Comparison of Wind and Seismic Effects on a Reinforced Concrete Chimney

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Abstract - *When designing any high rise structure, wind and seismic forces are the major lateral forces that have to be dealt with. As by the code recommendations, it is very unlikely that maximum wind accompanying maximum earthquake activity, we just have to design the structure for the maximum load which is induced by either wind or seismic. In this present study, a reinforced concrete chimney of gross height 67 m above base, which has a height of 60 m above base, is analysed for wind and seismic excitations. Seismic effects are evaluated through response spectrum analysis. For wind analysis, both along and across wind effects are considered. The design values so obtained are then compared to define the governing factor in stack design. The results indicate that seismic forces are the governing factor for the stack design.*

Keywords - *Tall RCC Chimneys, Along and across wind loads, Response Spectrum Analysis*

I. Introduction

A structure must be designed to carry every load during its service life, both horizontal and vertical. Among these, lateral loads should be seen with great caution as it tends more design forces. Wind load and seismic loads are the major lateral loads which are imposing on a structure.

Owing to the height, stack attracts a lot of wind forces. And by virtue of its importance, seismic excitation evaluation is also a momentous parameter. Hence, both these have to be carefully investigated. As said earlier, the height may wake various wind behaviours on the stack like vortex shedding, wind buffeting etc. So, assessing the dynamic behaviour of the stack also becomes crucial in the analysis. Indian standard clearly proposes that consideration of maximum wind along with maximum seismic is not necessary. On its behalf, we have to determine which lateral force induces maximum load.

In the present paper a stack of gross height 67 m and 60 m above ground level is analysed for both wind and seismic excitations. Dynamic wind effects as per available literatures are also researched. The results are then compared. For the stack M35 grade concrete and Fe500 grade steel are assumed. Unit weight of concrete is taken as 25 kN/m^3. The geometric propertis of the chimney at various locations are given in Table I.

Table I: GEOMETRIC PROPERTIES AT VARIOUS ELEVATIONS

Height above Base	Inner Diameter	Outer Diameter	Thickness
m	m	m	m
00.00	5.40	6.60	0.60
07.00	5.40	6.60	0.60
19.00	4.92	5.96	0.52
31.00	4.44	5.32	0.44
43.00	3.96	4.68	0.36
55.00	3.48	4.04	0.28
67.00	3.00	3.40	0.20

II. Mathematical Background

The analysis is perfumed conforming to the recommendations as per Indian standards.

The design wind speed V_z at any height and at a given site is expressed as [6],

$$V_z = V_b k_1 k_2 k_3$$

Where,

V_b	:	Basic wind speed in m/s
k_1	:	Probability or risk factor
k_2	:	Terrain, height and structure size factor
k_3	:	Local topography factor

And, the design wind pressure p_z in N/m^2 at any height above mean ground level is given by the relation [6],

$$p_z = 0.6 V_z^2$$

From this, along wind load can be computed as [7],

$$F_z = p_z C_D d_z$$

Where,

z	:	Height of any section of the chimney in m measured from the top of foundation
C_D	:	Drag coefficient of the chimney to be taken as 0.8
d_z	:	Diameter of chimney at height z in m

For across wind loads, sectional shear force, F_{z0i} and bending moment, M_{z0i} at any height z_0, for the i[th] mode of vibration, shall be calculated from the following equations [7],

$$F_{z0i} = 4\pi^2 f_i^2 \eta_{0i} \int_{z_0}^{H} m_{zi} \phi_{zi} d_z$$

$$M_{z0i} = 4\pi^2 f_i^2 \eta_{0i} \int_{z_0}^{H} m_{zi} \phi_{zi} (z - z_0) d_z$$

Where,

f_i : Natural frequency of the chimney in Hz in the i[th] mode of vibration

m_{zi} : Mass per unit length of the chimney at section z in kg/m

III. Analysis using Commercial Software

Commercial software STAAD.Pro V8i has been used for the analysis of along wind effects. The RC chimney is idealized as a cantilever beam of varying cross section of height 60 m above ground level which is fixed at its base. Response spectrum analysis is also carried out in STAAD.Pro V8i. All loads and features are calculated and applied in accordance with the relevant codes.

IV. Wind Analysis

A. *Along Wind Analysis*

The attributes considered are,

Wind Speed – 3 Seconds Guest, V_b : 44 m/s
Terrain Category : Category 1
Building Class : Class A [7]
Probability Factor, k_1 : 1.7680
Topography Factor, k_3 : 1.18

Using the height of the chimney, the size factor is worked out for every 12 m interval. And then using all these parameters, the drag force is computed and is applied on the structure. The calculations are summarized in Table II.

These drag forces are applied in the stack. As the stack is idealized as a stick model, the forces are applied as uniformly varying load. Then the structure is analysed to yield the wind induced shear and moment.

B. *Across wind analysis*

The attributes considered are,

Structural Damping, β : 0.016
Mass Density of air, σ : 1.2 kg/m^3
Effective diameter, d : 3.6667 m
Peak Oscillatory Lift Coefficient, C_L : 0.16
Strouhal Number, S_n : 0.2

Using the above parameters, the variables for the induced shear and moment are calculated and are described below. Then these attributes are pooled to get the design values and are tabulated in Table III.

Equivalent mass per unit length, m_{ei} = 8339.7977 kg/m
Mass damping parameter, K_{s1} = 103.9349
Peak deflection, η_{01} = 0.0517 m

Table III: COMPUTATION OF SECTIONAL SHEAR FORCE AND MOMENT

Node	Height	d_z	F_{z01}	M_{z01}
	m	m	kN	kNm
1	67	12	291.0184	0.0000
2	55	12	552.0778	3132.7122
3	43	12	791.7975	8885.9857
4	31	12	962.7991	15042.0450
5	19	12	1048.4630	19153.9121
6	7	7	1056.3805	19628.9619

Table II: COMPUTATION OF DRAG FORCE

Beam	Node at	Mean Diameter	Mean Thickness	k_2	V_z	Design Wind Pressure, P_z	Drag Force, F_z
		m	m		m/s	N/m^2	N/m
	-7						
1		6.6000	0.6000				
	0						
2		6.2800	0.5600				31521.3749
	12			1.114	102.2591	6274.1590	
3		5.6400	0.4800				30299.5444
	24			1.1525	105.7932	6715.3246	
4		5.0000	0.4000				28277.9179
	36			1.1825	108.5471	7069.4795	
5		4.3600	0.3200				25648.1610
	48			1.2060	110.7042	7353.2572	
6		3.7200	0.2400				22408.9994
	60			1.2204	112.0261	7529.9057	

Table IV: COMBINED WIND PARAMETERS

Along Wind Load		Across Wind Load		SRSS	
Shear	Moment	Shear	Moment	Shear	Moment
kN	kNm	kN	kNm	kN	kNm
0.0000	0.0000	291.0184	0.0000	291.0184	0.0000
268.9080	1613.4480	552.0778	3132.7122	614.0858	3523.7906
576.6860	6687.0110	791.7975	8885.9857	979.5458	11121.0097
916.0210	15643.2540	962.7991	15042.0450	1328.9382	21701.9472
1279.6160	28817.0720	1048.4630	19153.9121	1654.2950	34601.9651
1657.8720	46442.0000	1056.3805	19628.9619	1965.8279	50419.7928

Table V: COMPARISON OF WIND AND SEISMIC LOAD COMBINATIONS

Combination	Beam	Node	Axial Force	Shear-Y	Moment-Z
			kN	kN	kNm
1.5DL+1.5EL	1	2	15600.2730	4529.5425	87392.5845
	2	3	10932.5085	3991.5060	53642.8185
	3	4	7057.2135	2671.6080	41141.1210
	4	5	4007.0970	1703.9430	25104.1380
	5	6	1733.0775	1455.2790	10542.8490
	6	7	170.9235	878.5710	0.0000
1.5DL+1.5WL	1	2	13639.5405	2948.7419	75629.6892
	2	3	9111.1230	2481.4424	51902.9476
	3	4	5609.6280	1993.4072	32552.9209
	4	5	3008.3895	1469.3187	16681.5146
	5	6	1180.7370	921.1287	5285.6860
	6	7	0.0000	436.5276	0.0000

C. Combination of wind parameters

The along and across components of wind is then combined to get the actual effect of wind on the stack. As per code provisions, SRSS method is used to find the combined values. The values so obtained are tabulated in Table IV.

V. SEISMIC ANALYSIS

The structure is then subjected to seismic analysis. For the present analysis, response spectrum method is adopted. The structure is analysed using commercial software STAAD.Pro V8i. Basic parameters considered in the analysis are given below.

Seismic zone	:	III
Importance factor, I	:	1.75
Response reduction factor, R	:	1.00
Sub soil class	:	medium
Damping	:	5 %
Time Period, T	:	0.8807 sec

VI. COMPARISON OF RESULTS

Based on the results, a comparison of wind load and seismic load combination are given in Table V. Only the combination which yielded at maximum force parameters is discussed. It can be seen that seismic forces are the governing loads from design aspect. Although wind analysis yielded lesser design forces than seismic approach, the variation is not of much extent.

VII. CONCLUSIONS

A comparison study of wind and earthquake forces on a reinforced concrete chimney is discussed. The chimney is analysed individually for wind and earthquake induced lateral forces in order to determine the governing factor on stack design. The slenderness of the structure demanded to investigate the along and across wind behaviours of the structure. Introduction of dynamic forces is on the conservative side for evaluating wind-induced forces and moments, but seismic forces are predominant, as in the assumption earthquake cannot accompany maximum wind or maximum flood or maximum sea waves. However, variation between design forces induced by wind and seismic analysis is of minor extent. So, the same stack subjected to any other lateral load may exhibit a reverse behaviour. As far as concerned, seismic forces are the governing factors in stack design.

REFERENCES

[1]. Manohar S. N., "Tall Chimneys: Design and Construction".

[2]. Reddy K. R. C., Jaiswal O. R., Godbole P. N., "Wind and Earthquake Analysis of Tall RC Chimneys ", *International Journal of Earth Sciences and Engineering*, ISSN 0974-5904, Volume 04, No 06 SPL, October 2011, pp. 508-511.

[3]. Siva Konda Reddy B., Rohini Padmavathi V. and Ch. Srikanth, "Study of Wind Load Effects on Tall RC Chimneys", *International Journal of Advanced Engineering Technology, E-ISSN 0976-3945*, IJAET, Vol.III, Issue II, April-June, 2012, pp. 92-97.

[4]. IS 1893(Part 1):2002, "Indian Standard Criteria for Earthquake Resistant Design of Structures: General Provisions and Buildings".

[5]. IS 1893(Part 4):2005, "Indian Standard Criteria for Earthquake Resistant Design of Structures: Industrial Structures Including Stack-like Structures".

[6]. IS 875(Part 3):1987, "Indian Standard Code of Practice for Design Loads (other than Earthquake) for Buildings and Structures: Wind Load".

[7]. IS 4998(Part 1): 1992, "Indian Standard Criteria for Design of Reinforced Concrete Chimneys: Assessment of Loads".