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WIND FLOW AROUND HIGH-RISE BUILDINGS AND ITS INFLUENCE ON THE PEDESTRIAN COMFORT

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Abstract: *The contribution deals with wind flow around two high-rise buildings standing close to each other with surrounding lower parts and the effects of these objects on the territory around the buildings, which is supposed to be a recreational zone. The configuration of the objects relative to the prevailing wind flow is not optimal; two tower blocks are in a "wind catching layout". What is needed to improve is contribution to urban planning and cooperation with urban planners and architects in a collective research in the perception of urban space. The effect of considerably diversified parameters has to be quantified. The aim of the experimental measurements in the wind tunnel was to demonstrate the need for delay the high-rise buildings apart due to strong suction on leeward, as well as the Venturi-effect, which occurred in the space between the buildings.*

Keywords: Wind pressure coefficient, Local angle of wind attack, Wind environment, Roughness length, Reference wind speed, Effective wind velocity, Pedestrian wind comfort.

1. Introduction

In the aerodynamics of structures it is necessary to determine the wind load, which is represented by a simplified set of pressures or forces for the whole structure, or for the structural parts. The wind tunnel tests are used for the study of building complex and their surrounding and for some environmental problems, which depends on the turbulence intensity and integral length scale. In most urban areas, an important problem is the achievement of an acceptable wind comfort around the buildings, with aspects that concern the quality of life and the use of the area affected by the buildings, associated to social and economic impacts.

2. Wind load

The effect of wind load on a structure can be expressed by external wind pressure:

$$w_e(z) = c_{pe} \cdot q_p(z) = c_{pe} \cdot [1 + 7 \cdot I_v(z)] \cdot 1/2 \cdot \rho \cdot v_m^2(z) \qquad (1),$$

where: $$c_{pe} = \frac{\Delta p}{p_{\mathrm{dyn}}(z_{\mathrm{ref}})} = \frac{p(t) - p_0}{1/2 \cdot \rho \cdot \bar{v}^2(z_{\mathrm{ref}})}$$ is external wind pressure coefficient (2).

The value was calculated by Eq. 2, where *p(t)* is the wind pressure in measuring point on the surface of the model and p_0 is static pressure of undisturbed flow measured by Prandtl probe. Dynamic pressure of the mean wind velocity was considered in reference height (in our case, reference height was equaled to the height of the top edge of examined model).

$q_p(z)$ is peak velocity pressure, $v_m(z)$ is mean wind velocity at a height *z*, $I_v(z)$ is turbulence intensity at height *z*.

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The values of external wind pressure coefficients on the facade of high stand-alone building are specified in EN 1991-1-4. For two high buildings with weak interaction (Fig. 1) it is necessary to determine these values by experimental measurements. The experimental measurements were made in wind tunnel with boundary layer (BLWT) in Bratislava (see Hubova et al., 2014). New wind tunnel allows in its two measuring areas to simulate steady and turbulent wind flow. We tested the buildings configuration in the turbulent wind flow.

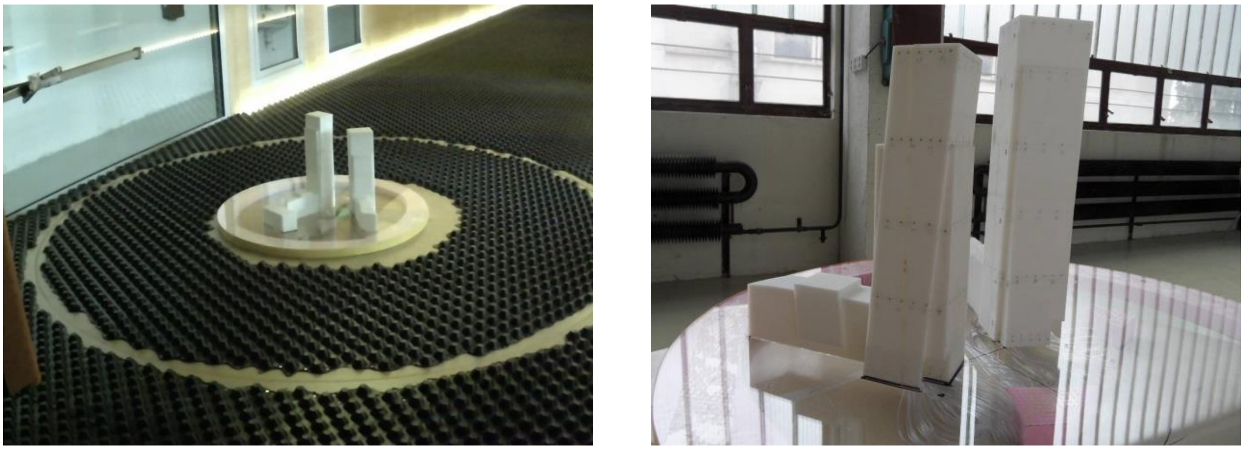

Fig. 1: Model of the high-rise buildings (SF 1:300) in turbulent wind flow and detail.

Reference wind speeds were selected so as to fulfill flow similarity of prototype and model. Velocities were chosen with regard to (ASCE Manuals 1999). In all positions measurements were made for 2 different velocities (9.255 m/s and 11.535 m/s).The model was rotated from initial positions (0 ° = North wind) every 22.5 º clockwise, thereby the changing of wind direction acting on the objects was simulated. We monitored the change of the wind flow on high buildings in sampling points for 6 height levels (see Fig. 2).

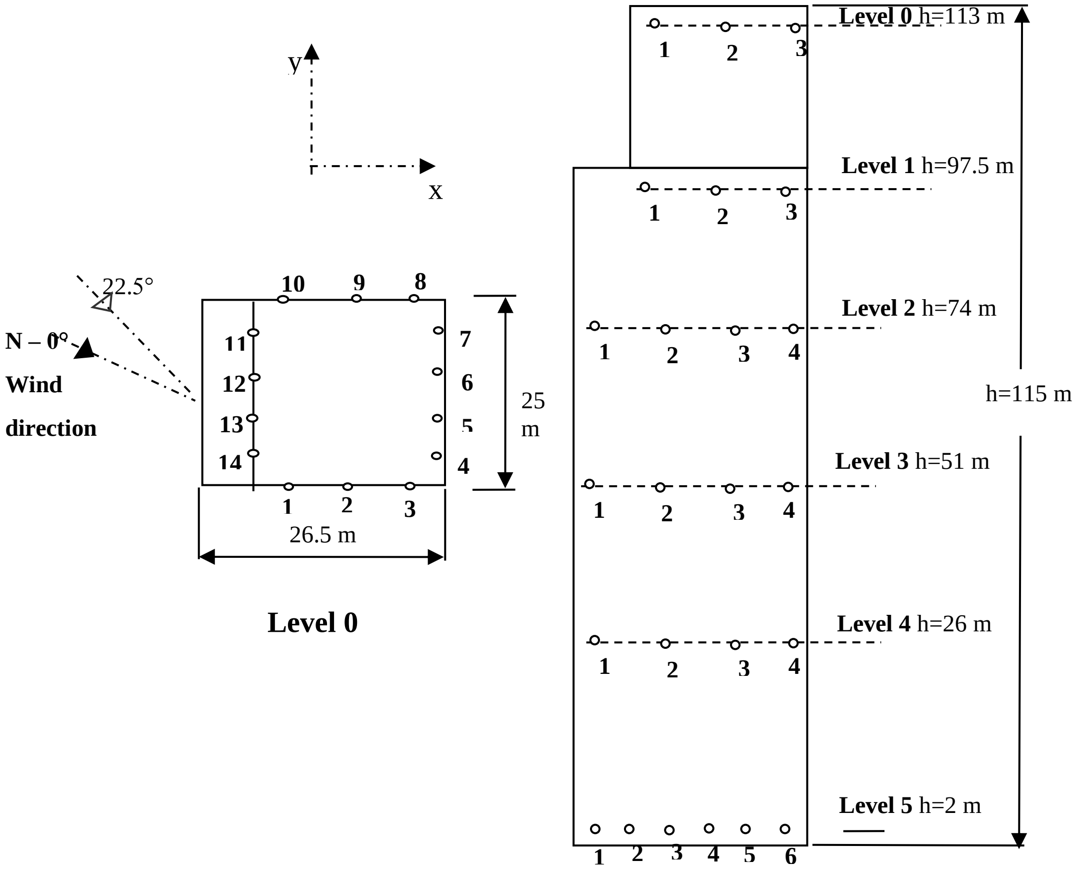

Fig. 2: Sampling points on the model of the higher building.

Measurements of local pressures under various wind directions using the turn table detected the direction in which we obtained the maximum values of wind pressures.

Comparison between the wind pressure on the facade of the 115 m high building obtained by calculation according to EN 1991-1-4 and the values obtained by experimental measurements (EXP) is shown in the graph in Fig. 3. The resulting values of wind suction obtained experimentally were significantly higher than values in accordance with EN standards. In the lower part of the building the suction values were twice as large as the standard values. The external wind pressure coefficients obtained from repeated experimental measurements made on model in turbulent wind flow indicate the local extremes of suction in certain directions.

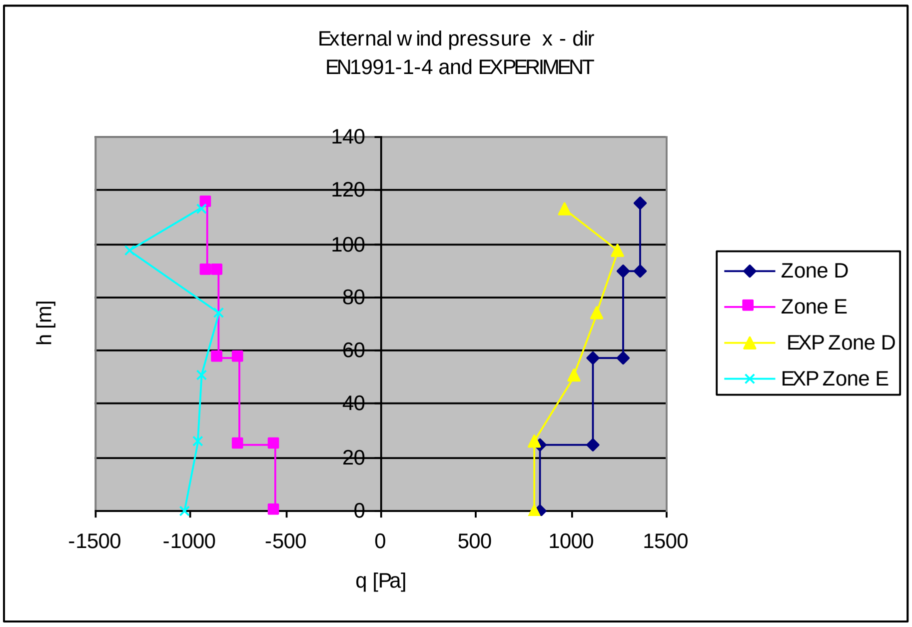

Fig. 3: Comparison of external wind pressure in windward D and leeward E zone.

3. Pedestrian wind comfort

Wind comfort criteria are based on the definition of the probability of exceedence P_{exc} of a given threshold effective wind speed V_{ef} at the pedestrian level ($z = 1.7 \div 2.0$ m) (see Tab. 1) and were defined by several institutions participating in COST 14 and authors (see Stathopoulos et al., 1992).

$$\mathrm{V_{ef}} = v_m(1.7 \div 2.0\,\mathrm{m}) \cdot \left[1 + g \cdot I_v(1.7 \div 2.0\,\mathrm{m})\right] \qquad (3)$$

*Tab. **1:** The scale of discomfort.*

V_{ef} [m.s^{-1}]	Pedestrian comfort
4	Standing, sitting - long period
6	The first feelings Standing sitting – short period
8	Slow walking
9	Walking is influenced
15	Walking is difficult

Tab. 2: Pedestrian wind comfort.

V_{ef} [m.s^{-1}]	Points
> 4 m/s	47 – 55, 61
> 6 m/s	19,20,21,22,23,25,29 - 38, 40 - 46
> 8 m/s	3,4,9,10,11,12,13,15,16,26,27,28, 39
> 9 m/s	A,B,C,E,F,G,O,N,M,H,I,J 0,1,2,5,6,7,8,16,17,18,

The effective speed at the pedestrian level was measured in 120 points (see Fig. 4), using a thermo-anemometer probe. The most unfavorable values are processed in Tab. 2.

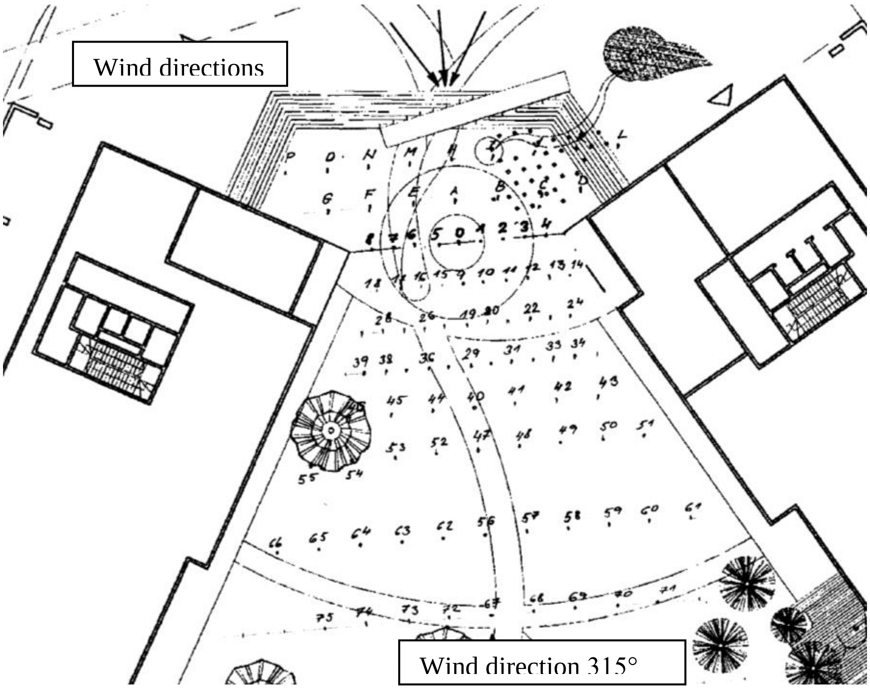

Fig. 4: Scheme of measurement points for determining the pedestrians wind comfort.

4. Conclusions

We analyzed the wind flow and effect of the structures between pair of tall building situated in central area of Bratislava and tried to find best situation for pedestrian wind comfort.

The external wind pressure coefficients obtained from repeated experimental measurements made on model in turbulent wind flow indicate the local extremes of suction in lower part of the building and in corners. Coefficients of suction in the corners were greater than – 2. The unfavorable situation is also the entry into the higher tower, where we measured suction - 1 050 Pa. We recommend not oriented entries in Northwest wind direction. The biggest problems will cause a north-west wind, which is by lower and higher buildings channeled into a narrow neck between buildings and wind speed is rapidly increased. Speed between buildings is affected by the distance between them the value of projects proposed 12.5 m causes a significant increase of wind flow near the ground. We recommend greater distance between buildings, to alleviate this phenomenon (see Tsang et al., 2009).

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