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FINITE ELEMENT ANALYSIS OF MICRO WAVE TOWER WITH DIFFERENT SECTIONS

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ABSTRACT- The communication industries have seen a tremendous increase in last few years .The four legged self supporting towers are widely used in worldwide for the communication purposes. The study is done to describes the analysis and design of microwave tower of 60 meter height with different cross section (I, C, Hollow circular section) for seismic along with the wind effect. Validation of finite element model was done by performing two-bar truss analysis by finite element computation using ANSYS. This study intends to implement finite element analysis via mechanical APDL package of ANSYS to the structure that is subjected to wind and seismic load. The structure was modeled by using CATIA software. ANSYS result of tower structure with hollow circular section produces least displacement and shear stress than I and channel sections.

Keywords: [microwave Tower, CATIA, ANSYS APDL, static analysis, seismic analysis.]

1. INTRODUCTION

Steel towers are used for different purposes such as communication, radio transmission, air traffic controls, satellite receptions, oil drilling masts, television transmission, power transmission, flood light stands, meteorological measurements, etc. The microwave towers, which are space structures in steel, carry mainly communication antennae. These towers are mostly square in plan, made of standard steel sections and connected together by means of bolts and nuts. The towers are designed and constructed indifferent shapes, types, sizes configurations and materials. The heights of tower are fixed by the user and structural designer has the task of designing the general configuration and joint details.

This paper discusses microwave tower with different sections. In most studies the researches have considered the effect of wind only on the four legged self-supporting towers. In this dissertation, studies have been carried out on models with different section for seismic along with the wind effect. The wind effect on the structure is studied by using the wind speed and the seismic effect on the structure is studied by carrying out the modal analysis and response spectrum analysis. The slender structures are commonly used for tower. Investigations carried out to analyze towers with different sections and different loading have been presented. The towers have been analyzed for wind loads and seismic load with ANSYS, 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. The results have been used to identify the techno - economical section for 60 m height of towers.

Konno and Kimura [10] presented the effects of earthquake loads on lattice telecommunication towers atop buildings and obtained the mode shapes, the natural frequencies, and the damping properties of such structures. Simulation of a stick model of the tower using lumped masses and a viscous damping ratio of 1% was used in their studies and observed that in some of the members, the forces due to earthquake were greater than those due to wind.

Schmidt et al., [14] demonstrated the results of an optimization conducted on the deep wind concept, considering rotor design. Optimized blade profile having a low weight and high stiffness is obtained according to the design evaluations based on the standstill calculations in ANSYS software. a constant or uniform blade section is considered throughout the rotor. The displacement fields of the rotor from the standstill simulations for a blade thickness of 18%, 21% and 25%. It is demonstrated that significant weight and load reductions on the rotor are achieved on a rotor with stall control and pultruded grp blades.

Yoshii et al., [12] experimentally and analytically studied the failure mechanism of the conventional tower foundation, pointed out the significance of the occurrence and propagation of splitting cracks while the steel legs were pulled out, and developed a.Design formula defining the pull-out capacity. By contrast, a design method for single-pole towers is still required.

The literature review has suggested that use of a finite element modelling of steel structure is indeed feasible. A number of researches in the field of transmission tower with different heights and bracings have been performed. The finite element analysis was mainly carried out using ANSYS and STAD PRO software's. So it has been decided to use ANSYS APDL in finite element analysis for the steel tower structures.The towers have been analyzed for wind loads with ANSYS to compare the maximum joint displacement of each tower.

A number of researches in the field of transmission tower with different heights and bracings have been performed. The finite element analysis was mainly carried out using ANSYS and STAD PRO software's. So it has been decided to use ANSYS APDL in finite element analysis for the steel tower structures.

The objectives of the current study are To study the effect of wind and earthquake load for different sections of the tower structures. Static method for wind loading, modal analysis and response spectrum analysis for earthquake loading have been considered.

To asses most effective section using tower structure.

Tower cost estimation for different cases. To asses techno-economic analysis of tower structure.

2. FINITE ELEMENT MODEL VALIDATION

Finite element model for the study must be validated analytically prior to further finite element analysis. Chan and Fong presented the experimental and analytical investigations on bare and composite rectangular hollow sections (RHS) used as members of trusses. One truss was composed of square hollow section (RHS) and square hollow section (SHS) steel tubes in all members and another truss was composed of concrete-filled RHS and SHS steel tube as compression members and SHS bare steel tube used as tension member.

Consider Three-dimensional truss consisted of 19 members who included two 50×30×3 RHS tubes and seventeen 60×60×3 SHS tubes. The member properties are as shown in table. The two bars or element are positioned 45^{o} with respect to the fixed base at the left side .The two bar truss was analyzed by ANSYS software. The average width, depth and thickness of both sections are listed in Table I.

Items	values	
Steel Sections	50×30×3	60×60×3
		60.53
Breadth (mm)	30.08	60.53
Depth (mm)	2.96	3.25
Yield Stress (*fy*) N/mm^2	399.17	376.12
Ultimate Tensile Stress(*fu*) N/mm^2	448.30	439.91
Young's modulus (*Es*) kN/mm^2	203.87	217.50

TABLE 1- MATERIAL PROPERTIES

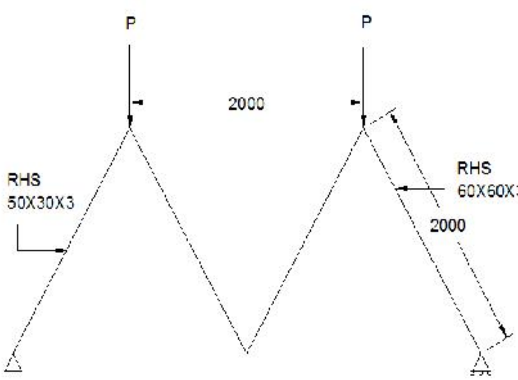

Figure 1- The dimension of the trusses in mm

The dimension of the trusses shown in figure 1. Under static analysis the numerical model was computed to validate to compute the experimental result. The finite element results are compared with exact solution.

The experimental flexural buckling about the principal minor axis of the failure member took place and shown in Figure 2. Maximum applied force is 74.4 kN.

Figure 2 - The failure shape of steel member truss [13]

A. VALIDATED RESULT

The maximum applied load on the steel truss by Static analysis through ANSYS APDL software is 64 kN The information regarding the finite element modeling and finite element analysis of the specimens were explained in this chapter. ANSYS numerical Finite element result produced accurate value of the exact result with 14% of error.

3. MODELLING AND LOADING

In this study, a 60 m height tower of square in plan is considered which is having a base width of 8.297m and reduces to 1.468 m at the top. The analysis has been done for the following sections in regular tower structure for the entire tower as shown in figure 3 and 4.

A tower with leg and bracing members as I sections (LI & BI).

A tower with leg and bracing members as C sections (LC & BC).

A tower with leg and bracing members as hollow circular sections (LHC& BHC).

A tower with leg as hollow circular and bracing as channel sections (LHC & BC).

A. GEOMETRY OF TOWER

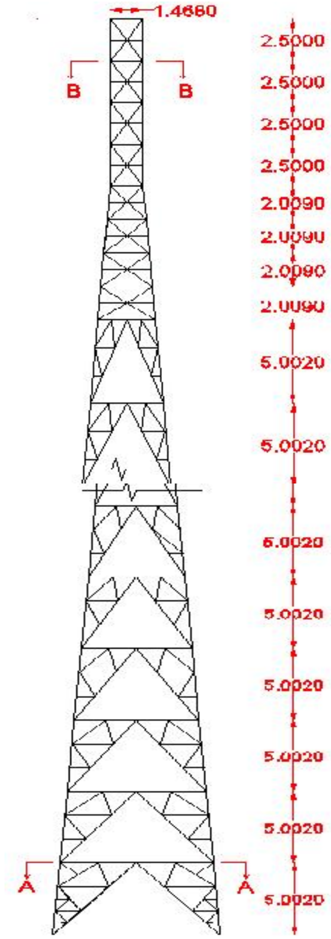

Figure 3- Front view of microwave tower.

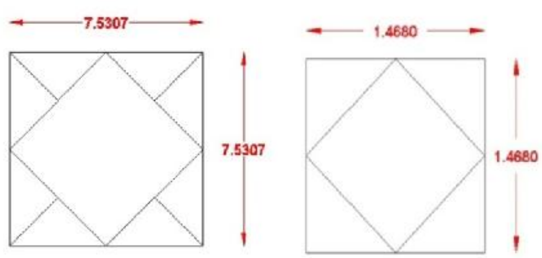

Figure 4 - Sections AA and Section BB.

For the present analysis, the members of the tower are modeled by using beam 188 element. All details of the microwave tower structure are.

Height of tower	= 60 m
Base width	= 8.297 m
Top width	= 1.468 m
Number of panel	= 16
Number of joints	= 64
Bracings	= K and X bracings

4. STATIC ANALYSIS OF MW TOWER

This work aimed to study the static and dynamic analysis of a microwave tower structure with different cross section. This work is divided into two distinct phases. In a first step carried out linear static analysis of the tower.

A. MATERIAL PROPERTIES

The SS-308 contains low carbon to avert carbide precipitation during welding as well as weld service. Chemical compositions are summarized in table 7.1.

Young's Modulus	=1.93E+05MPa
Yield Strength	= 240 Mpa
Poisson's ratio	= 0.3
Density	= 8000 kg/m^3
Allowable Strength	= 144 Mpa

B. LOADING

The towers used in this study are assumed as rigidly connected at the base and all degrees of freedom at the bottom nodes are restrained. For the calculation of wind loads by static method the following parameters were considered as per IS: 875 (part 3)1987.wind speed 55m/s, risk coefficient(k_1),terrain, height and structure size factor (k_2)category 1 and class a (assumed), topography factor (k_3)1.36 (assumed). The design wind speed (Vz) is obtained by multiplying the basic wind speed (Vb) by the factors k_1, k_2 and k_3.

The basic wind speed (Vb) = 27.7778 m/s that is 100 Km/hr.

The design wind speed (Vz) $= Vb \times k1 \times k2 \times k3$.

k_1 =1
k_2 =1.4
k_3 =1.36
Vz =27.7778 × 1 × 1.4 × 1.36
= 52.8889 m/s
The Design wind pressure $Pz = 0.6\ Vz^2$
= 0.6 ×52.8889^2
=1678.341 N/m^2
Wind load, F = $CF \times Pz \times A$
CF, pressure coefficient = 1.2
A, surface area = 222.475 mm^2
F = 448066.8 N
Antenna load = 100 kg.
= 980.66 N. For 8 th panel from top.
= 150 kg.
= 1470.995 N for 5 th panel from top.

Items	I	C	Hollow circular
Size	150×75 ×6	150×75 ×6	152.4 mm outer dia 138 mm inner dia
Area	1728 mm^2	1728 mm^2	3281.79 mm^2
Izz	42.43×10^4 mm^4	93.76×10^4 mm^4	0.866×10^7 mm^4
Iyy	0.598×10^7 mm^4	0.598×10^7 mm^4	0.866×10^7 mm^4

TABLE 2-DETAILS OF TOWER

C. LOAD CASES

Determining reaction force and reaction moments of mw tower structure for given load cases using FEA.

- Dead load
- Dead load + Wind load
- Dead load +Seismic effect

The analysis has been done for the MW tower with I, C, hollow circular section. The material properties are shown in table II.

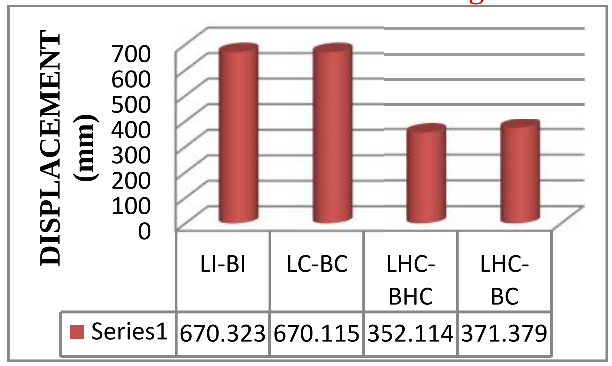

Figure 5- Displacement for different section

Figure 5 and 6 are the graph showing displacement v/s different sections and shear stress v/s different sections respectively. From graph the tower with LHC& BHC shows maximum reduction of displacement and shear stress in comparison with LI & BI, LC& BC and LA-BA.

The green bar in graph shows the regular tower with hollow circular section, which is taken for the comparison.

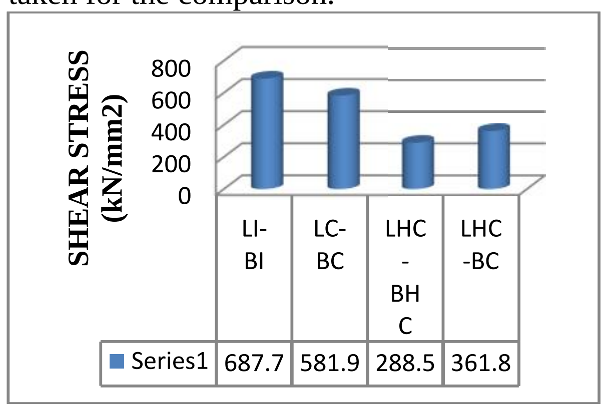

Figure 6- Shear stress for different section

5. SEISMIC ANALYSIS OF TOWER

A. Modal Analysis

Modal analysis is the study of the dynamic properties of structures under vibrational excitation. Any physical system can vibrate. The frequencies at which vibration naturally occurs, and the modal shapes which the vibrating system assumes are properties of the system, and can be determined analytically using modal analysis. Detailed modal analysis determines the fundamental vibration mode shapes and corresponding frequencies. This can be relatively simple for basic components of a simple system, and extremely complicated when qualifying a complex mechanical device or a complicated structure exposed to periodic wind loading. These systems require accurate determination of natural frequencies and mode shapes using techniques such as finite element analysis.

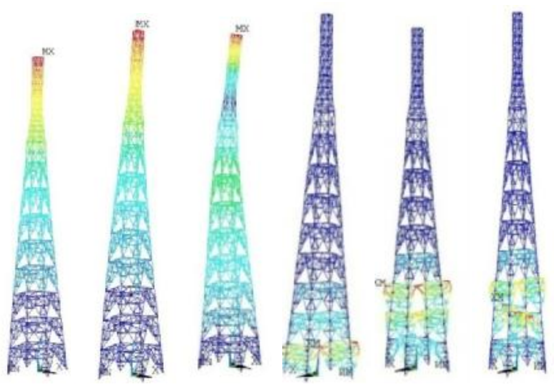

Figure 7- Mode shapes for LI-BI

Figure 7 illustrated the first six vibration modes of the structural model for leg and bracing as I section. Graphs are plotted between displacement at the top of tower and tower section for LI-BI,LC-BC,LHC-BHC and LHC-BC are shown in Fig.8,9,10 and 11 respectively.

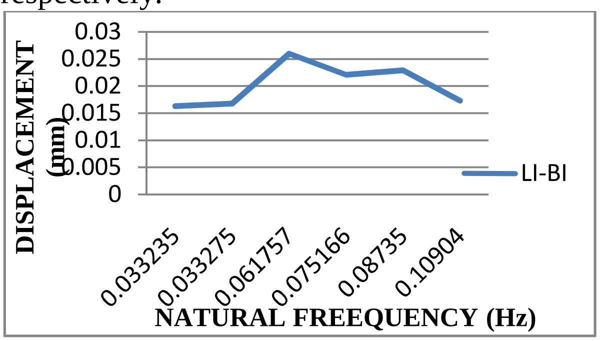

Figure 8- Natural frequency Displacement graph for LI-BI

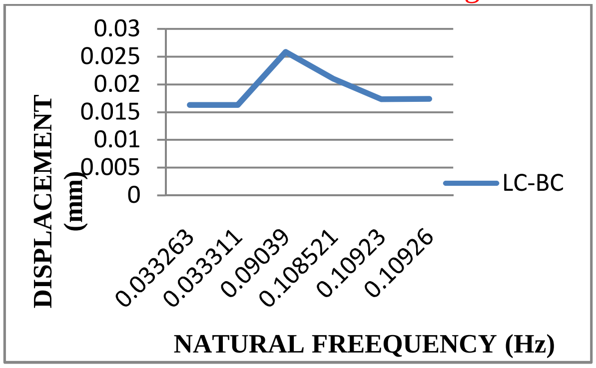

Figure 9- Natural frequency Displacement graph for LC-BC

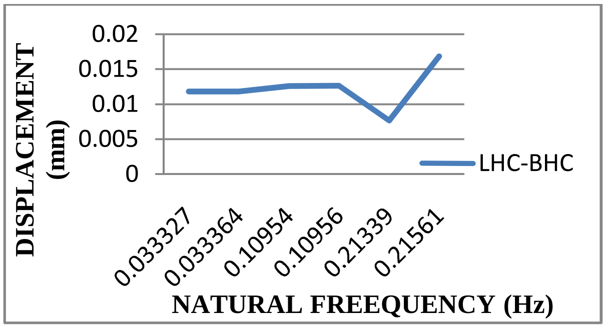

Figure 10- Natural frequency Displacement graph for LHC-BHC

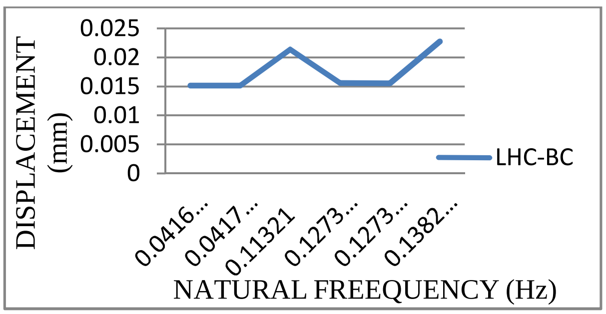

Figure 11- Natural frequency Displacement graph for LHC-BC

The Circular hollow sections used in tower shows a maximum reduction of displacement in comparison with channel and I section. Figure illustrates the regular tower with LHC & BHC shows maximum reduction of displacement in comparison with LC& BC, LI& BI and LHC-BC. However, there is no much reduction of displacement between the tower with LC& BC and LI& BI.

The leg member as hollow circular and bracing as channel section used in tower shows a maximum reduction of displacement in comparison with channel and I section. But the value greater than hollow circular section. This is due to; the moment of inertia of circular hollow section is larger than angle section.

B. RESPONSE SPECTRUM ANALYSIS

Earthquake is the natural calamity known to mankind from many years, from the ancient time researches' researched many ways to protect the structures. There was a need to control the damage caused by earthquake to the structures. In order to perform the seismic analysis and design of a structure to be built at a particular location, the actual time history record is required. However, it is not possible to have such records at each and every location. Further, the seismic analysis of structures cannot be carried out simply based on the peak value of the ground acceleration as the response of the structure depend upon the frequency content of ground motion and its own dynamic properties. To overcome the above difficulties, earthquake response spectrum is the most popular tool in the seismic analysis of structures. There are computational advantages in using the response spectrum method of seismic analysis for prediction of displacements and member forces in structural systems.

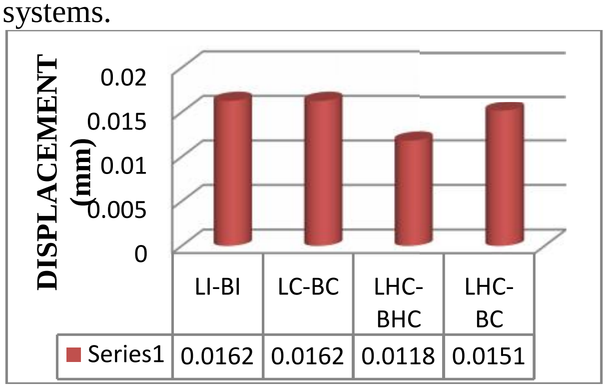

Figure 12- Displacement for different sections

The figure 12 shows the deformation of different sections in response spectrum analysis. I section shows maximum displacement and hollow circular section has minimum deformation.

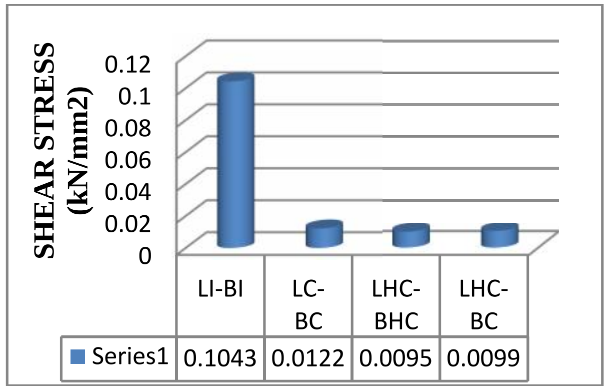

Figure 13- Shear stress for different sections

I section shows 0.0228 mm and hollow circular section has 0.0118 mm .C and leg section hollow circular with bracing C section shows approximately equal deformation the values are 0.016275 mm and 0.01518 mm respectively. Similarly the shear stress is maximum in I section and minimum in hollow circular section that is 0.104304 kN/mm^2 and 0.009512 kN/mm^2 respectively. Variation is almost similar in hollow circular and combined hollow circular and channel section that is 0.009512 $kNmm^2$ and 0.009946 kN/mm^2.Common channel section provided tower shows 0.01222 kN/mm^2 stresses are shown in figure 13. In both cases the most effective section is hollow circular section.

6. RESULTS AND DISCUSSION

The finite element numerical method proved to be quite useful and accurate in the process of assessing the structural analysis of the tower wind study.

Outcome of the static analysis on 60 m MW tower design 1, 2, 3and 4, the values of maximum displacement of the top of the structure as well as the maximum stress are tabulated in table .It is observed that the

Sections	Size	Length	Weight (kg/m)	Total weight tonne	Cost
I	150×75×6	3763	14	52.68	2528640
C	150×75×6	3763	14	52.68	2528640
LHC	152.4	3763	26	97.84	5044000
LHC-BC	150×75×6 152.4	233 3530	26 14	55.478	2687176

TABLE 3- DETAILS OF WEIGHT AND COST FOR DIFFERENT SECTIONS

highest stress among the design is 687.753 N/mm^2.for Tower structure with I section which having highest displacement 670.323 mm. It is obvious here that higher maximum stress contributes to higher deflection in our case of fixed mounted tower.

Outcome of the modal analysis on microwave tower structure are shown in table and the values of maximum displacement with frequency are plotted in graph below It is observed that the highest displacement among the different modes of different section.

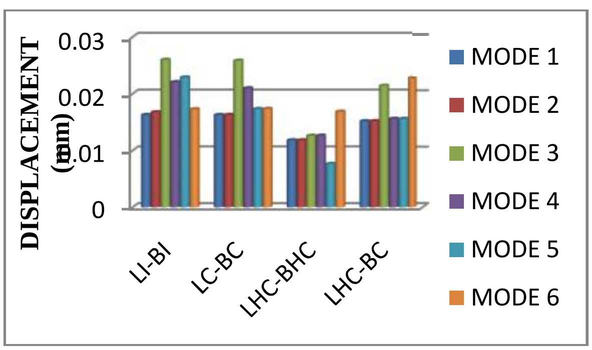

Figure 14- Mode –Displacements graph for different sections

From the figure 14, LHC-BHC displayed the least natural frequency than the other common sections since its stiffness was found to be higher due to more weight of the structure as compared to I and channel section

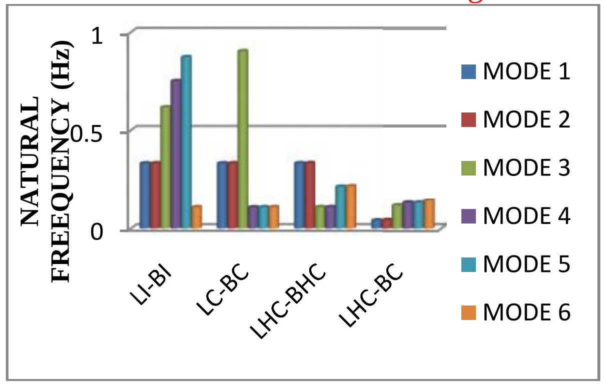

Figure 15- Mode –natural frequency graph for different sections

From figure 15 Circular hollow sections are perhaps the most efficient as they have equal values of radius of gyration about every axis. But connecting them is difficult but satisfactory methods have been evolved in recent years for their use in tall structures. Single channels or C-sections and I section are generally not satisfactory for use in compression, because of the low value of radius of gyration in the weak direction. They can be used if they could be supported in a suitable way in the weak direction. In both case of analysis shows I section has maximum value and Hollow section has minimum value of deformation and shear stress. In this present study gives hollow sections are most effective than other sections

7. TOWER COST ESTIMATION FOR DIFFERENT SECTION

The comparison of cost with respect to the section is given in table III.The cost of mild steel (240 Mpa) is Rupees 52/- per kg for hollow section and 48/- per kg for other sections. Thease rates of mild steel have been arrived based on present market rates and may change from time to time due to market fluctuation. Hollow circular section has maximum weight and cost among other sections that is 97.84 tonne and 5044000 /- respectively. The cost of LHC-BC approximately equal to C section.

The weight obtained from all four type of tower configuration with respect to the sections is plotted against each other in figure 16.

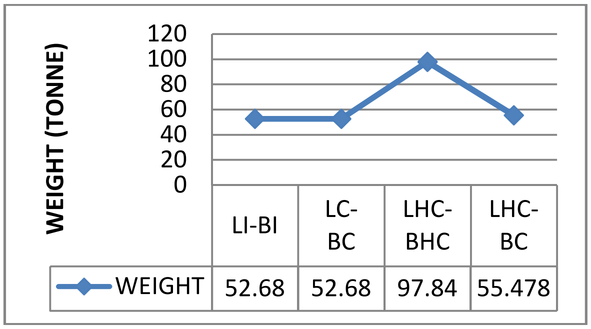

Figure 16- Weight -sections graph

One can observe that the least weight of tower is obtained for the first and second case of tower that is I and channel section with size 150×75×6. Finally to arrive at a conclusion regarding which case is economical for particular weight of tower and by using a particular section. LHC-BC case of tower structure is most effective in both safety and economic than other case like LI-BI, LC-BC and LHC –BHC

CONCLUSION

In this thesis, analytical studies have been presented to find the most effective structure of steel microwave tower with I, C, hollow circular and leg as hollow circular and bracing as channel section .The joint displacement and shear forces are obtained from the ANSYS are analyzed to find out the most effective section .The following conclusions are obtained from the analytical result.

The circular hollow sections used in tower shows a maximum reduction of displacement in comparison with channel and I section.

Hollow circular section can be use more effectively in leg and bracing member in comparison with the I, Channel and Hollow circular section in regular tower under static and seismic analysis.

In the case of fixed mounted tower, higher maximum stress contributes to higher deflection.

It can be concluded that the wind is the predominant factor in the tower modeling than the seismic forces but the seismic effect cannot be fully neglected.

The frequency of the tower with hollow circular section have the least natural frequency since its stiffness is higher as the weight of the structure is more as compared to other sections.

For leg as hollow circular and bracings as channel section is most effective in both safety and economical analysis of microwave tower structure.

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