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WIND FLOW AROUND AN ATYPICAL BUILDING AND BUILDING CONFIGURATIONS

O. Hubová[*], L. Konečná[**]

Abstract: *This paper deals with a solution of air flowing around an atypical building. A result is an important parameter - the pressure coefficient on the structure. It is necessary for design of buildings and structures (or part of structures) in terms of wind load calculations. Wind tunnel measurements of wind flow and wind pressures distributions around an atypical building (a cross-section was shaped as quarter circle and building configurations with weak interaction) were performed in BLWT STU in Bratislava for 24 wind directions and different wind speeds. The results were compared with EN 1991-1-4 and they pointed to the conservative approach of standards as well as local peak pressures on the façade.*

Keywords: Wind tunnel measurements, Intensity of turbulence, Steady Wind Flow, Wind pressure Coefficient, Local angle of wind attack.

1. Introduction

Wind environment studies around idealized building and building configurations were carried out with the major focus on flow caused by strong wind with different directions. In this research, a series of parametric wind tunnel studies was carried out to investigate the effects of building width, height and the building configurations on the wind pressure distribution Beranek (1984), Statopoulos (1992), Richards (2007). In the article, we will discuss this issue for atypical high building and Twin City A1 project in Bratislava. We will indicate the high wind speed areas for strong wind conditions and try to find optimal solutions in terms of the planned new buildings groups.

2. Gust wind velocity

The effect of wind on a structure is composed of the mean wind speed increased by the turbulent component, which is reflected in the peak coefficients *g(t)*. The maximum impact velocity can be expressed as follows:

$$\hat{v} = v_m(z) + g(t) \cdot \sigma_v(z) = v_m(z) \cdot \left[1 + g(t) \cdot I_v(z)\right], \tag{1}$$

where $v_m(z)$ is mean wind velocity at a height z, $g(t)$ is peak factor, t is time, $\sigma_v(z)$ is standard deviation of the turbulence, $I_v(z)$ is turbulence intensity at height z.

The wind load - peak velocity pressure is:

$$\frac{1}{2} \cdot \rho \cdot \hat{v}^2 = q_m(z) \cdot \left[1 + g(t) \cdot I_v(z)\right]^2 = q_m(z) \cdot \left[1 + 2 \cdot g(t) \cdot I_v(z) + g^2(t) \cdot I_v^2(z)\right]. \tag{2}$$

Eq. 2 is often simplified neglecting quadratic member. The peak factor due to meteorological measurements is taken to be $g(t) = g = 3 \div 3.5$. The wind pressure in EN 1991-1-4 (2005) is expressed by Eq. 3, where peak factor $g(t) = 3.5$.

$$w = \left(c_{pe} - c_{pi}\right) \cdot \left[1 + 7 \cdot I_v(z)\right] \cdot 1/2 \cdot \rho \cdot v_m^2(z), \tag{3}$$

[*] Assoc. Prof. Ing. Olga Hubová, PhD.: Slovak University of Technology Bratislava, Faculty of Civil Engineering, Departement of Structural mechanics, Radlinského 11, 810 05, Bratislava; SK, olga.hubova@stuba.sk

[**] Ing. Lenka Konečná, PhD.: Slovak University of Technology Bratislava, Faculty of Civil Engineering, Departement of Structural mechanics, Radlinského 11, 810 05, Bratislava; SK, lenka.konecna@stuba.sk

where $\rho = 1.25\ kg/m^3$ is air density, c_{pe} is external and c_{pi} is internal pressure coefficient. It is possible for typical shapes of constructions to find the values c_{pe} and c_{pi} in Section 7 - EN 1991-1-4 (2005).

2.1. Wind flow around atypical structures

The wind pressure distribution on these structures can be obtained by experimental measurements in the wind tunnel or by CFD simulation for a suitable model of turbulence. Lately, it is possible to see high-rise structures in the shape of quarter circle (see Fig.1a, b).

Experimental measurements were performed in BLWT of Slovak Technical University in Bratislava. Wind tunnel was designed with open circuit scheme with total length of 26.3 m, two operation spaces with the dimensions of the cross-section 2.6×1.6 m and with adjustable ceiling.

We tested the model of building in two spaces - in steady and turbulent wind flow (see Fig. 1c, d) by changing of wind direction and wind velocity. The measurements were conducted using pressure scanner DSA 3217 (Scanivalve). Measured profile - quarter circle with a radius of 0.16 m and length of 1.1 m was placed centrally in front of the measuring space and 0.8 m above the floor. There was measured the steady flow. Initial position of segment (rotation angle 0°), dimensions and 16 measured pressure taps are shown in Fig. 1e. Wind velocity has been set by using software LabVIEW. The model was rotated every 15º, thereby was simulated the changing of wind direction acting on the object. The evaluation of the measured data enables to determine the most unfavorable position with maximum values of suction and wind pressure for different wind speeds (Fig. 2a). A model with height h = 0.273 m and radius r = 0.11 m (scale 1:380) was placed in the middle of rotating table in turbulent wind flow. The mean wind velocity and intensity of turbulence profiles were simulated with plastic foil FASTRADE 20 and wall 150 mm. Boundary layer simulations proved to be in good agreement with logarithmic law, Hubová & Lobotka (2014). ABL simulation with value roughness length z_0 = 0.7 – 0.77 m is between terrain category III – IV according EN 1991-1-4 (2005), closer to the terrain category IV. The measurements were made at the heights z_A = 0.258 m, z_B = 0.136 m and z_C = 0.015 m above the floor. Resultant value was determined as average of 1 000 samples (in each tap). The measurements were carried out for reference wind velocities at the top of building $v_{ref,1}$ = 8.83 m/s and $v_{ref,2}$ = 12.72 m/s (see Fig.2 b).

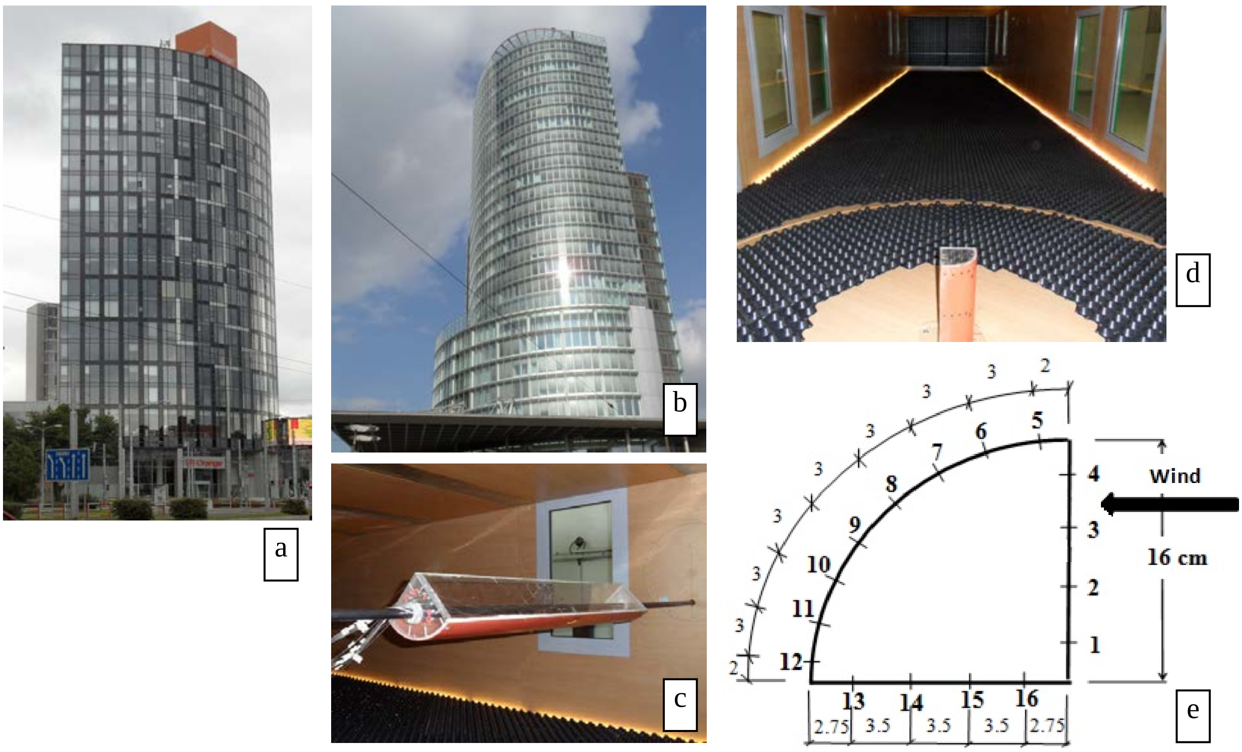

Fig. 1: High-rise building shaped as quarter circle (a, b); model of quarter circle in steady wind flow (c) and turbulent wind flow (d); cross-section of the model with dimensions in [cm] and pressure taps.

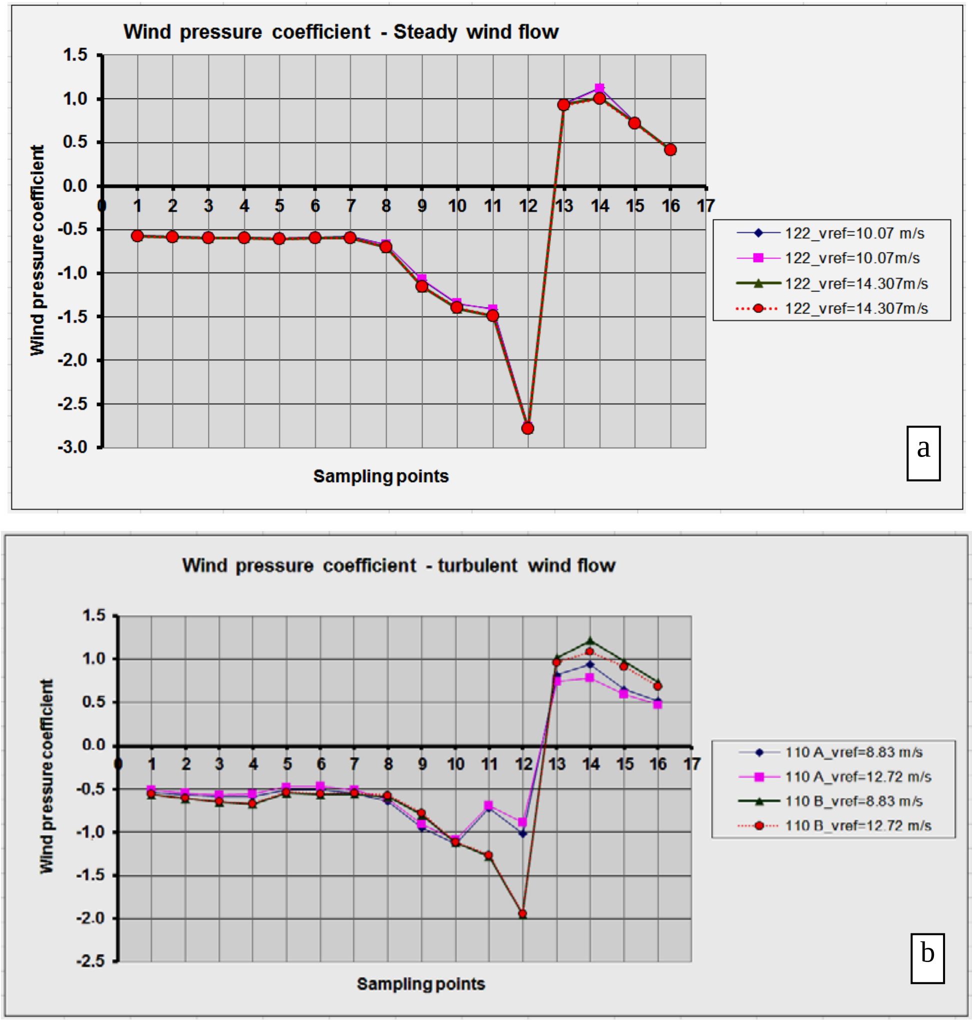

Fig. 2: External wind pressure coefficient in steady (a) and turbulent wind flow (b).

2.2. Wind flow around building configuration

The strong interaction occurs principally for all configurations if the distances between the buildings are less than 5 times the high. We monitored the distribution of wind pressure on future high-rise building TWIN A1 in the center of Bratislava. The orientation of the building in relation to the prevailing wind directions plays an important role in wind load. 90 m high buildings with surrounding lower parts (scale 1:300) were tested in BLWT in turbulent wind flow and the model was rotated every 15º (see Fig. 3).

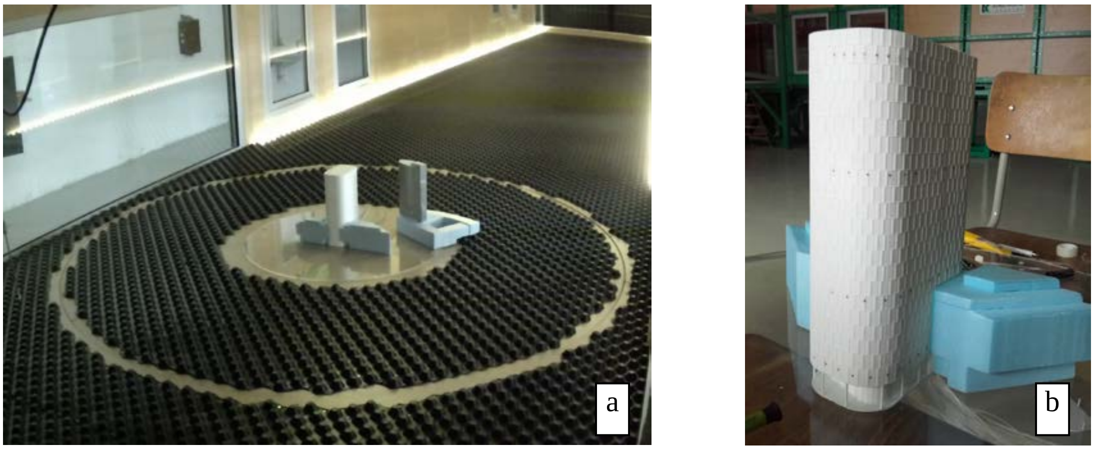

Fig. 3: Building configurations - TWIN A1 and VUB Bank buildings (in the scale 1:300) (a); detail of the TWIN A1building (b).

Comparison of the wind pressure on the facade of the white building obtained by calculation according to EN 1991-1-4 and the values obtained by experimental measurements (EXP) is shown in the graph in the Fig. 4. We used internal pressure coefficients $c_{pi} = 0.2$ and $c_{pi} = -0.3$ according to EN 1991-1-4. The resulting wind pressures on the preparing new building obtained experimentally were significantly lower than conservative values in accordance with EN standards. Local sucking on the rounded corners of the facade, was significantly higher than Normative coefficient $c_{pe} = - 1.2$ for the region around the corner of the building and reached values $c_{pe} = - 1.47$.

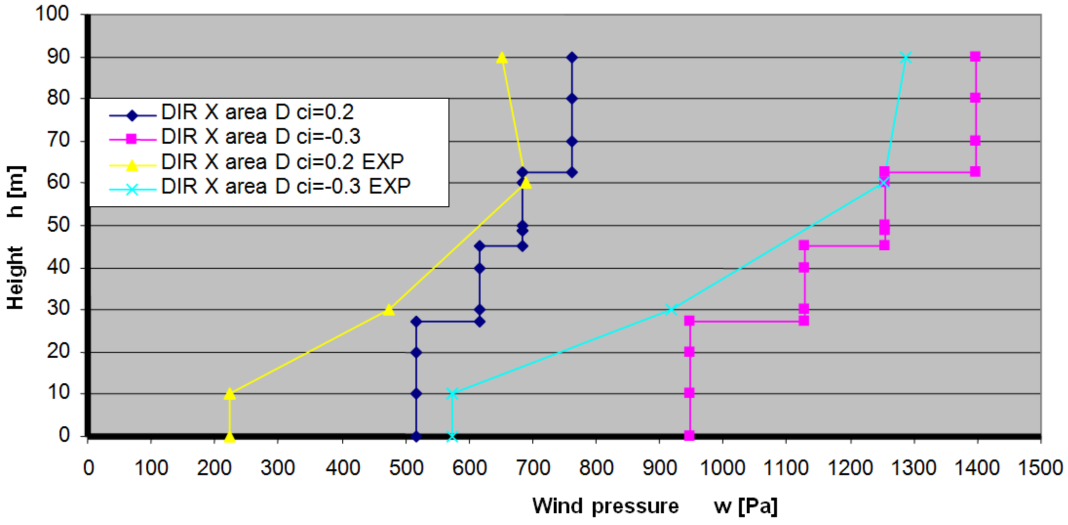

Fig. 4: Comparison of the wind pressure in X direction (prevailing wind direction).

3. Conclusions

The external wind pressure distribution and external wind pressure coefficients obtained from repeated experimental measurements made on models in steady and turbulent wind flow indicates the local extremes of suction in certain directions. Extreme values of the external wind pressure coefficients reached values of suction around -2 ÷ -2.78. It is evident from the graphs (Figs. 2 and 4), that in upper part of the structures, the pressures are affected by specific wind flow around the free end of the structure. In the case of atypical shapes of high buildings and structures in groups the wind tunnel investigation is recommended.

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References

EN 1991-1-4: Eurocode 1: Action on structures – Part 1-4: General actions - Wind actions, (2005).

Beranek, W.J. (1984) Wind Environment around Building Configurations. HERON 29 No.1/1984, pp. 1-70. Delft, Netherlands.

Koloušek, V., Pirner, M., Fischer, O. &, Náprstek, J. (1983) Wind effects on Civil Engineering Structures. Academia Praha, Elsevier, coed, London.

Pirner, M. & Fischer, O. (2003) Zatížení staveb vetrem, ČKAIT Praha.

Hubová, O. (2007) The effect of the wind on the structure. Slovak Journal of Civil Engineering, Vol. XV, No. 3. ISSN 1210-3896.

Hubová, O. & Lobotka, P. (2014) The Natural Wind Simulations in the BLWT STU Wind Tunnel, in: Porceedings of ATF 3nd Conference on Building Physics and Applied Technology in Architecture and Building Structures. E-Book of reviewed papers, May 6-7, 2014, Austria, Vienna, pp. 78-84. ISBN 978-3-200-03644-4.

Stathopoulos, T., Wu,H. & Bédant, C. (1992) Wind environment around buildings: a knowledge –based approach. Journal of Wind Engineering and Industrial Aerodynamics, 41-44, pp.2377-2388.

Richards, P.J., Hoxey R.P, Connel B.D. & Lander D.P. (2007) Wind-tunnel modeling of the Silsoe Cube. Journal of Wind Engineering and Industrial Aerodynamics, 95, pp.1384- 1399.