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Along Wind Response of Communication Tower

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Abstract—*Communication towers are the slender structures used to support antennas. Analysis and design of these dynamically sensitive structures is generally governed by wind loads. Wind forces on these structures are calculated by gust factor method according to international codes and standards. In this paper a 30m tower is considered and forces are calculated using various codes. The standards used in the paper for comparison are IS 875-1987, Indian Draft IS875, ASCE 7-2010, AS-NZS 1170.2-2011 and HK-2004. Comparison is also done on definition of wind characteristics, gust factor, and wind loads for similar condition of topography and basic wind speed. Terrain category with well scattered obstruction is considered and concluding remarks are given.*

Keywords*: Gust factor; wind loads; communication tower; wind characteristics*

1. INTRODUCTION

In present century communication technology has become significantly important. The need for tall structures like towers has been increasing with the requirements for effective communication particularly the television, radio, GSM and internet traffic. Due to the growth in use of cellular phones, there is increase in demand in design and implementation of communication towers. In case of emergency (natural disasters) communication towers plays a vital role in transfer of information. Important infrastructures like dams are depended on these structures for transfer of data. Further another predominant application is in military (defence) where these towers are used in radar technology. For such an increasing demand there is need to evaluate this structures. To calculate wind loads, dynamic analysis is done. In the previous studies B.Venkateswarlu et al. (1993) has done the stochastic analysis to calculate dynamic wind response on microwave lattice tower. The gust response factor computed was compared, with values obtained by formulae’s recommended by Indian, Australian, British and ASCE standards with derived simplified expressions. Yin zhou et al. (2002) has done assessment of the source of this scatter through a comparison of the along-wind loads and their effects on tall buildings recommended by major international codes and standards. Dae kon kwon, and Ahsaan kareem (2013) has done similar observations in wind load comparison on tall buildings by using eight major international codes. P.Harikrishna et al. (1999) has done analytical and experimental studies on the gust response of a 52 m tall steel lattice tower under wind loading. Analytical comparison of calculation of gust factor is done by different codes i.e. Indian, Australian and British codes. 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. This paper describes the comparison of wind loads on microwave tower and its characteristics by different international wind codes and standards. The standards used for comparison are IS 875-1987 (Indian code), IS 875 (Indian Draft code), ASCE 7-2010 (American code), AS-NZS 1170.2-2011 (Australian code) and HK-2004 (Hong Kong code). Comparison is done on definition of wind characteristics, gust factor, and wind loads, for this one numerical example is illustrated in paper.

2. PARAMETERS FOR WIND LOAD CALCULATION

Different international codes are giving different procedure to calculate gust factor and the procedure to calculate wind loads is same in general way which is given in this paper. Wind load depends on basic wind velocity, turbulence intensity, turbulence length scale, gust factor, effective area, wind pressure etc. Following are the parameters considered for wind force calculation.

2.1 Risk Category

In every code there are different categories to calculate wind speed, this is classified according to development of area, i.e. depends on the obstruction in the flow of wind. Indian and American code is having four different categories whereas Australian code is having three different categories. Hong Kong code is having single category. In this paper for comparison of codes second category with well scattered obstructions is considered.

2.2 Basic Wind Velocity

Basic wind speed depending on the location of tower is required for analysis and is denoted by (V_b). In every code there are maps or pre-determined basic wind velocity according to location. This basic wind velocity is calculated by taking average gust time of 3 sec, 10 min or1 hr. In ASCE

2010 and AS-NZS 2011 the average gust speed is 3 sec for height of 10 m above the ground and in Hong Kong code 1 hr. gust period is given.

2.3 Design Wind Speed

The basic wind speed is converted to design wind speed by modifying it including the effects for terrain, topography, importance of structure, ground roughness, return period and size of the structure, and local topography. Mean Probable design life is considered for 100 years for towers. General design wind speed is given as

Design Wind Speed = $V_b \times k_1 \times k_2 \times k_3$ (1)

Where, V_b is basic wind speed and k_1, k_2, k_3 are factors for topography, importance of structure, return period of structure and directionality factor.

2.4 Design wind pressure

Codes are giving design wind pressure as design wind speed multiplied with factor to convert it in pressure. For design wind pressure Hong Kong code is giving direct values with respect to height. In other codes in general it is given as Velocity Pressure

$$p_z = 0.6 k_1 k_2 k_3 V_b^{\,2} \quad (2)$$

2.5 Force Coefficient

Force coefficient is calculated by calculating solidity ratio. Solidity ratio is equal to the effective area (projected area of all the individual elements) of a frame normal to the wind direction divided by the area enclosed by the boundary of the frame normal to the wind direction.

Force coefficient for lattice towers of square or equilateral triangle section with flat sided members for wind blowing against any face are given in codes. In this paper flat sided members are used. All the codes are giving values for the force coefficient for circular and flat sided members

2.6 Gust Loading Factor

In general wind speed in the atmosphere increases as increase in the height from zero at ground level to maximum at the required height. For calculation purpose this wind variation is separated in two parts i.e mean and fluctuating components. Mean wind load component is calculated from average wind speed decided for particular region in different codes. Fluctuating component is evaluated by considering dynamic amplifications, size reduction effects, turbulence in wind etc. This is taken into account in gust average time considered in codes and the gust factor. A gust factor, is the ratio between a peak wind gust and average wind speed over a period of time

Wind load acting on tower is calculated

$$F = q_z G C_f A_f \quad (3)$$

Where, q_z is the design wind pressure, G is the Gust factor, C_f is the force coefficient and A_f is the effective area.

3. GENERAL CONSIDERATION OF STEEL LATTICE TOWER

Microwave square lattice tower of 30 m height as shown in Fig.1 is considered to be in an open ground terrain with well scattered obstructions. The base width of tower is of 5m and top width is of 2m having 10 numbers of panels. The members used are different steel angel sections in leg, bracing and horizontal members shown in Fig.1.

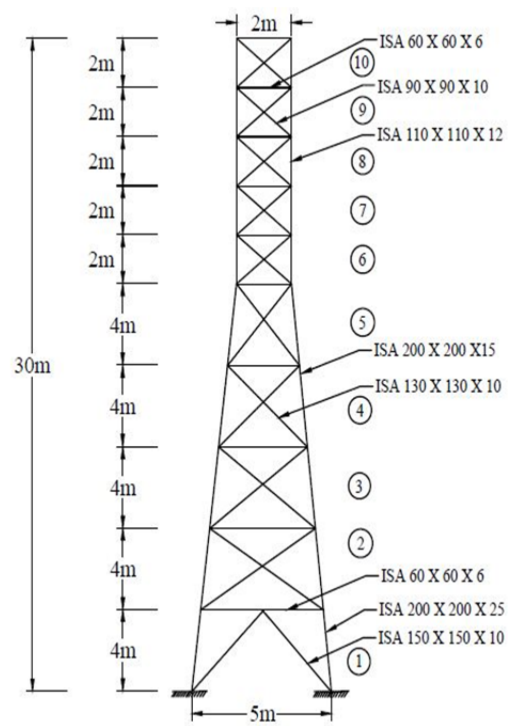

Fig. 1: Details of Microwave Lattice Tower of 30 m Height

Table 1: Calculation Procedure for Wind Forces from Different codes

Symbol/ Codes	IS 875-1987	AS/NZS 1170.2.2011	ASCE.7.2010	HK 2004	Draft code IS875.3
$\overline{Z}$	H	H	0.6H	H	H
g	Fig. 8 of code	$g_R = \sqrt{2\ln(600 n_a)}$ [a] $g_v = 3.7$	$\ln(3600 n_1) + \frac{0.577}{\sqrt{2\ln(3600 n_1)}}$ [a] g_v	$g_v = 3.7$ $g_R = \sqrt{2\ln(3600 n_a)}$	$g_v = 3.5$ $g_R = \sqrt{2\ln(3600 f_0)}$ [a]
B	Fig.9 of code	$1 + \frac{\sqrt{0.26(h-s)^2 + 0.46 b_{sh}^2}}{L_h}$ [b]	'	$\frac{1}{\left[1 + \frac{\sqrt{36H^2 + 64b^2}}{L_H}\right]}$ [h]	$\frac{1}{\left[1 + \frac{\sqrt{36(h-s)^2 + 64 b_{sh}^2}}{2L_h}\right]}$ [j]
E	Fig. 11 of code	$\frac{\pi N}{(1+70.8 N^2)^{5/6}}$ [c]	$\frac{7.47 N_1}{(1+10.3 N_1)^{5/3}}$ [e]	$\frac{0.47}{(2+N^2)^{5/6}}$ [i]	$\frac{\pi N}{(1+70 N^2)^{5/6}}$ [k]
S	Fig. 10 of Code	$\frac{1}{\left[\frac{3.5 n_a h(1+g_v I_h)}{V_{des,\theta}}\right]\left[1 + \frac{4 n_a b_{0h}(1+g_v I_h)}{V_{des,\theta}}\right]}$	$R_H R_b (0.53 + 0.47 R_L)$ [f]	$\frac{1}{\left[1 + \frac{3.5 n_a h}{\overline{V}_h}\right]\left[1 + \frac{4 n_a b}{\overline{V}_h}\right]}$	$\frac{1}{\left[\frac{4 f_0 h(1+g_v I_h)}{V_h}\right]\left[1 + \frac{4 f_a b_{0h}(1+g_v}{V_h}\right]}$
G/ C_{dyn}	$1 + g_f r \sqrt{\left[B(1+\phi)^2 + S\right.}$	$\frac{+2 I_h \sqrt{g_v^2 B_s + \frac{H_s g_R^2 S E_t}{\zeta}}}{(1+2 g_v I_h)}$	$=0.925\left[\frac{1+1.7 I_{\overline{Z}} \sqrt{g_Q^2 Q^2 + g_R^2 R^2}}{1+1.7 g_v I_{\overline{Z}}}\right.$	$+ 2 I_h \sqrt{\left[g_v^2 B + \frac{g_f^2 SE}{\zeta}\right.}$	$\frac{1 + 2 I_h \sqrt{g_v^2 B_s + \frac{H_s g_R^2 SE}{\beta}}}{(1+2 g_v I_h)}$
F	$C_f A_e p_z C_{dyn}$	$(0.5\rho_{air})[V_{des,\theta}]^2 C_{fig} C_{dyn} A_z$	$q_z G C_f A_f$	$C_f A_z \overline{q}_z G$	$C_f A_e p_z C_{dyn}$

[a]Where n_a, η_1 and f_0 first mode natural frequency

[b] $L_h = 85(h/10)^{0.25}$ a measure of the integral turbulence length scale at height h in m

[c] $N = n_a L_h [1 + (g_v I_h)] / V_{des,\theta}$ reduced frequency

[d] I_h turbulence intensity, obtained from Table 6.1 of AS-NZS 1170:2 2011 by setting *z*= *h*

[e] $N_1 = \frac{n_1 L_{\overline{Z}}}{\overline{V}_{\overline{Z}}}$ where $L_{\overline{Z}} = l\left(\frac{\overline{Z}}{10}\right)^{\overline{\epsilon}}$ and $\overline{V}_Z$ is the mean hourly wind speed at height $\overline{Z}$

[f] $R_l = \frac{1}{\eta} - \frac{1}{2\eta^2}(1 - e^{-2\eta})$ for $\eta > 0$, $R_l = R_h$ setting $\eta = 4.6\eta_1 h \overline{V}_Z$, $R_l = R_B$ setting $\eta = 4.6\eta_1 B \overline{V}_Z$ and $R_l = R_L$ setting $\eta = 15.4\eta_1 L \overline{V}_Z$

[g] $Q = \sqrt{\frac{1}{1 + 0.63\left(\frac{B+h}{L_{\overline{Z}}}\right)^{0.63}}}$

[h] $L_H = 1000\left(\frac{h}{10}\right)^{0.25}$ the effective turbulence length scale

[i] $N = n_a L_h / \overline{V_h}$ *N* reduced frequency (non dimensional)

[j] $L_H = 100\left(\frac{h}{10}\right)^{0.25}$

[k] $N = f_0 L_h [1 + (g_v I_h)] / V_h$ reduced frequency

Wind loads are calculated by taking single terrain category of sub-urban type terrain and basic wind speed of 39 m/s. Comparison of equations of all the codes to calculate forces are given in Table 1. The forces are calculated by gust factor method and this are applied on the nodes of the tower at height given in Table 2. Model is prepared in SAP 2000 and deflections are calculated. Tower is having cross bracing and the angle members used are 200×200×25 and 200×200×15 for leg members for slant portion, 110×110×12 for straight leg members, 150×150×10 for cross bracing till 12m height, 130×130×10 till 20m height, 90×90×10 from 20 to 30m height, and 60x60x6 horizontal members throughout height of tower. Damping used is 0.02 for steel towers according to codes.

4. FORCES COMPARISON

Forces calculated using different codes at respective height of tower is given in Table 2. Calculation is done using the equations given in Table 1 by the gust factor method in which it is seen that maximum forces are coming at bottom of the tower and minimum at top, this is because forces are the function of area, wind pressure, gust factor etc.

Table 2: Comparison of Forces from Different Codes

Height (m)	Forces in kN				
	Indian IS 875 Part3 1987	Indian Draft Code IS 875	Australian code AS-NZS 1170:2 2011	American Code ASCE 7-2010	Hong Kong Code 2004
2	14.619	9.316	10.167	13.845	7.404
6	14.481	9.529	10.960	12.495	8.665
10	12.961	8.859	10.671	12.812	8.986
14	12.469	8.451	8.626	12.010	8.325
18	10.422	7.793	7.452	11.270	8.175
21	4.512	3.214	3.596	4.522	3.089
23	4.473	3.303	3.617	4.609	3.127
25	4.516	3.395	3.640	4.691	3.166
27	4.564	3.486	3.663	4.768	3.206
29	4.615	3.800	3.685	4.840	3.248
30	4.646	3.608	3.695	4.875	3.270

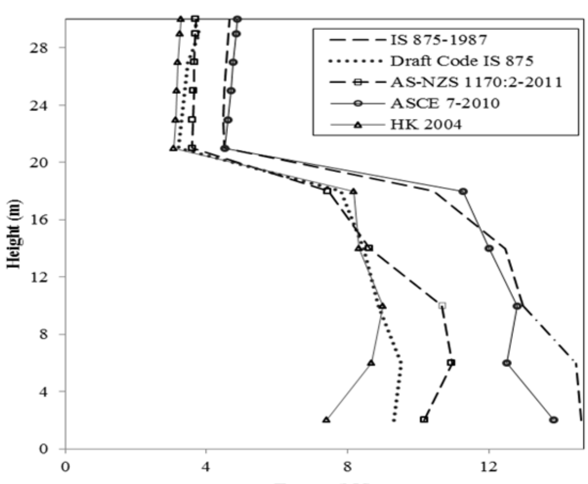

Fig. 2: Graph Showing Comparison of Wind Forces

The main reason for this variation is area at the base is more and at top is less. The area of the tower which is constant will have nearly same forces acting on the tower along the height. For force calculation natural frequency of tower, solidity ratio, force coefficient were calculated. Wind pressure will vary linearly as the height increases i.e. pressure will increase as the height increases whereas gust factor will decrease as the height increases. Comparison is done by applying converting factors for average gust wind of 3sec, 10 min and 1hr for different codes which depends on basic wind speed.

5. CONCLUSION

From the results obtained as given in Figure.2 it is seen that IS code 875-1987 is giving higher forces which is due to the presence of graphs for calculation of various factors whereas in draft code of IS 875 the gust factor equations are given which gives an accurate values of wind forces which are acting on the tower. The AS-NZS code and ASCE code gives nearly same value due to similar flow conditions and gust factor equations. HK 2004 code values are varying with the height with respect to other codes. Hong Kong code is giving least values as compared to other codes. If the tower effective area over which wind forces acting is remaining same then the wind force will also be nearly same over that area. All the wind codes are based on the gust factor method to calculate wind loads however each code will give distinctive definitions and equations for wind parameters which leads to the variation of forces

6. ACKNOWLEDGMENT

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