower panels.

**Gomathianayagam, S, June 2000**

Triangular towers attract lesser wind loads compared with square towers. But they are used only for smaller heights due to difficulties in joint detailing and fabrication using angle sections.

The use of tubular joints greatly improved the aesthetic qualities of the structural tube members provided a wide range of applications for a triangular cross section are used for truss members, the range of different standard shapes and sizes produced is much lesser than wide flange shapes and availability of some standard shapes is still limited.

**N. Prasad Rao, September 2001**

In order to reduce the unsupported length and to increase their buckling strength, the main legs and the bracing members are laterally supported at the 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 bracings with secondary bracings were commonly used in microwave towers.

For optimization of telecom towers, limiting the displacements and stresses to allowable limits optimizes the weight using different sections.

**J.D. Holmes, 1994**

The need to design a lattice tower considering resonant dynamic response to wind loads arises when their natural frequencies are low enough to be excited by the turbulence in the natural wind.

Abraham August 2005

The structural loads produced by wind gusts depend on size, natural frequency and damping of the structure in addition to the inherent wind turbulence. One of the approaches used for evaluating the dynamic response of lattice towers is the Gust Facto Method.

**Conclusions:**

The analysis of microwave antenna tower with different sections and configuration are done for wind loads. The following conclusions may be drawn from above analytical results. Square hollow sections can be used more effectively in leg members in comparison with the angle sections in regular tower under Static method and GFM. Square hollow sections used in bracings along with the leg members do not show much reduction of displacement compared to tower with square hollow sections used in leg members under Static method and GFM.

X and M bracing in square hollow sections for legs and bracings at the lower first panel shows a maximum reduction of displacement in the comparison with the tower with square hollow sections for legs and bracings in the lower second, lower first and second panel with different configuration in both static and GFM

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**CONCLUSION**

The modified stress ratios which are obtained after structural modifications are tabulated below:

Section	Existing Member	Over Stress Ratio	Modified Member	New Stress Ratio
T14-Horizontal	Pipe P2.5x.203 (Grade 50 ksi)	106%	Pipe P2.5x.276	84.3%
T14- Redundant diagonal-1	Pipe P1.5x.145 (Grade 36 ksi)	102.8%	Pipe P1.5x.20	81.5%

#### DISCUSSION:

The main aim of the paper is to introduce the new methodological approach for the optimum utilization of existing towers and to use the existing towers to their full capacities. This can be checked and achieved by removing and adding additional proposed loads (Updated Antennas, Feedlines, Climbing ladders etc). The experiences obtained by different researchers in their studies of analysis and design of towers have been approached by three case studies that have been indicated above. Based on the observations discussed in these case studies the authors would like to draw the following conclusions:

1. The tower under consideration gives the calculation of optimal values of tower width and inclination of bracing members, considering the towers height, steel grade and wind load intensity.
2. As strength of the Steel increases, optimal width of the tower decreases. The optimal inclination of bracing members in a tower of round solid bar is virtually independent of towers height and wind load intensity. Its average value is 35 degrees.
3. The wind analysis results showed that irrespective of tower height, modeling strategy does not significantly affect the displacement pattern, particularly maximum lateral displacement at the top of the tower.
4. Truss model, in general, reflects the lower bound on stresses, irrespective of height, due to dominance of the axial stresses.
5. The bending components normal to the plane of the element are of lower order
6. Square hollow sections used in bracings along with the leg members do not show much reduction of displacement compared to tower with square hollow sections used in leg members under Static method and GFM

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