Response of television tower to wind load

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Abstract. This paper presents an analysis of the response of television tower to wind load. Computational model of tower is a model with the mass concentrated in the center of gravity of each part of the tower. The values of wind pressure were obtained using a record of wind speed.

1 Introduction

Reinforced concrete core of the tower consists of a rod with a square base 7×7 meters. External structure consists of a steel box columns that are above the platform and through steel beams connected with the core. In this amount of reinforced concrete construction continues and ends steel pipe, culminating in a laminate tube transmitters, which will consist of the tower. Individual platforms are woven into the reinforced concrete cores and corners hanging on a steel construction, Fig. 1.

Fig. 1. The television tower.

2 Computational model of supporting tower

The dynamic model of the tower is a system of concentrated masses in selected centers of mass of the tower [1]. Static computational model contains a reinforced concrete rod in the core of tower, steel platformy nad rods (box columns), steel and laminate tube.

To the level of 130 m are located platforms and reinforcing rod, Fig. 2a. Static computational model is shown in Fig. 2b, the dynamic Fig. 2c.

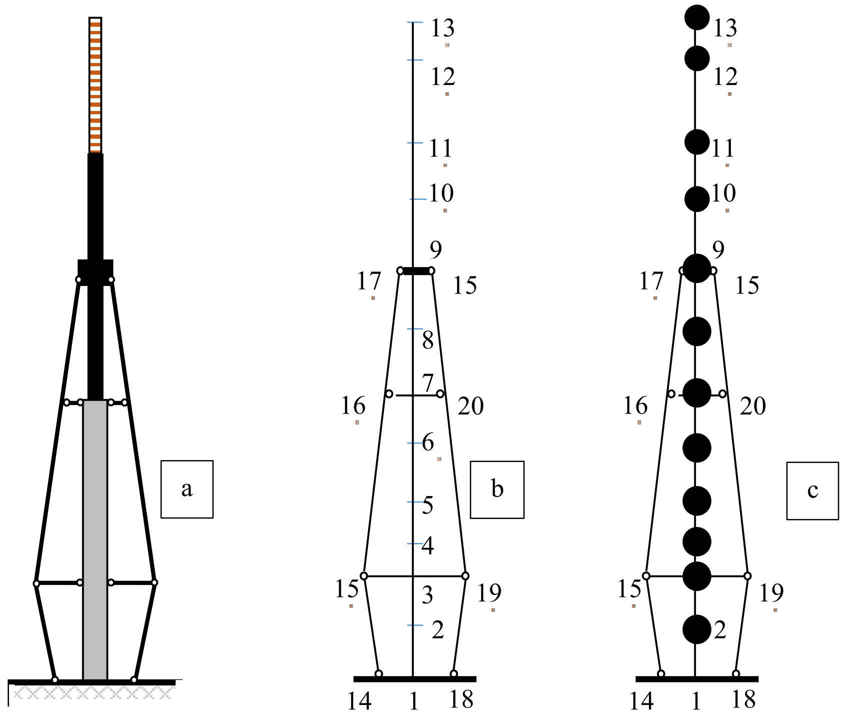

Fig. 2. Computational model of the tower.

3 Quasi-static calculation of the response of the tower

Modeling the wind speed is simulated by course with discrete time interval Δt. Wind pressure $w(t)$ is depending on the wind speed stated by the generally valid relation for laminar flow

$$w(t) = c\ A\ q(t) = c\ A\ \frac{v^2(t)}{16} \tag{1}$$

Displacement due to the load impulse is given by

$$u(t) = w(\tau)\,W(t-\tau)\,\mathrm{d}\tau \tag{2}$$

where $W(t)$ is an influence function that is the response of systems with one degree of freedom to the unit impulse

$$W(t) = \frac{e^{-\delta\omega_0 t}}{m\sqrt{1-\xi^2}\ \omega_0}\sin\sqrt{1-\xi^2}\ \omega_0\, t \tag{3}$$

Displacement in time $\tau = k\ \Delta t$ and $t = j\ \Delta t$ is

$$u_j = \sum_{k=1}^{k=j-1} w_k \, W[(j-k)\,\Delta t] \tag{4}$$

where $W(t-\tau) = W[(j-k)\,\Delta t]$

After the substitution, the elastic force in system with one degree of freedom after a single transformation is defined by the formula

$$F_j = 2\,\pi\,\kappa \sum_{k=1}^{k=j-1} w_k \; \mathrm{e}^{-\delta\kappa(j-k)} \sin 2\,\pi\,\kappa\,(j-k) \tag{5}$$

where δ is the logarithmic decrement.

4 Methodology of processing record wind speeds

In methodology following assumptions are valid:
a) continuous chart recording wind speed is substituted by a discrete step system [2]
b) discrete values of wind speed shall be determined by discrete pressure values based on the unit area of wind $c{\cdot}A = 1$
c) the pressure values were averaged and represent the static value of wind pressure q_s
d) the relation $w_d = w - w_s$ determines the maximum value of the dynamic component
e) dynamic wind pressure will be standardized $q_d / q_{d,\max} \leq 1$
f) the relative value of dynamic load is defined by the relation

$$\frac{F_j}{F_{jk,\max}} = 2\,\pi\,\kappa \sum_{k=1}^{k=j-1} \frac{q_{dk}}{q_{d,\max k}} \mathrm{e}^{\delta\kappa(j-k)} \sin 2\pi(j-k) \tag{6}$$

g) the dynamic coefficient of increase in wind pressure (dynamic factor) is defined by the relation

$$\beta = \max \frac{F_j}{F_{j,\max}} - 1 \tag{7}$$

h) impact factor is related to the maximum wind pressure resulting from the relation

$$\beta = 1 + \beta \frac{q_{d,\max}}{q_{\max}} \tag{8}$$

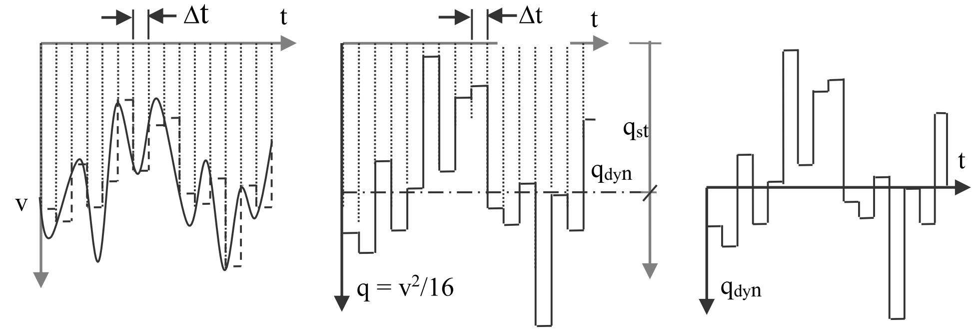

Fig. 3. Substitution of continuous recording of speed and wind pressure by the discrete one.

i) for producing the sum of equations (6) it is appropriate to limit the correlation length of t_w

$$t_w = t - \tau = (j - k)\Delta t = m\,\Delta t \qquad (9)$$

4.1 Analysis of wind speed record

Wind speed record [3] during a severe storm recorded maximum wind speed v = 45 m/s. Wind speed record was taken in a period of about 9 minutes. The speed record of 30 values per minute corresponding to the time interval is in Fig. 4.

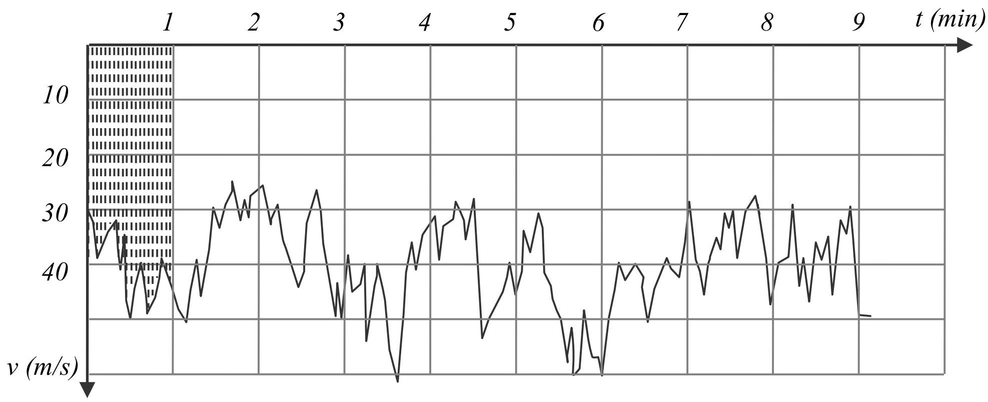

Fig. 4. Wind speed record.

a) Determination of mean and maximum dynamic components of the wind pressure Fig. 4 is in Table 1.

Table 1. Static and dynamic share stress.

q_s [kNm^{-2}]	$q_{d,\max}$ [kNm^{-2}]	$q_{\max}$ [kNm^{-2}]	$q_s / q_{\max}$	$q_{d,\max}/ q_{\max}$
0.588	0.458	1.046	0.56	0.44

b) Determination of mean and maximum dynamic components of the wind pressure is in Table 2. It indicates maximum load ratio for different values of logarithmic decrement and vibration period of the non-damped natural vibration.

Table 2. Determination of mean and maximum dynamic components.

δ	T_0 [s]				
	0.5	1.0	2.0	3.3	5.0
0.150	0.413	0.829	0.852	1.430	1.717
0.075	0.413	0.867	0.971	1.593	1.957
0.025	0.406	0.883	1.661	2.028	2.496

c) Determination of the gust dynamic coefficient

Gust factor φ is determined for $T_0 = 3.5$ s and the logarithmic decrement $\delta = 0.15$.

Table 3. Calculation of the gust factor φ.

φ	T_0 [s]				
δ	0.5	1.0	2.0	3.3	5.0
0.150	0.732	0.925	0.935	1.189	1.315
0.125	0.735	0.926	0.943	1.218	1.329
0.100	0.738	0.927	0.952	1.242	1.353
0.075	0.742	0.941	0.987	1.261	1.421
0.050	0.743	0.938	1.010	1.328	1.524
0.025	0.739	0.959	1.291	1.452	1.658

4.2 Numerical calculation

The load was calculated from the blast effects of wind calculated. Mechanical parameters and geometrical characteristics of the tower are shown in Table 4.

Table 4. Mechanical and geometrical characteristics of the tower.

No.	m^*	l	EI	No.	m	No.	l	EI
-	$kg \cdot 10^3$	m	$N \cdot m^2$	-	$kg \cdot 10^3$	-	m	$N \cdot m^2 \cdot 10^{10}$
1	496	32.8	$5.104 \cdot 10^9$	11	48	11	20.5	$0.025 \cdot 10^9$
2	1236	15.6	$6.268 \cdot 10^9$	12	27	12	10	$0.024 \cdot 10^9$
3	1100	5.4	$6.737 \cdot 10^9$	13				
4	838	9.4	$6.260 \cdot 10^9$	14				
5	1606	16.2	$5.555 \cdot 10^9$	15, 19				
6	1157	13.5	$4.853 \cdot 10^9$	16, 20				
7	326	21.6	$0.555 \cdot 10^9$	17, 21				
8	166	19.4	$0.158 \cdot 10^9$					
9	75	19.3	$0.036 \cdot 10^9$					
10	60	19.2	$0.021 \cdot 10^9$					

The calculation of load forces from the blast effects of wind is shown in Table 5.

Table 5. Load characteristics.

Sec.	l	b	$c_{f,0}$	c_f	$A_{\mathrm{ref}}(z)$	$w_p(z)$	F_i	φ	F_i
1	16.2	18.0 4.0	15.6	1.19	73	161	644	1.2	773
2	15.6	25.7 4.0	15.6	1.19	408	161	644	1.2	773
3	5.4	32,7 4.0	5.4	1.24	343	161	564	1.2	677
4	9.4	30.5 4.0	9.4	1.28	226	151	459	1.2	551
5	16.2	27.6 4.0	16.2	1.33	353	156	490	1.2	588
6	13.5	22.6 4.0	13.5	1.42	335	167	602	1.2	722
7	21.6	17.6 3.0	21.6	1.52	309	179	269	1.2	323
8	19.4	11.5 3.0	19.4	1.0	236	94	100	1.2	120
9	19.3	5.4 3.0	19.3	1.2	58	14	336	1.2	403
10	19.2	3.0	19.2	1.2	58	94	100	1.2	120
11	20.5	2.6	20.5	1.2	59	14	168	1.2	202
12	10	2.6	10	1.2	46	14	84	1.2	101
13	5	2.6	10	1.2	13	14	41	1.2	50

5 Conclusion

The present method of determining the effects of blast wind upon structures is applicable to support systems, such as antenna masts, towers, bridges and civil buildings.

References

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2. Ch. Petersen, *Anchored masts and chimneys* (W.E&S. 1970)
3. F. Steiger, Measurement of wind speed on the antenna mast, Stahlbau **34** (2008)