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External Pressure Coefficients on the Atypical High-Rise Building – Computing Simulation and Measurements in Wind Tunnel

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Abstract

This paper deals with determination of the external pressure coefficients on the new planned high-rise building with atypical cross-section. The building will be built in the center of Bratislava (Slovakia). The real area surrounding of the designed building was also considered. The main aim of this research was to find out the accuracy of the results obtained by computing simulation. Two types of surfaces of the model were taken into account – smooth and rough ones. The real structure had the surface roughened by using a façade with windows and columns between them. As the reference values of external pressure coefficients were considered the results obtained from the experimental measurements carried out in the wind tunnel laboratory. Short description of the designed structure and its surroundings, wind tunnel laboratory, experimental measurements, scale model of the structure, and computing simulation with considered input parameters are mentioned here. The Computational Fluid Dynamics (CFD) simulation was performed using 3D Reynolds-averaged Navier-Stokes CFD with the SST k-ω turbulence model. At the end of the paper, obtained results are discussed and some recommendations for planning engineers are presented.

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Keywords: BLWT; wind effects; experimental measurements; CFD; external pressure coefficients; high-rise building; atypical cross-section of the structure

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1. Introduction

At present, it is always a big challenge for architects and planning engineers to design a new high-rise building. Mostly, they prefer atypical shape of the structure which is unique and could hold public's interest. With respect to the fact that the wind load is an important input parameter in design of structure, its value can be determined by using standards (only selected shapes are mentioned, [1]), computing simulation (approximate estimation of the real results, [2-5]) or experimental measurements in wind tunnels (more accurate results, [6-8]). In the case of atypical structures, computing simulation is a cheaper solution. However, it is very important to use good input parameters. Wind tunnel tests are more expensive solution but they can solve different problems: investigation of the atypical structures or complex of structures, assessment of pedestrian comfort, aeroelastic tests (dynamically similar models of structures), terrain and topographic studies (wind flow above the complicated terrain, estimation of the terrain roughness, assessment of the wind energy potential of the locality), pollutants dispersion (dissipation of the impurities, trajectories of pollution). The best solution is setting the computing simulation by results obtained from wind tunnel tests.

Wind effects should be considered in design of structure, in assessment of the local effects on façade of structure, pedestrian comfort around the structure and on the terraces, and also in assessment of their utilization for energy production by using small wind turbines or crossflex, [9].

Nomenclature

$c_{pe,0}$	external pressure coefficient [-]
ρ	air density [kg/m^3]
$v(z_{ref})$	mean wind velocity in reference height [m/s]
$p(t)$	wind pressure in measuring point [Pa]
p_0	static pressure of undisturbed flow measured by reference probe [Pa]
ψ_α	end-effect factor [-]
Re_m	Reynolds number of the model [-]
Re_{norm}	Reynolds number according to standards [-]
d	characteristic dimension of the model [m]
υ	kinematic air viscosity, equalled to 1.5*10^{-5} [m^2/s]
v	undisturbed wind velocity [m/s]
v^*	shear velocity [m/s]
κ	von Karman constant, equalled to 0.42 [-]
k	turbulent kinetic energy [m^2/s^2]
ε	turbulence dissipation rate [m^2/s^3]
ω	specific turbulence dissipation rate [1/s]
I_t	turbulence intensity [%]
z	the height coordinate [m]
K_s	roughness height [m]
z_{ref}	reference height [m]
z_0	aerodynamic roughness height [m]
Y_p	mesh height [m]

2. Description of the structure

Designed high-rise building TWIN CITY A1 Bratislava is a new project of developer company HB Reavis. This building will be built in the center of Bratislava in front of the Central Bus Station. A cross-section has the shape of the rectangular with rounded corners. Total dimensions of the real structures are (27.3×48.9×91.5) m (w×l×h), Fig. 1a. The façade is not smooth, but there are columns between the windows. Detailed view of the façade is shown in Fig. 1b. It should be very difficult to create the exact model with this type of façade for computing simulation; therefore two types of the surfaces of the model were considered – smooth and rough ones. In this research, only flat roof without