WIND ACTION ON A HIGH-RISE BUILDING OF ATYPICAL SHAPE – MODEL TESTS IN WIND TUNNEL

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Abstract: This paper focuses on wind tunnel model tests conducted at Wind Engineering Laboratory of Cracow University of Technology in order to determine wind action on construction and façades of a high-rise building located in the centre of Warsaw, Poland. The building is 95 m tall. Wind pressure was measured at 256 points on the exterior surfaces (walls, rooftop and terraces) for 24 different wind directions with a step of 15°. Model tests scale was 1:175. The model included subject building and its surroundings in the radius of 175 m. Pressure coefficients determined in the tests allowed for calculation of aerodynamic forces F_x and F_y and moments M_x, M_y and M_z on each storey of the building and its foundation. The investigations give a good oversight not only of wind pressure distribution on a high-rise building located in dense urban environment, but also of the actual influence of wind action on the cladding and the bearing structure. Based on the tests, general instructions were released for consulting engineers and façade designers.

Keywords: wind engineering, aerodynamic interference, wind pressure, local and global wind actions, structural design

1. Introduction

Wind tunnel tests focused on a high-rise building *Rotunda Towers* located in the centre of Warsaw. The building planned height was 95 m. Its form is based on an irregular polygon in top view, resembling two merging towers. (comp. Fig. 1). The subject building was recreated with its surroundings in a radius of 175 m. Interference of these surroundings and the resulting pressures on subject building's surfaces was the main concern during the wind tunnel tests [1].

a) b)

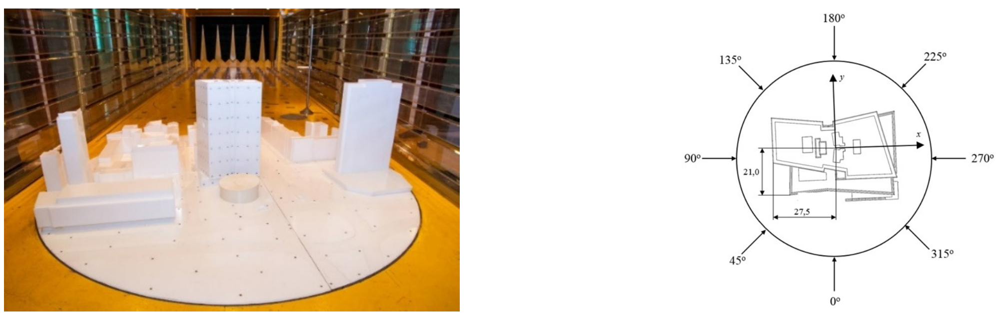

Fig. 1 – Building model and its surroundings: a) physical model in the working section of wind tunnel, b) location of the geometric centre and main wind inflow directions

2. Characteristics of wind tunnel tests

Wind pressure was measured at 256 points on the external surfaces (walls, rooftop and terraces) for 24 different wind directions with a step of 15°. The tests were conducted using two *DTC*

Initium pressure scanners and a Pitot-Static (Prandtl) tube for reference. The experiments were performed at the following conditions:

- power law exponent of the mean wind velocity profile α=0.30 (dense city centre);
- average turbulence intensity I_v=15% at the reference level of 0.55 m;
- reference wind velocity V_{ref} = 11.3 m/s.

The obtained results were dimensionless wind pressure coefficients, which allow for easy transition from model to natural scale [2]. They are calculated as:

$$C_{pe,i} = \frac{p_{e,i}}{q_{ref}} \tag{1}$$

where: $C_{pe,i}$ – wind pressure (external) coefficient at i-th measuring point, $p_{e,i}$ – mean wind pressure at i-th measuring point, q_{ref} – reference pressure velocity from Prandtl tube.

3. Resulting aerodynamic forces and moments on the structure

Design wind pressures, calculated with respect to [3], were subsequently applied as pressure loads into building's numerical model in *Autodesk Robot Structural Analysis* for 8 different wind directions (see Fig. 1b). The numerical model was created as a stiff, fixed cantilever beam with nodes at each storey level, located in the geometrical centre of the building. This allowed for determination of aerodynamic forces and moments at the foundation and at each storey, shown in Fig. 2.

a) b)

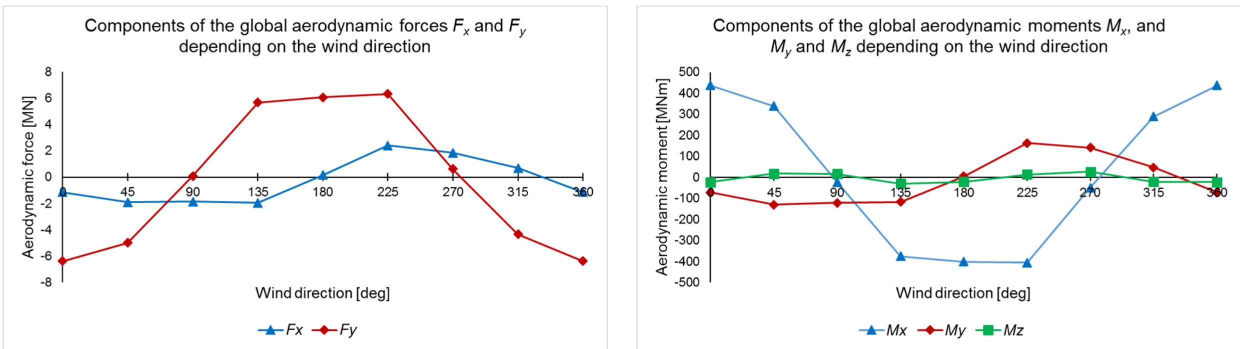

Fig. 2 – Relationships between wind inflow direction and global aerodynamic a) forces, b) moments

4. Conclusions

As can be seen in the graphs in Fig. 2, the nature of every global force is strongly influenced by wind direction, ranging from negative to positive values in a sinusoidal fashion. Values of horizontal force F_y and bending moment M_x reach values which are considerable even for a structure of such massive dimensions. Extremes of these forces and moments occur for different wind direction angles.

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References

[1] Flaga A., Flaga Ł., Szeląg A., Kłaput R., Kocoń A., Krajewski P., Pistol A., Augustyn A. (2018). *Wind tunnel model tests of a high-rise building located at al. Jerozolimskie 44 in Warsaw.* (L4/746/2017/P) [in Polish].

[2] Flaga A. (2008). *Wind engineering. Fundamentals and applications.* Warsaw, Poland: Arkady [in Polish].

[3] PKN. (2008). Actions on Structures. General Actions. Wind Actions. PN-EN 1991-1-4 [in Polish].