Abstract - The primary objective of this project is to analyze the towers with different heights and different bracing configurations to show the optimal solution. Hence, this research project is aimed to suggest the efficient bracing system for a lateral load on towers using STAAD analysis. The research work will be limited to the analysis of steel towers only. It is found from the existing literature that considerable work has been carried out on static and dynamic response of towers, strengthening and upgrading of existing towers and optimization of towers. But to the Author’s knowledge, no work appears to have been reported on the economical bracing suitable for a particular type of tower.

Keywords: Lateral bracing, lateral load, bracings, Earthquake load

I. INTRODUCTION

Many industries and communications demand towers for variety of purposes. Steel towers are normally used for the following:

1. Microwave transmission for communication
2. Radio transmissions
3. Television transmission
4. Satellite receptions
5. Air traffic controls
6. Flood light stands in stadiums and at large flyover intersections
7. Power transmission lines
8. Meteorological measurements
9. Derrick and crawler cranes
10. Oil drilling masts
11. Overhead water tanks

The height of towers varies from 20 m to 500 m for various purposes

- 100 to 400 m for television
- 50 to 200 m for radio transmission and communication network
- 15 to 50 m for flood lights
- 10 to 45 m for power transmission.

The height of the tower is fixed by the user and the structural engineer has the task of designing the general configuration of the member and joint details. Towers are configured as free standing towers or Guyed towers. Free standing towers are generally preferred since they require less base area.

The towers are invariably analyzed as trusses with the loads applied at the joints and the members are designed either as ties or as struts. The tower is subjected to gravity loads as well as horizontal loads. In order to strengthen the towers against the lateral forces and to control the sway, the towers are invariably braced vertically. There are many types of bracing systems in common use such as X-bracings, XB- bracings, K- bracings, Y- bracings, W- bracings, Arch bracings, etc. Towers are usually provided with one type of bracing or other. There appears to be no published work to identify the economical bracing. There is therefore a need to identify the economical bracing system for a given tower i.e. given range of tower heights such as television tower, power transmission tower, flood light tower, etc.
II. LITERATURE REVIEW

National and International Status:

Venkateswarlu, B., e-tal (1994) have computed the dynamic response of wind sensitive structures subjected to a random wind force using stochastic analysis. They have presented a spectral approach for computation of the along-wind response and the gust response factor of microwave lattice towers by developing a computer program. They have compared the gust response factor computed for a microwave lattice tower of 101 m height by this method with the values calculated using the formulae recommended in the Indian, the Australian, the British and the ASCE Standards.

Visweswara Rao (1995) presented a method for the development of optimized tower design for transmission line tower. He has carried out the optimization with reference to both tower weight and geometry by developing a computer program using fuzzy logic.

Harikrishna e-tal (1999) has carried out the design of dynamically sensitive steel lattice towers against wind loads using a gust response factor (GRF) approach. Most of the international codes for wind loads recommend the GRF which is evaluated using a semi analytical approach considering the modal co-ordinate alone. However, British standards and Australian standards for steel lattice towers recommend different GRFs for the design of main leg members and main bracings, and for serviceability criteria. A full-scale field experiment on a 52 m tall steel lattice tower has been carried out to measure wind characteristics and structural response. They have evaluated the GRF for base bending moment and top deflection using the measured structural response and compared with those obtained from the IS, AS and BS codes.

Gomathinayagam,S., e-tal (2000) have studied the effect of antenna loads on steel lattice towers, developing a method to compute antenna loads for Indian wind climatology.

Albermani e-tal (2004) have carried out analytical and experimental studies of a tower sub-structure assembly that was strengthened with a variety of diaphragm bracings under two types of loading. They have concluded that the analytical and experimental results agreed reasonably well and showed that simple diaphragm bracing systems can be very effectively used in the upgrading of older transmission towers. They have implemented successfully an upgrading scheme using diaphragm bracings on an existing 105 m high TV tower.

Ghodrati Amiri,G., and Massah,S.R.. (2007) have investigated the seismic sensitivity of 4-legged telecommunication towers based on modal superposition analysis. For this purpose, ten of the existing 4-legged self-supporting telecommunication towers in Iran were studied under the effects of wind and earthquake loadings. A number of empirical relations have been presented that can help designers to approximate the dynamic response of towers under seismic loadings.

Banik,S.S. e-tal (2010) have introduced a capacity curve for transmission line tower considering inelastic behaviour under wind loads. However, they have acknowledged that the results presented by them might not be considered definitive since the actual probabilistic characterizations of the high intensity tornado and downburst winds are not entirely clear in the wind engineering community.

Prasad Rao,N., e tal (2010) have presented different types of premature failures observed during full-scale testing of Transmission line towers at Tower Testing and Research Station, Structural Engineering Research Centre, Chennai. They have studied the failures observed during testing and discussed the reasons in detail. Non-linear finite element analysis is useful in understanding the system behavior and for prediction of failure pattern and ultimate load. Based on the test results the importance of studying the failures is highlighted. The need for testing of transmission line towers is emphasized

III. METHODOLOGY

To start with a tower with X-Bracing system will be analyzed as a 3D Truss system for wind loading and seismic loading as per Indian conditions. The total weight and the drift will be noted. The next step is to analyze the same tower with different bracings one after the other. The weights and the drifts will be noted. Analyzing the above, the economical bracing system for the above specified tower will be demarcated.
IV. BRACING TYPES

For the steel towers normally we use 5 types of bracings namely XX, XB, K, W and Y bracing types. Here we have analyzed all the five types of bracing for lateral loads like wind load and Earth quake loadings.

<table>
<thead>
<tr>
<th>XX-Bracing</th>
<th>XB-Bracing</th>
<th>K-Bracing</th>
<th>W-Bracing</th>
<th>Y-Bracing</th>
</tr>
</thead>
</table>

Fig.1. The diagram shows the models with various types of bracing in 56m height towers.

Fig.2. The diagram shows the models with various types of bracing in 30m height towers.
V. LOADING

The loadings and load combinations here we used according to the Indian standard codes 1893-2002 for earth quake and 875 Part I, II and III – 1987.

Dead load according to IS 875 (Part I) -1987
Live load according to IS 875 (Part 2) – 1987
Wind load (According to IS 875 (part 3) – 1987)

In order to determine the wind load on tower, the tower is divided into different panels having a height ‘h’. These panels should normally be taken between the intersections of the legs and bracings.

For a lattice tower of square cross section, the resultant wind load Found in Newtons, for wind normal to the longitudinal face of tower,

\[
V = V_b k_l k_2 k_3
\]

\(V_b\) = design wind speed at any height \(z\) in m/s;
\(k_l\) = probability factor (risk coefficient) \(-1\)
\(k_2\) = terrain, height and structure size factor

Wind speed for the proposed area was 44m/s

<table>
<thead>
<tr>
<th>Height</th>
<th>(k_2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>1.05</td>
</tr>
<tr>
<td>15</td>
<td>1.09</td>
</tr>
<tr>
<td>20</td>
<td>1.12</td>
</tr>
<tr>
<td>30</td>
<td>1.15</td>
</tr>
<tr>
<td>50</td>
<td>1.20</td>
</tr>
<tr>
<td>100</td>
<td>1.26</td>
</tr>
</tbody>
</table>

\(k_3\) = topography factor \(-1\)

Pressure calculation, \(P = 0.6 Vz^2\)

\[
\begin{align*}
P_{10} &= 0.6 \times (44 \times 1 \times 1.05 \times 1) \times 2 = 1280.66 \text{ N/m}^2 \\
P_{15} &= 0.6 \times (44 \times 1.09 \times 1 \times 1) \times 2 = 1380.09 \text{ N/m}^2 \\
P_{20} &= 0.6 \times (44 \times 1 \times 1.12 \times 1) \times 2 = 1457.11 \text{ N/m}^2 \\
P_{30} &= 0.6 \times (44 \times 1 \times 1.15 \times 1) \times 2 = 1536.22 \text{ N/m}^2 \\
P_{50} &= 0.6 \times (44 \times 1 \times 1.20 \times 1) \times 2 = 1672.70 \text{ N/m}^2 \\
P_{56} &= 0.6 \times (44 \times 1 \times 1.26 \times 1) \times 2 = 1844.16 \text{ N/m}^2
\end{align*}
\]
VI. SEISMIC LOAD (ACCORDING TO IS 1893-2002)

As transmission line towers are comparatively light structures and also that the maximum wind pressure is the chief criterion for the design, the Sectional Committee felt that concurrence of earthquake and maximum wind pressure is unlikely to take place. However in earthquake prone areas the design of towers/foundations shall be checked for earthquake forces corresponding to nil wind and minimum temperature in accordance with IS 1893 : 1984 ‘Criteria for earthquake resistant design of structures.

Seismic parameters
City - Coimbatore
Zone - III
Response reduction factor (RF) - Steel frame with concentric braces
Importance factor (I) - All general building
Rock and soil site factor (SS) - Medium soil
Type of structure - Steel frame building
Damping ratio (DM) - 2% (P.No:25/ IS1893-2002)
VII. LOAD COMBINATION (ACCORDING TO IS 1893-2002)

1. 1.7DL + 1.7LL
2. 1.7DL+1.7WLx
3. 1.7DL-1.7WLx
4. 1.7DL+1.7WLz
5. 1.7DL – 1.7WLz
6. 1.7DL + 1.7EQx
7. 1.7DL – 1.7EQx
8. 1.7DL + 1.7EQz
9. 1.7DL – 1.7EQz
10. 1.3DL+1.3LL+1.3WLx
11. 1.3DL+1.3LL-1.3WLx
12. 1.3DL+1.3LL+1.3WLz
13. 1.3DL+1.3LL-1.3WLz
14. 1.3DL+1.3LL+1.3EQx
15. 1.3DL+1.3LL-1.3EQx
16. 1.3DL+1.3LL+1.3EQz
17. 1.3DL+1.3LL-1.3EQz

VIII. ANALYSIS

Analysis was carried out using the software STAAD Pro 2007 version. For analysis we choose 56m and 30 m height towers with bracings. First modeling the structure with various types of bracings and applied the loading. Dead load as self weight and live load as member load Wind load calculated according to IS codes with an wind speed of 44m/s and applied as intensity for various heights. Seismic loading is applied to the model.

After applying the loads, combinations were checked according to the codes. The analysis was performed for Load data, Static check, code check and optimization of the provided section.
Total weight of steel used in different types of bracings in kN
The results were shown below for example:
Staad pro code checking (IS-800)

**Table 1: Total weight in kN**

<table>
<thead>
<tr>
<th>Type of bracing</th>
<th>Y</th>
<th>W</th>
<th>K</th>
<th>XB</th>
<th>XX</th>
</tr>
</thead>
<tbody>
<tr>
<td>56M</td>
<td>207.714</td>
<td>141.77</td>
<td>50.14</td>
<td>98.876</td>
<td>99.258</td>
</tr>
<tr>
<td>30M</td>
<td>18.862</td>
<td>38.928</td>
<td>18.699</td>
<td>21.471</td>
<td>43.787</td>
</tr>
</tbody>
</table>
X. CONCLUSION

According to our analysis result the K type bracing is seems to be the optimized bracing for lateral loads on steel towers. Results shown above will confirm that the total weight or material consumption for K type bracing is less compared with other types of bracings.

REFERENCES

10. Effective bracing of trussed towers against secondary moments, F. Al-Masharyl, A. Arafahl and G. H. Siddiqi