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DEVELOPMENT OF LOCAL WIND CLIMATE AS AN ELEMENT OF RURAL PLANNING[1]

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Summary. Planning in rural areas needs interdisciplinary approach, combining knowledge in several fields such as ecological construction, local energy supply systems, physics of buildings and infrastructure, development of wind climate. The article presents the issues of rural planning including the wind comfort criteria. The analysis was based on the results of experimental and numerical methods to assess wind conditions at pedestrian level.

Key words: local wind climate, rural planning, rural areas

INTRODUCTION

Spatial planning of rural areas should take into account their multi-functionality, creating conditions for the various economic activities conducted in compliance with the environmental aspects and the development of social and cultural functions. The issues that concern planners, such as the optimal location of farms or drawing of routes, are an integral element of planning which is the impact on the local wind conditions. The presence of buildings significantly changes the local wind climate in the place of their location. The factors that make up the outer atmosphere of the buildings are: force and direction of wind, its velocity, air pollution, raindrops lifted with the wind and sunshine. Each of these factors depends on the shape, size and orientation of buildings to the direction of wind flow and their interaction with surrounding buildings or other landscape elements in the environment, such as trees [Blocken and Carmeliet 2004]. Increased wind velocity around building leads to uncomfortable or even dangerous

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conditions for pedestrians, decreased wind speeds lead to insufficient removal and accumulation of pollutants of various origins, such as dust, gaseous pollutants, odours, garbage, acoustic effects. Discomfort due to wind velocity at pedestrian level is one of the problems that are considered most important. In the framework of the European COST Action C14, the first Working Group has gathered various wind comfort criteria with the purpose of discussing the present state-of-the-art, identifying differences, and initiating a common criterion or code of good practice [Koss 2006].

This article describes the problems of rural planning including the wind comfort criteria. Wind climate in urban areas and any of their engineering implications (architectural design, land development) is important to planners, designers, building contractors. This article focuses on the importance of this issue for the environment. All existing criteria for wind comfort specify threshold values or comfort ranges for respective weather parameters. Several criteria have been developed in the wind engineering community for evaluating the wind-induced mechanical forces on the human body and the resulting pedestrian comfort [Blocken and Carmeliet 2004]. The article presents experimental and numerical methods for the determination of local wind conditions in the built-up area, and suggests the method of selecting the optimal configuration of building elements ensuring proper comfort for users.

PROGRAM OF THE STUDY

As a result of experimental and numerical analysis of air flow, the wind conditions in an existing building arrangement can be determined, and changes caused by the introduction of new facilities in an existing housing development can be predicted. The air flow across built-up area is an extremely complex phenomenon. The direction and speed of air streams are affected by both the array of buildings, their size, as well as characteristics of the ground and turbulence. The building arrangement can sometimes cause an increase of velocity and turbulence of air flow, leading to adverse effects such as wind discomfort, pollutant dispersion or heat loss in buildings. Simultaneously, buildings are a barrier to air flow, causing problems with ventilation in built-up areas. Application of modelling techniques allowed to obtain images of flow structure around objects that provide information about the location of the air stagnation zone and areas characterised by a marked increase of velocity gradients.

The general task of the research program focuses on the optimisation of buildings configuration to provide local wind comfort. The paper analyses a simple example of inline arrangement of two buildings as a function of variables, describing their distance to each other, „immersion" in the boundary layer and height ratio H_1/H_2 (see Fig. 1). Width of both models as well as height of downwind one were kept constant and had the following values: D = 0.04 m, H_2 = 0.048 m, and inflow velocity U_0 = 13 m/s [Gnatowska 2010a, b]. The results of numerical testing presented in this work relate to three values of fixed ratio of objects height $H_1/H_2 = 0,6$; $H_1/H_2 = 1,0$ and their „immersion" in the boundary layer $H_2/\delta = 0,6$.

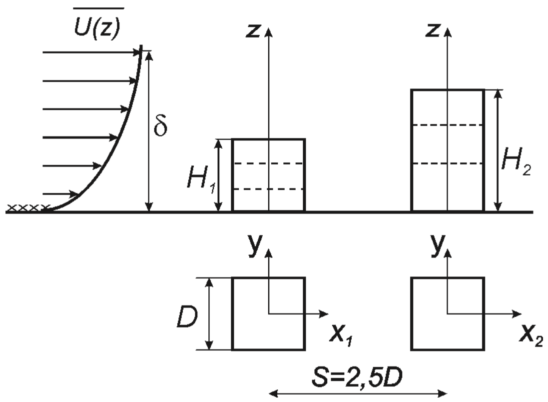

Fig. 1. Schematic diagram of objects configuration in tandem arrangement

The experimental studies were conducted in an environmental wind tunnel, at ITM CzUT, using surface oil visualisation technique as a primary method of detection of specific areas of flow around a group of objects in the analysis of the buildings aerodynamics. The numerical simulations used to locate the characteristic zones around bodies arrangement were performed with the use of the FLUENT commercial code in RNG version of k-ε turbulence model [Gnatowska 2010a]. According to the literature [Ferreira *et al*. 2002, Gnatowska 2010a] this model is widely used for flows in a built-up environment. Ferreira *et al*. [2002] have found a good agreement between computation and measurement of the building interference effects on pedestrian level comfort.

RESULTS AND DISCUSSION

The scope and shape of wind discomfort areas may be affected by a wide range of factors associated with the external environment suggested by Blocken and Carmeliet [2004], such as wind power, wind direction, thermal conditions, air quality, noise level etc., which are derived from the environmental aerodynamic effects.

The issue of detection zones of discomfort, the result of numerical simulations, was analysed as an example of distributions of longitudinal component of the reduced average speed by the longitudinal component of mean velocity measured at the height of the first object of the undeveloped area U/U_{H1} (Fig. 2). In the analysed system, areas with high wind discomfort include external areas of buildings and also the space between the objects, which are the result of the „down-wash" phenomenon for $H_1/H_2 = 0,6$. This effect consists in washing of front side of the leeward object with large air masses, which results in strong air

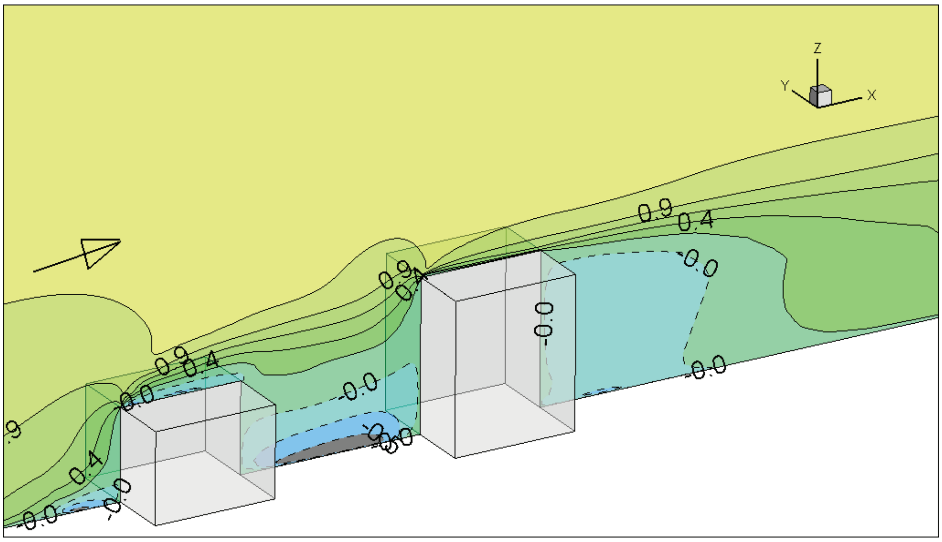

Fig. 2. The contour of longitudinal component of mean velocity U/U_{H1} in the plane $y/D = 0$

circulation in the area between objects, which determines the flow structure between them. Strong convection stabilises the flow between objects, but on the other hand causes significant increase of the flow velocity at ground level and, consequently, raises the wind discomfort. Numerical modelling perfectly reflects the nature of flow in the areas of attack on objects, where the horseshoe vortex is formed (backflow zone marked by broken line – Fig. 2).

This issue is discussed *inter alia* in the work of Gnatowska [2010a], where the procedures to enable comparison of the available literature based on the criteria of comfort and an estimate generated by the error can be found.

According to Fig. 3, which presents the results of the surface oil visualization, the biggest changes in the flow field are observed for the space between objects and outside of the analysed system. This method allows the identification of topology of the flow around obstacles set on the ground, and thus the location of zones of wind silence and higher wind velocity. Comparison of calculations and experimental data concerning the location and scope of characteristic features of wind flow over the ground in the vicinity of the studied objects points to a qualitative similarity of the results in the zone between the buildings and in the wake behind the system. Its presence is clearly visible in the images from oil visualisation.

The results obtained by oil visualisation were considered sufficiently clear to serve as a reference for the results of numerical simulations which included the unfavourable configuration [Jarża and Huptas 2005].

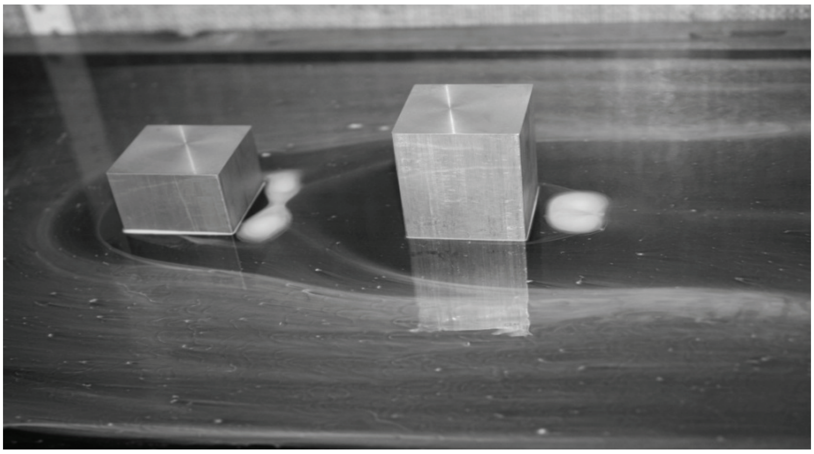

Fig. 3. The oil flow visualisation around two objects in tandem arrangement $H_1/H_2 = 0.6$; $S/D = 2,5$; $H_2/\delta = 0,6$.

CONCLUSIONS

Experimental studies in full- and model-scale have been the main tool used to characterise the turbulent flow in ground-level zone over a long time. The dynamic development of mathematical models and technological progress have enabled prediction of the pedestrian wind environment around buildings based on CFD (Computational Fluid Dynamics), but it is advisable to combine the methods of numerical simulation with experimental modelling.

Attaching too little attention to the climatic conditions can lead to many problems such as air pollution, too strong or weak solar radiation, poor lighting of buildings. Increased air flow within the streets, squares and other urban spaces often becomes the cause of discomfort to pedestrians, heat loss in buildings, or structural damage to buildings [Koss 2006, Stathopoulos 2009]. Knowledge of the velocity distribution around the buildings, both existing and proposed, becomes extremely important.

The choice of the optimal configuration of buildings that ensures proper user experience of the built-up area requires taking into account a greater number of often conflicting criteria. It is necessary to prioritise and give each of the criteria appropriate importance. The combination of numerical simulation with the multi-criteria optimisation procedures is the way to create a practical calculation tool, useful in the design of building arrays. It allows the modelling of local wind conditions to determine the location of the wind discomfort zones and optimising development conditions for pedestrian comfort criteria, including the number of decision variables.

Similar analyses for various configurations and conditions can be conducted for the selection of optimal solutions with respect to various wind comfort criteria. The numerical method used here can be a convenient tool, helpful in considering a wide number of variations.

REFERENCES

Blocken B., Carmeliet J., 2004. Pedestrian wind environment around buildings: Literature review and practical examples. J. Therm. Envel. Build. Sci. 28(2).

Ferreira A.D., Sousa A.C.M., Viegas D.X., 2002. Prediction of building interference effects on pedestrian level comfort. J. Wind Eng. Ind. Aerodyn., 90.

Gnatowska R., 2010a. Wind comfort problems in built-up areas (in Polish). Zesz. Nauk. Polit. Rzeszowskiej, 271, Budownictwo i Inżynieria Środowiska 57, 4.

Gnatowska R., 2010b. Design of built-up areas taking into account sustainable development at the regional level (in Polish), in: Zrównoważony rozwój regionów, Toruński J., Wyrębek H. (eds.), Wyd. Studio Emka, Warszawa.

Jarża A., Huptas M., 2005. Formation of local wind climate as part of the urban areas planning (in Polish), in: Zrównoważone systemy energetyczne – monografia pod red. Waldemara Wójcika. Lubelskie Towarzystwo Naukowe, Lublin.

Koss H.H., 2006. On differences and similarities of applied wind comfort criteria. J. Wind Eng. Ind. Aerodyn., 94.

Stathopoulos T., 2009. Wind and comfort, Proc. of EACWE 5, Florence.

KSZTAŁTOWANIE LOKALNEGO KLIMATU WIATROWEGO JAKO ELEMENT PLANOWANIA OBSZARÓW WIEJSKICH

Streszczenie. Zintegrowane podejście do planowania przestrzennego obszarów wiejskich polega m.in. na interdyscyplinarności wykorzystywanej wiedzy z szeregu dziedzin (budownictwo ekologiczne, lokalne systemy zaopatrzenia w energię, kształtowanie klimatu wiatrowego). W artykule zaprezentowano zagadnienia planowania przestrzennego obszarów wiejskich, w tym kryteria komfortu wiatrowego. Analiza została oparta na wynikach badań eksperymentalnych i na obliczeniach warunków wiatrowych na poziomie pieszych.

Słowa kluczowe: lokalny klimat wiatrowy, planowanie przestrzenne, obszary wiejskie