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APPLICATION OF MODEL METHODS IN DESIGNING AND MODERNIZATION OF BUILT-UP AREAS

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Processes of spatial planning and modernization of built-up areas require a complex combination of issues important for the development of sustainable urban structures, such as: ecological constructure, wind climate (Environmental Aerodynamics), land development. The presented analyses refer to numerical (CFD) and experimental (in a tunnel) methods of modelling the air flow in a space between buildings. The subject of the research is a part of a built-up area consisting of a tandem of two buildings of different heights and exhibiting the “down-wash” effect.

Keywords: modelling methods, spatial planning

1. INTRODUCTION

Spatial palnning and modernisation of built-up areas require a comprehensive approach of numerous diverse disciplines that make up the functioning of the municipal entity. They are such spheres as: economy, society, ecology covering broad aspects of sustainable development (including transport and construction). Dealing with these problems and their implementation are of particular significance, not only because of the improvement of living conditions in the cities and the quality of the public space, but also because it is an important factor in rising the competitiveness of cities. Among such issues as: urban regeneration, the optimal location of buildings or laying out routes, which are the concerns of architects, engineers, urban planners, also recognition of local wind conditions should be taken into account. To environmental factors that make up the ambient atmosphere of buildings, include the following: wind speed and direction, air pollution, wind-lifted raindrops and sunhine. Each of these factors depends on the shape, dimensions and orientation of the building

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in relation to the wind inflow direction and its interaction with other objects in their vicinity, such as other buildings, trees or landscaping elements [3]. Increased wind speed around buildings leads to feelings of discomfort and may even pose dangers to pedestrians, while the reduced wind speed causes the accumulation of pollutants of various origins, such as gaseous pollutants, dust, wind-flying garbage, sound effects, etc.

This issue is important because of the increased public interest in functionality of the buildings and surrounding areas, forcing architects, engineers and urban planners to consider a number of often conflicting factors and searching for the solutions which would ensure the quality of life for residents (figure 1).

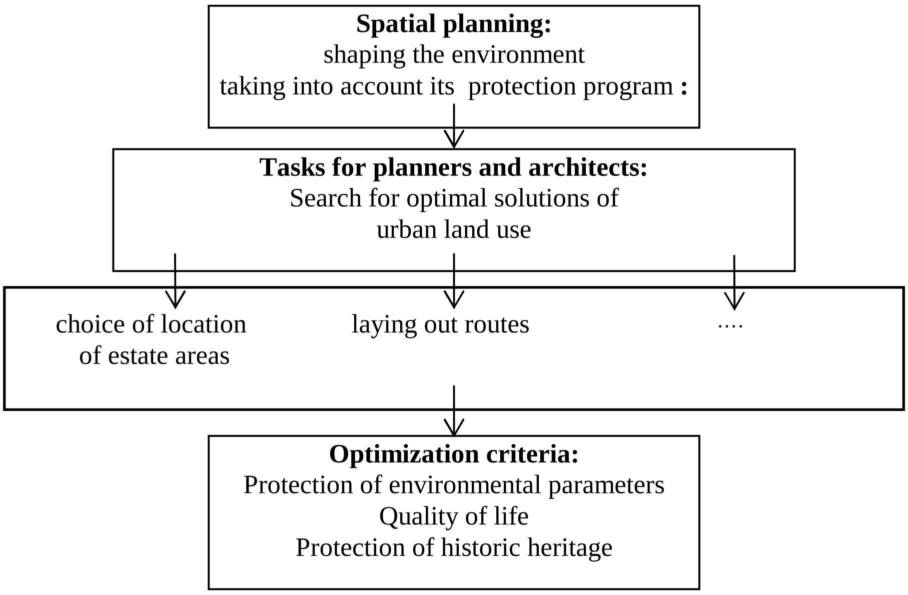

Fig. 1. A chart of planning and modernization of built-up areas. Source: own elaboration

Spatial planning and modernisation of built-up areas and any related engineering processes (architectural design, land development) constitute an important concern for urban planners, designers and constructors. In addition, knowledge of the aerodynamics of the environment can help shape the ambience and wind climate of urban facilities suitably in order to provide their users with the appropriate comfort [1, 4-5]. The article emphasises the importance of this problem in the process of planning and modernization of the built-up areas. The paper presents experimental and numerical methods for determining local wind conditions in urbanized areas, and proposes a method of selecting optimal configuration of structural elements providing adequate comfort for their users.

2. PROCEDURES OF MODELLING METHODS

Traditional modelling methods of environmental research in built-up areas, base on research conducted in the wind tunnel applying similarity criteria. Among the most widely used experimental studies are visualizations such as: smoke, oil, and using threads sticked into the model, the determination of pressure distribution on the walls and roof of the building and the surrounding subsoil, measurements of speed, turbulence and stresses. A typical configuration of the wind tunnel with an open circuit used in the modelling of a ground-level layer is shown in Figure 2. The measuring part of the tunnel together with the instrumentation is located in its central parts. The tested system and its surroundings is mounted on a turntable (with the scales to measure the aerodynamic forces) allowing the change of the direction of factor flowing into it. The “working” factor is the air, movement of which is forced by axial fans located downstream of the tunnel in order to obtain average speed within the range of 5-20m/s. At the inlet of the tunnel there is a fabric filter and a grid system as well as other elements stabilizing the flow. Typical scales of models of large buildings are in the range 1:200 to 1:500. Experimental model analysis as opposed to real facility testing allows the isolation of the studied phenomena from interfering influences. Test cycles can be repeated under controlled laboratory conditions. By using increasingly sophisticated techniques and sensors such as thermal anemometer, laser anemometer or visualization techniques, values, which are impossible to determine in research on real objects, may be obtained. Wind tunnels can provide test conditions which are both well-defined and possible to control, but they do not include all of ground-level atmospheric characteristics. Research is also conducted on real objects in order to obtain data on wind loads and to determine the atmospheric wind characteristics, necessary for the proper simulation of natural wind. The results of experimental studies are also a good material to verify the developed numerical modelling methods. In addition, numerical modelling methods (CFD) have recently become a significant tool supporting the development of the aerodynamics of the environment. Their use in solving problems of wind-engineering and of aerodynamics of structures are referred to as computational wind engineering (CWE). The review of CWE methods presented in the work of Mochida and Lun [6] shows their significant development as a tool in the analysis of environmental design.

The use of experimental and numerical modelling methods of air flow enables the determination of wind conditions in the existing system of a built-up zone, as well as to predict the changes caused by modernization.

2.1. Research subject and method

The subject of the analysis is a tandem configuration of objects, which is schematically shown in Figure 3. It shows the basic relations of geometric parameters of objects and defines the coordinate system. Dimension S is the distance between the elements. Parameter S/B=1.5 – 3.0 in the study (where B is the length of the edge of the object). The height of the buildings remained unchanged, as described by parameter H1/H2=0.6.

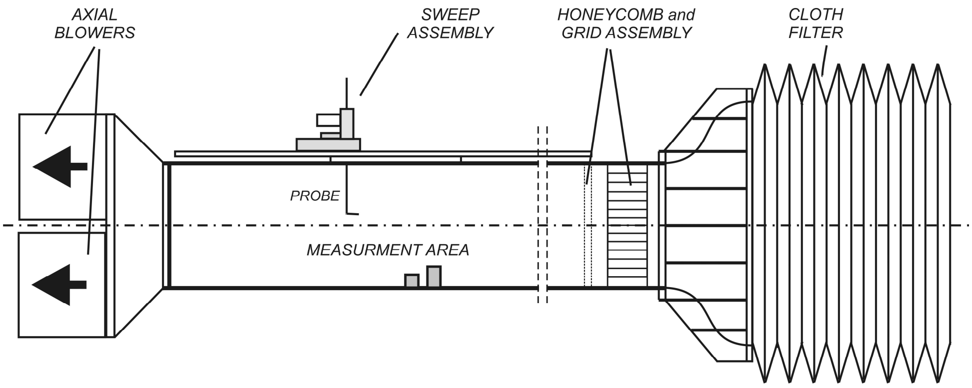

Fig. 2. A typical configuration of the wind tunnel with an open circuit used in the analysis of a number of wind engineering issues.

The considered case refers to the flow of air from the lower object, which results in the occurrence of the so-called "down-wash" effect. The phenomenon, in which large masses of air run down along the front wall of the leeward building, results in a strong circulation of air in the space between the objects.

The geometry of the system was chosen on data presented in [7], which indicates that the analysed case as a common architectural problem, causing extremely adverse wind effects. The results of the surface oil visualization were compared with the distributions of average speed in the modelled area between the buildings which were obtained in numerical simulations.

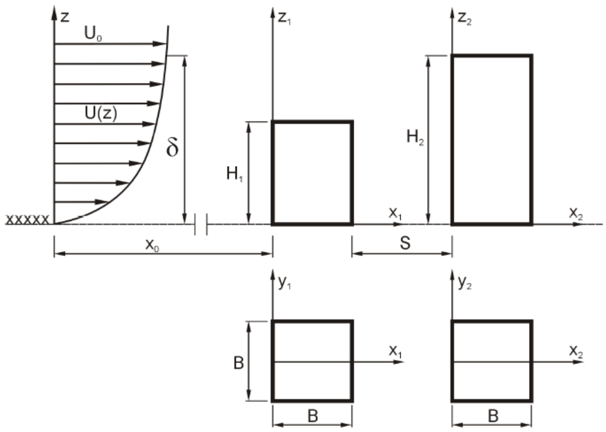

Fig. 3. Diagram of the considered configuration of objects in a tandem system

Air flow in the scale of a housing estate or simple building structures is a very complex phenomenon. Factors that affect the direction and the speed of air streams are as follows: arrangement of buildings, their size, and surface characteristics or turbulence. The arrangement of buildings can increase the speed or turbulence of the airflow, thus resulting in adverse effects, such as discomfort, wind, spread of pollution, or heat loss in buildings. At the same time, buildings may form, in certain situations, a barrier for the flowing air, causing problems with ventilation in built-up areas. The distance between adjacent buildings is one of the main parameters to be taken into consideration. Figure 4 shows how this parameter affects the shape of the flow. It presents the change in pressure distribution when a subsequent building is put in the aerodynamic trace of wind of the former building. We can observe that a too small distance between the objects causes the occurrence of a substantial vacuum in the area between the buildings.

As the space between the buildings increases, the flow begins to level off, as a result the situation resembles the one at the front of the first building.

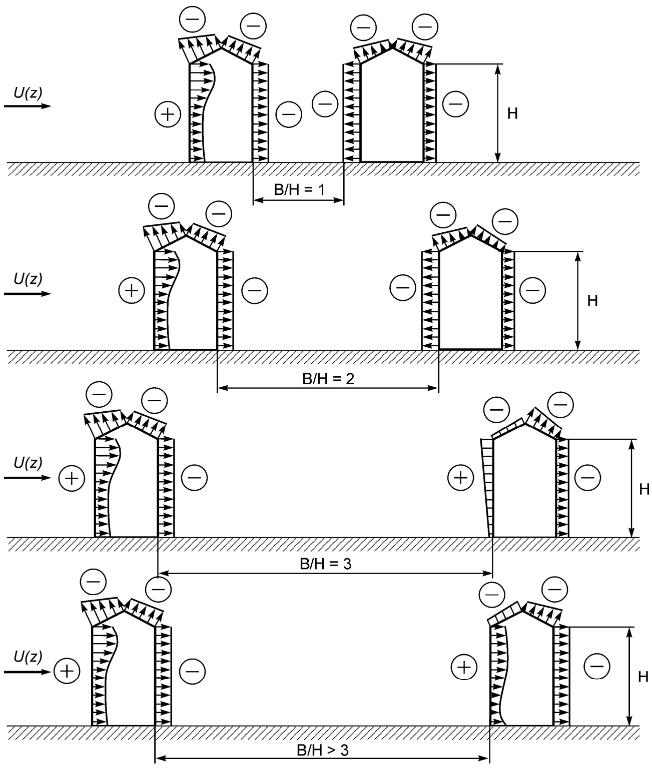

Fig. 4. The distribution of static pressure on the surface of objects as a function of the distance between them.

2.2. Examples of modelling methods application

To illustrate the usefulness of these modelling methods, the numerical results and the experimental measurements for the tested configuration of objects are presented below. Figure 5 presents the velocity distribution in the form of U/U0 (where U0 is the average velocity in the flow undisturbed by the presence of objects). Basing on the presented visualization of the velocity distribution in the space between the buildings, we can confirm the occurrence of the so-called. downwash effect. In these places, the air accelerates considerably, swirls and then flows back since the space is supplied with air mass flowing along the windward wall of the leeward building. For larger spacing of buildings (Fig.5b), the area of the backflow behind the windward object is also larger, but the value of speed in this case is smaller in comparison to the first configuration (Fig. 5a). It means that the increase in the distance between buildings has a positive effect on the flow around them. Further increase in the space between the objects (Fig. 5c) results in the reduction of disadvantageous wind conditions.

As shown in Fig. 6, demonstrating the results of the surface oil visualization, the biggest changes in the flow field are also observed in the space between objects, and in the immediate vicinity of the buildings. The surface oil visualization technique is considered a helpful experimental tool used in the detection of specific zones of wind flow around obstacles erected on the ground, and thus the location of the areas of low wind zones and the ones characterised with the increased speed of wind.

a)
b)
c)

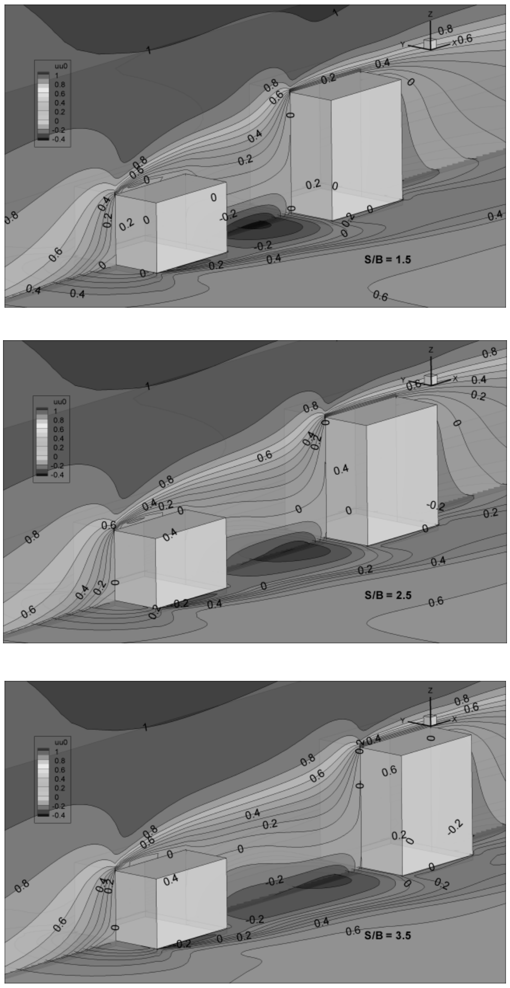

Fig. 5. Contour plot of the velocity distribution U/U0 in the objects' vicinity i.e. in planes *y/B=0* and *z/B=0*: a) *S/B* = 1.5, b) *S/B* = 2.0, c) *S/B* = 3.0

a)

b)

c)

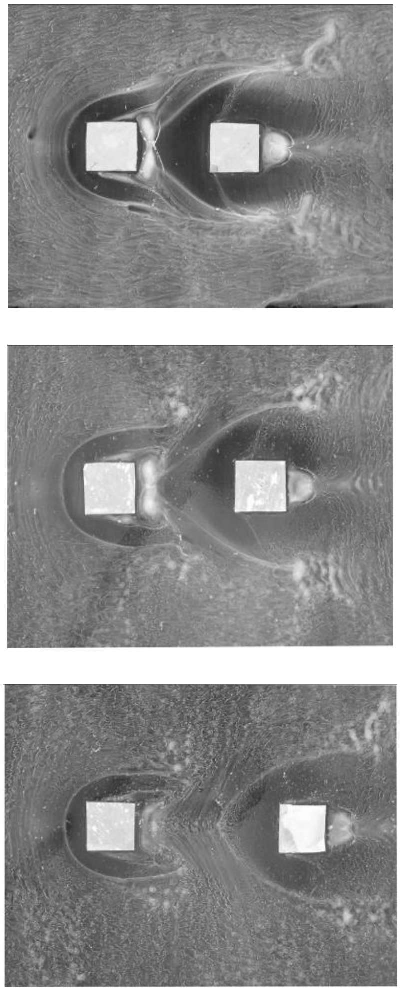

Fig. 6. The results of oil visualization of in the objects' vicinity in the tandem configuration: a) S/B = 1.5, b) S/B = 2.0, c) S/B = 3.0

Summarising, as a result of aerodynamic research, subject of which includes built-up areas, the images of velocity fields and pressure distributions on the walls of buildings are obtained. The interpretation of the findings provides answers to the questions referring to the impact of buildings on the direction and intensity of local wind conditions [4].

The knowledge is then used by architects and engineers in order to:

- realise undertakings related to designing new construction projects, revitalization projects and development of public spaces, demolition or partial demolition of buildings and structures;

- provide comfort for residents by eliminating the tiring gusts of wind near buildings, drafts and noise caused by air movement;
- anticipate, among others, the course of the dispersion of pollutants rising from factory chimneys as well as to find locations of particularly high concentrations of pollutants.

3. SUMMARY

The air flow in urban areas often causes discomfort for pedestrians, heat losses in buildings, or even damage to building structures. It is particularly important to recognise the velocity distribution of winds around the existing and designed buildings, as well as the ones subject to modernization. An integrated approach to land-use planning of the built-up areas reveals its interdisciplinary character.

Experimental model tests in wind tunnels have long been the dominant tool used to characterize the wind flow in the ground-level zone. Numerical methods for modelling of wind flows in urban areas are increasingly frequently used (tools for architects and urban planners) due to the dynamic development of mathematical models and technological progress, but in order to find optimal solutions, it is necessary to analyse a large number of flow systems dependent on the mutual configuration of buildings, their geometry and location in relation to the wind inflow [2, 5]. This enforces the use of numerical simulations coupled with optimization procedures in order to develop a computational tool to determine the position of discomfort zones as well as to optimize building conditions (zoning).

ACKNOWLEDGEMENT

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ZASTOSOWANIE METOD MODELOWYCH W PROJEKTOWANIU
I MODERNIZACJI OBSZARÓW ZABUDOWANYCH

S t r e s z c z e n i e

Procesy planowana przestrzennego i modernizacji terenów zabudowanych wymagają kompleksowego połączenia zagadnień istotnych w tworzeniu zrównoważonych struktur urbanistycznych, m.in.: eko-budownictwa, klimatu wiatrowego (Aerodynamika Środowiska), zagospodarowania terenów. Eksperymentalne badania modelowe w tunelach aerodynamicznych były przez długi czas dominującym narzędziem stosowanym w celu scharakteryzowania przepływu wiatru w warstwie przyziemnej. Dzięki dynamicznemu rozwojowi technologicznemu coraz powszechniej stosowane są numeryczne metody symulacji przepływu wiatru w obszarach zabudowanych. Przedmiotem prezentowanych badań jest fragment obszaru zabudowanego składający się z układu tandem dwóch modeli budynków o różnych wysokościach charakteryzujący się występowaniem efektu „down-wash”.