THE INFLUENCE OF WINDSCREEN ON WIND FLOW

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Summary

The paper presents the results of numerical simulation of wind flow around group of buildings in an existing housing estate. As a result of investigation some zones in which wind comfort can be disturbed has been determined. In order to improve wind condition around buildings a windscreen has been proposed. Three types of wind screens have been considered: earth berm, acoustic screen and row of trees. The effect of windscreen on the wind flow patterns has been investigated for eight direction of wind. Calculation have been made with the use of Fluent CFD code. Numerical simulation has been based on the turbulence viscosity model k - ε and wall function

Keywords: Windscreen, numerical simulation, pedestrian comfort

1 Introduction

In urban areas, due to the interference of buildings, the near ground flow exhibits sudden changes in speed and direction, which are difficult to predict. The wind flow at ground level around buildings is the result of complex interaction between the wind (mean vertical speed gradient, turbulence) and the buildings themselves (shapes, sizes, position etc.).

The more or less arbitrary setting of the buildings can create zones of over speed and vortices in the passages, playgrounds, open spaces etc, and lead to very unpleasant wind effect on people's comfort or even on vegetation and urban traffic.

Wind conditions near building corners can be dangerous because of very sudden changes in wind speed and wind direction. A sudden increase of wind speed to 15 m/s or more can be sufficient to bring people out of balance [1]. If the air temperature in winter is low, the chilling effect of wind could be so strong that pedestrians cannot walk comfortably and safely. Therefore, it is essential to reduce the wind speed around buildings. There are several methods which can be used to improve wind comfort in urban areas. The most common are shelterbelts, fences, walls etc.

Windbreaks are built using various materials and techniques. They can consist of trees properly selected and strategically planted (shelterbelts), or they can simply be fences (made of any suitable material) palisades, walls, earth berms, artificial sand dunes, etc.

Their basic function is to create an area protected from strong wind, increase productivity and improve the quality of the living environment. Different structures of windbreaks, in terms of length, height, composition by species and penetrability to the wind have easily visible effects on the microclimate in its vicinity [2, 3, 4]. In most studies the windbreaks are assumed existing in open space without any objects in its vicinity which can disturb air flow. In a built-up area however, the presence of buildings become crucial. The large size of surrounding structures and high density housing affect effectiveness of the windbreaks.

2 Numerical solution

Analysed urban structure consists of seven dwelling buildings creating two interiors. It is located in suburban area in Warsaw. Occupants of those buildings complained for unpleasant wind condition especially during winter time.

Dimensions of the buildings and their arrangement presents **Tab. 1** and **Fig. 1**.

Tab. 1 Buildings dimensions.

Buildings	W	L	H
	m	m	m
4, 6	27	9	15.5
5, 7	32	9	15.5
3	32	9	15.5
1, 2	10, 25	10	12

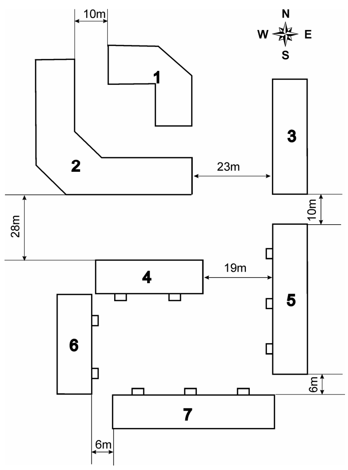

Fig. 1 Buildings arrangements.

The area around buildings from west and south side is rather flat with single low obstacles. From north and east side buildings are surrounded by other structures with the same height, located in a distance about 150 m and 50 m respectively. In the case of the north wind direction relatively large distance to the closest buildings makes them less important as the shelter for the complex. Besides north and northeast wind directions occur very rarely. However buildings located on the east side of the analysed buildings complex in some situations could disturbed wind flow. In the case of the east wind direction the velocities in the passage between buildings 3 and 5 would be probably lower. On the other hand for the southeast direction corner streams of the surrounding buildings could bolster wind flow in the canyons. Because of the computer limitation adjacent structures haven't been included in the simulation.

The numerical analysis has been conducted with aid of the standard k - ε model proposed by Launder and Spalding [5]. The governing equations are the time-averaged, momentum, continuity and the k - ε model equations. [6]. In order to prescribe the boundary conditions the wall function method by Launder and Spalding [5] has been used. Inlet condition assumed in simulation are described in [6].

3 Results

The analysis has been done for a height of 1.8 m (pedestrians height). The results of CFD simulation were presented as the ratio of the mean wind speed *V* at the pedestrian height to the reference wind speed at the same height (V/V_o).

To improve wind conditions in analyzed urban structure windbreaks have been proposed. Three different kinds of windbreaks have been considered: earth berm, acoustic screen and shelterbelts. Surrounding of the analysed urban structure determined arrangement of the windbreaks. **Fig. 2** and **3** show the location of windbreaks.

In the case of shelterbelts two kinds of their arrangement have been considered. In the first case (shelterbelt 1) raw of the trees were located as on the **Fig. 2**. In the second one (shelterbelt 2) additional raw of the trees has been introduced as the protection from the southwest winds (**Fig. 3**).

To reach the highest effectiveness a shelterbelt assumed in simulation was made out of trees and shrubs and was perpendicular to the west. The geometry of the trees used in the study was as follows: crown height 5-9 m, diameter of the crown 5-7 m, stem height 1-2 m. The shelterbelt width was 130 m, the average height 7 m and length 10 m.

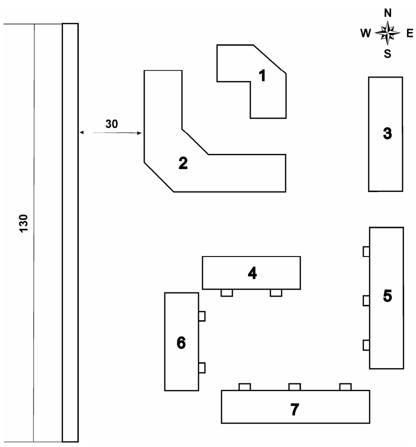

Fig. 2 Location of the windbreaks

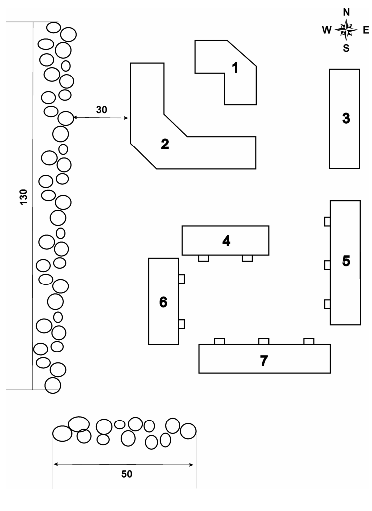

Fig. 3 Locations of the trees

The second windbreak, which has been proposed in the study is earth berm. Its dimensions were as follows: length 10 m, width 130 m, height 4 m. The shape of the earth berm (rather flat top) allows for future plantings.

The street with traffic density about 1000 vehicles per hour and 20 % of heavy vehicles borders on the west side with the buildings complex. To protect inhabitants from the traffic noise, acoustic screen has been proposed as the third option of the windbreaks. The acoustic screen width was 130 m, the height 4 m and length 0.25 m. In that case effective of the noise barrier in reducing of sound levels is about 15 dB.

In order to assess the effects of windbreaks on wind flow patterns, numerical simulations have been done for eight directions of wind.

The area of maximum protection is on the leeward side, but even on the windward side there is a zone of reduced wind speed. In the corners of the windbreak, there is a small area, where the speed is higher than the speed of the undisturbed flow. It is the most evident in the case of acoustic screen and west wind direction (**Fig. 6**). The maximum value of V/V_o noted in this area was about 1.68.

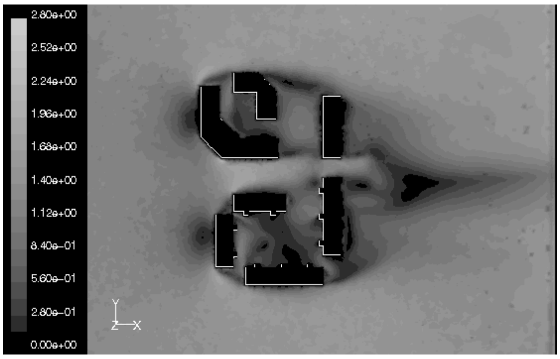

Fig. 4 Wind speed ratio for West wind direction

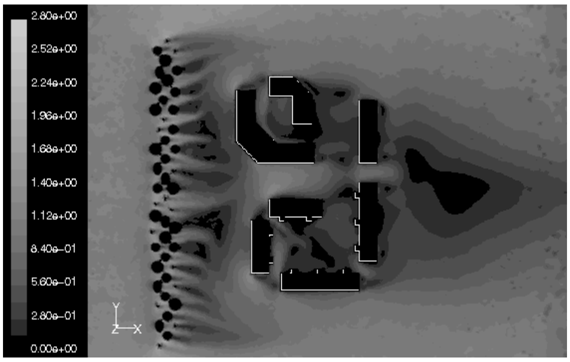

Fig. 5 Wind flow patterns around buildings with row of trees

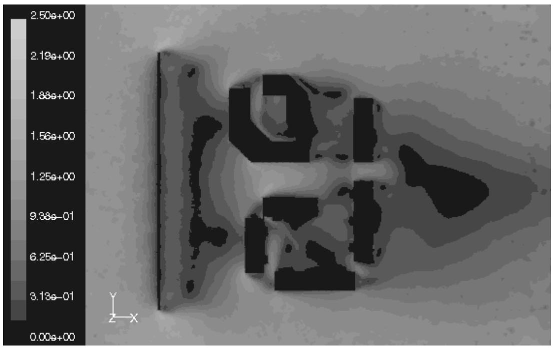

Fig. 6 Wind flow patterns around buildings with acoustic screen

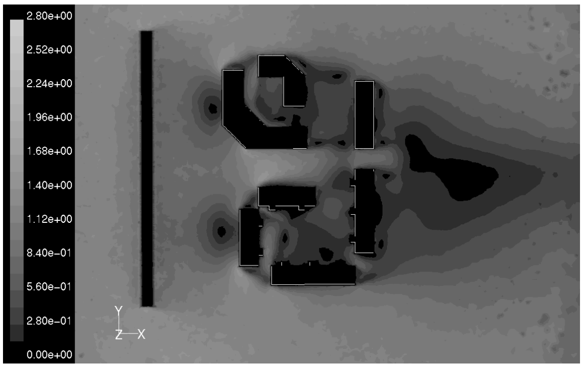

Fig. 7 Wind flow patterns around buildings with earth berm

In the case of western winds simulation has shown the maximum wind speed in a canal between two interiors. By introducing windbreaks, independently of their kind, situation has been improved (**Fig. 4-7**). In the upstream corner stream maximum value of V/V_o changes from 1.7 to 1.46.

Fig. 8 shows distribution of V/V_o in the passage between buildings 2 and 4 for different windbreaks. In all cases decreasing in V/V_o has been noted. The best results have been achieved for shelterbelts both with one and two rows of trees. The maximum difference in V/V_o was about 0.7.

Wind flow from southwest direction had serious influence on the wind comfort condition.

Numerical simulation confirmed that the most affected region was passage between buildings 6 and 7. Application of windbreak reduced partially the wind speed in this area. **Fig. 10** shows distribution of wind speed ratio in the analysed pathway.

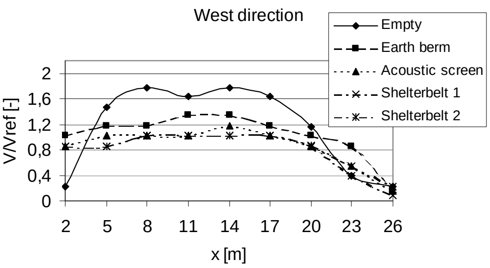

Fig. 8 Distribution of wind speed ratio V/V_o in the passage between buildings 2 and 4 for different windbreaks and West wind direction.

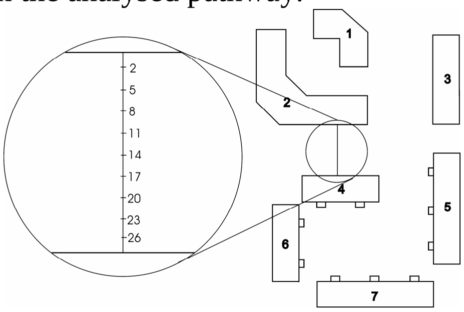

Fig. 9 Location of the passage

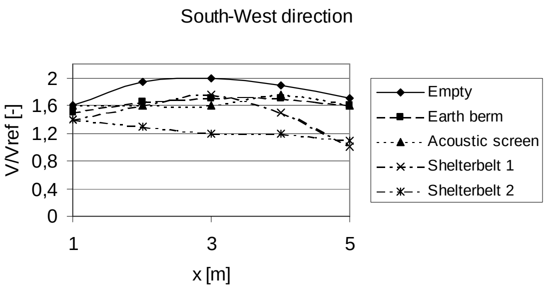

Fig. 10 Distribution of wind speed ratio V/V_o in the passage between buildings 6 and 7 for different windbreaks and West - South wind direction.

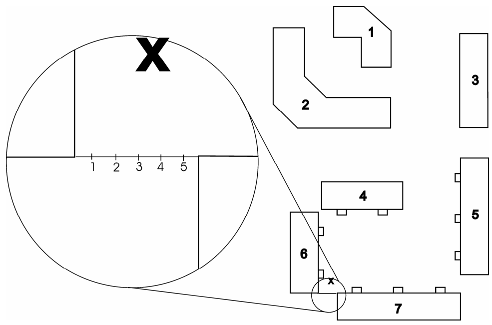

Fig. 11 Location of the passage

As could be expected the best solution has been obtained for the shelterbelt 2. Additional row of trees in the southwest part of the buildings complex reduces wind speed ratio about 0.6. In order to check the influence of this shelterbelt in the case of wind flow from different direction the vertical bar graph has been made showing values of V/V_o in a point located in the most affected area (**Fig. 12**). Location of the point has been shown on the sketch in **Fig. 11**.

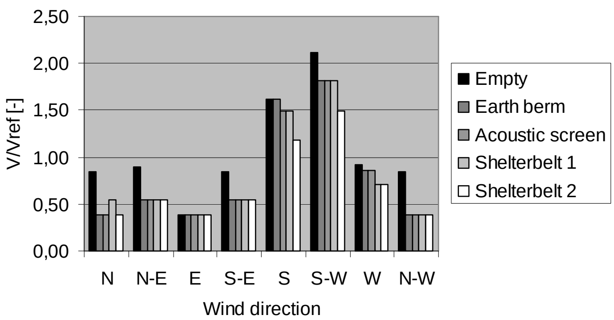

Fig. 12 Wind speed ratio in the analysed point for different wind direction.

The clearest influence of shelterbelt 2 on wind speed reduction can be noted for almost all wind direction. Only in the case of the west and east winds windbreaks can change wind flow slightly. Shelterbelt 2 consisting of two rows of trees give the best protection among the all considered type of wind screens when wind flow from west and southwest direction. In the corner streams of the upstream buildings wind speed ratio changes from 2 to 1.62.

4 Conclusions

Three types of windbreaks have been considered in the study: shelterbelts, earth berm and acoustic screen. The arrangement of buildings and local roads system limited the possibility of their location to the west and southwest side of the complex. Taking into account that west winds are prevailing location of the windbreaks on the west side can provide shelter for the buildings. The analysis has shown that the shelterbelt with two rows of trees was the best solution. In almost all cases vegetation has decreased the wind speed in passages. By appropriate trees planting, several improvements can be achieved in a field of aesthetic, noise and pollutant control and microclimate.

Unfortunately in the case of northeast and southeast wind direction situation has not been changed. The buildings' surrounding prevents introducing windbreaks in the windward corners of the buildings. Only small group of bushes can be used but it doesn't considerably change the wind flow pattern.

Numerical simulation of wind flow around buildings seems to be a useful tool for architects and urban planners. By proper buildings configuration and suitable utilize of vegetation one can steer the urban microclimate.

References

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