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Pedestrian Wind Comfort Evaluation for Sun Valley Campus

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Abstract. Public spaces play an important role in the social life and they are considered as the mirror and the reflection of the society. The uncomfortable microclimatic condition such as the air temperature, wind speed, solar radiation, etc. may encourage the pedestrian to avoid using these areas which effect directly the integration of residences and promote their segregation. In particular, the wind is considered as the parameter that influences the pedestrian comfort the most. However, it is heavily present in the design stage of urban and architectural projects at some places around the world, due to the complexity of the interaction with the urban fabric that create aerodynamic phenomena in the immediate environment of building and public space. Our subject of research focus on the Sun Valley living area inside the Laser Valley Land of Lights, which is one of the biggest projects in Romania that aim to attract high tech industry around the world's most powerful laser, Extreme Light Infrastructure Nuclear Physics ELI NP Project. Sun Valley was the result of an architecture international competition with the objective to provide an open research ecosystem based on sustainable development. Through this paper, we aim to investigate the wind environment in the design stage of the project. Mainly, we focus on the wind effects that are taking place in the large open space inside the campus on pedestrian comfort and safety, in order to provide comfortable area that promote the social life between residences. In this context, we describe the set-up of our research on the pedestrian comfort in the public space from the wind perspective, where Wind Tunnel measurement study on the pedestrian level (1.5 m to 2 m height from the ground) was carried out for 8 different wind directions in the TASL1-M Boundary Layer Wind Tunnel at the Aerodynamics and Wind Engineering Laboratory "Constantin Iamandi" (LAIV) in the Technical University of Civil Engineering Bucharest (UTCB). Furthermore, the preliminary result of the experiment performed in the TASL1-M Boundary Layer Wind Tunnel are described.

1. Introduction

Public space reflects the societies that shaped them as they actively participate in shaping human behaviour [1]. It has always played a central role in the life of cities, where all groups of society, regardless of age, income, status, religion or ethnicity, can meet face to face in the space of the city [2] and new interpersonal links can be also created.

The use of public outdoor space for different activities is strongly influenced by microclimatic parameters such as temperature, air movements and solar radiation that influence outdoor comfort.

An uncomfortable climate condition can prevent people from using it. An appropriate climate design for public spaces has been largely neglected, where the only focus was the indoor environment for a long time. Nowadays, with the evaluation of sustainable development, research on comfort and health in open urban spaces and the overall quality of urban life is growing [3].

Among the microclimatic parameters that influence outdoor comfort and largely depend on the urban form are the wind speeds and solar radiation. Solar radiation has been widely studied and evaluated qualitatively and quantitatively in the different phases of project design. However, pedestrian wind speed has generally neglected by urban designers, although it is an important environmental element, which determines user satisfaction in open spaces [4].

In this study, we focus on the pedestrian urban wind environment, which is different from the urban wind environments and the natural wind environment mainly due to the presence of buildings and other objects such as trees.

Wind environment is the condition of wind in a specific area with spatial and temporal distributions, when assuming that the thermal effects are neglected, wind environment can be described by Eq. (1).

$$\vec{v} = \vec{v}(x, y, z, t) \quad (1)$$

The vector $\vec{v}$ in in Eq. (1), characterises the wind velocity in a specific location and a given time and x,y,z are the Cartesian coordinates of the location; t represents time.

In Eq. (1), the height above the ground is represented by the z coordinate. For the pedestrian wind environment studies, 1.5 m is commonly used for the z value, which may differ according to the different scientific and engineering fields. For example, structural engineers, when investigating the wind force on tall buildings, take in consideration the wind environment at elevations higher than 1.5 m, even over 100 m above the surface. Urban physicists mainly study the wind environment close to the ground.

The Urban wind environment affects many qualities of city performances such as structural wind loading on buildings, thermal and mechanical comfort of people, city ventilation and natural ventilation potential for buildings. Mechanical comfort, thermal comfort, and city ventilation persist in the study on pedestrian level urban wind environment. The Study of important review works [5] reveals that most pedestrian wind assessment studies mainly focus only on the mechanical comfort, however, limited study considers other factors such as thermal comfort [6].

Pedestrian wind environment assessment has been studied since the 1970s, Givoni [7], for instance, pointed out that the wind profile described by a simple mathematical equation such as the power law does not represent the real wind conditions near the urban ground level. Building configuration, e.g. its height, width, building arrangements and density, are part of the significant factors affecting wind velocity near the ground level.

Lawson and Penwarden [8] reported about the death of two old women in 1972 due to dangerous wind conditions near tall building.

Nikolopoulou et al, [9] considered that the pedestrian comfort is an important factor in the success and the use of the spaces by individuals.

Kubota and al. [10] conducted wind tunnel tests at the pedestrian level in residential neighbourhoods of major Japan cities. Furthermore, significant work has been expended to predict strong wind regions. Shoda and Murakami [11] worked on two and more buildings, and conducted numerous wind tunnel tests in order to obtain basic data.

Several important wind comfort criteria were proposed. Penwarden and Wise [12], suggested their wind comfort criteria for pedestrian. Since then, several comparison studies were done.

Koss [13] mainly studied and compared the five wind comfort criteria in Ratcliff and Peterka [14] work furthermore, the criteria integrated by other countries (the U.K., France, Denmark, and the Netherlands) were compared.

Blocken and al [5] compared four wind comfort criteria. Among them were the criteria that were proposed in Davenport and Isyumov [15], Melbourne [16].

Potential wind nuisance, so far were only advised by wind engineering specialists due to that, it is hardly considered in the design stage of the building. A wind tunnel test is most of the time done after the project is built and already used by occupants due to that, only adding provisional solutions is possible to improve the wind condition.

2. Assessment of the pedestrian wind environment with Wind-tunnel techniques

The assessment of the pedestrian wind environment can be piloted us post-occupancy assessment or in-design assessment which was carried in this study.

In-design assessment is conducted mainly to evaluate a building or a project in the design stage. At this phase of the project, the pedestrian wind environment cannot be physically measured and measurement is not possible. Due to that, theoretical calculations and simulations are frequently used to predict the pedestrian wind environment that allow to project a specific modification for the design before the project execution.

However, Post-occupancy assessment is to assess a part or entire area of the city using data that can be collected after the project is built and occupied. Furthermore, is defined as the investigation of an occupied or proposed environments [17]. In this case it is difficult to project big modification in order to improve the wind environment quality.

Pressure distribution along the lateral surface of project can be studied in order recognize the area with higher pressure concentration and if the boundary layer separation evolve in turbulence that affect the pedestrian comfort.

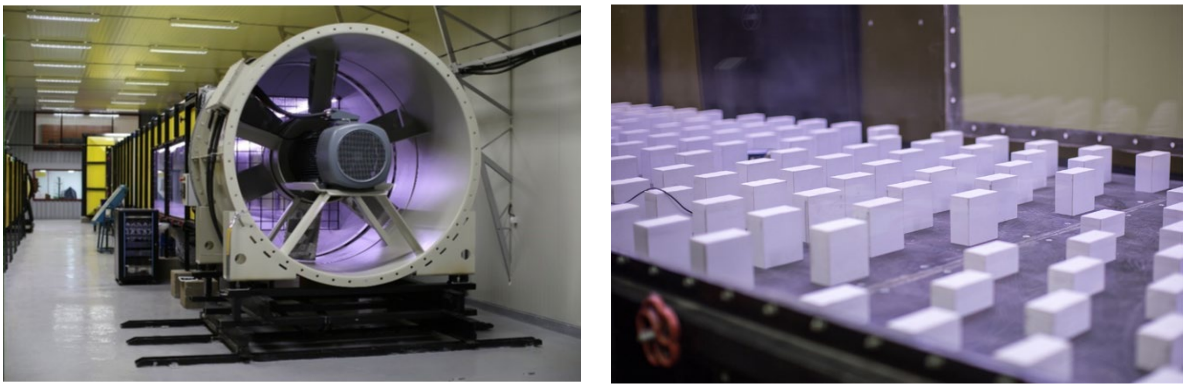
The pedestrian wind environment can be mainly obtained by wind-tunnel testing or numerical simulation with CFD. Wind-tunnel measurements can be performed in many techniques such as hot-wire or hot-film anemometry [18], pulsed-wire anemometry, Irwin probes commonly referred as low-cost techniques.

Among this technique, there are “point measurement” Hot-wire anemometry, hot-film anemometry, pulsed-wire anemometry and Laser-Doppler anemometry, Irwin sensors that provide measurement of the air speed over a small area. On the other hand, there are area techniques such as infrared thermography, and Particle Image Velocimetry that provides spatially continuous data on the flow conditions about a large part of the considered area [19].

3. Experimental setup of wind tunnel and instrumentation

In this study, we carried out pressure measurements on the cylindrical building and wind tunnel measurement on the pedestrian level wind around the campus inside the project Laser Valley Land of in Bucharest, Romania in order to predict the strong wind regions that may affect the pedestrians comfort.

The study was conducted at the Aerodynamics and Wind Engineering Laboratory “Constantin Iamandi” (LAIV) at the Technical University of Civil Engineering Bucharest (UTCB) ‘Figure 1 a)’. The wind tunnel length is 27 m, while the active section of the wind tunnel has a length of 18.9 m. The wind tunnel cross-section of the experimental vein is square; the characteristic length is 1.75 m [20].



a) b)

Figure 1. a) Wind tunnel, b) roughness bricks

The roughness system located between the two experimental veins ‘Figure 1 b)’, the variable height roughness system is distributed homogeneously, which is able to modify the roughness automatically on the bottom of tunnel (by changing the height of 560 bricks between 0 and 200 mm) ‘Figure 1 b)’ In our study we lift the roughness up to 10 cm in order to have wind profile ‘Figure 2’ similar to the one in Bucharest. The wind flow in the aerodynamic wind tunnel is correlated with the mean wind speed profile of Bucharest in accord to the Romanian code CR 1-1-4/2012.

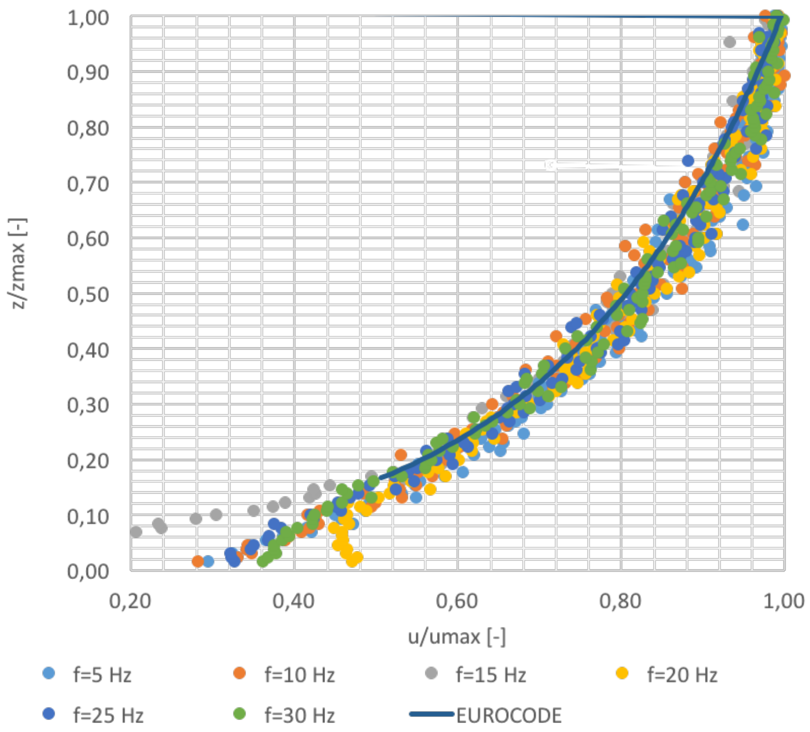


Figure 2. Mean wind speed profile, Bucharest [21]

3.1. Experimental model

The building models are made of polystyrene with a geometric scale of 1:65, the models are mounted on a rotating disc inside the wind tunnel in order to investigate the effects of different wind directions. The disc is mechanically controlled to perform rotation as well as up and down motions, which is used to conduct aerodynamics studies of wind action on buildings and pollution diffusion testing.

The diameter of the tower in the model is 16 cm, the height of the tower in experimental model was fixed 38 cm and 8,2 cm for adjacent houses. H and h are the tower height and houses height, respectively.

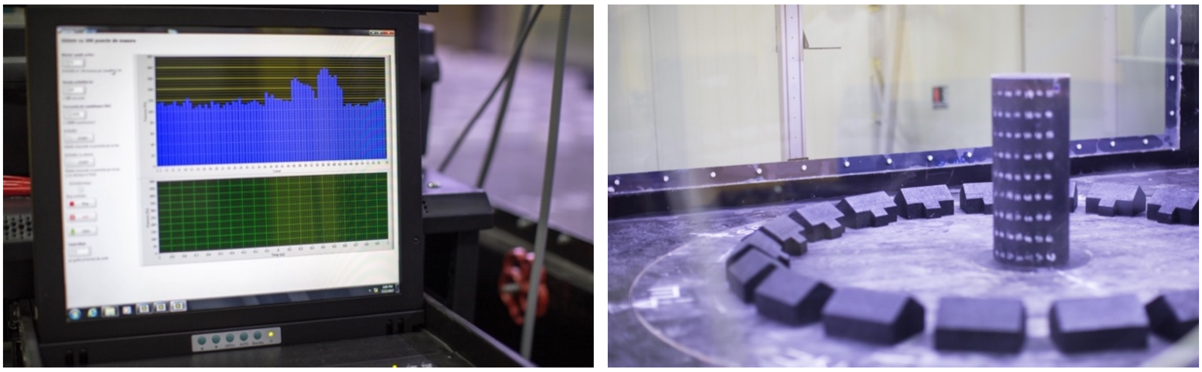
Eight directions have been considered. For each case, two components of the wind velocity were registered in the horizontal level placed at 1.5 m full scale (1.5/scale height at model scale) height.

The model has 78 Pressure taps that were placed on ¼ of the tower lateral surface; among that, 15 pressure taps are placed on the top of the model.

Pressure distribution on the ¼ surface of project was studied in order investigate the area with higher pressure concentration and if the boundary layer separation cause any turbulence that disturb the pedestrian comfort.

The velocity in the free stream, measured in the centroid of the cross-section located upwind the model, after the wind tunnel honeycomb was equal to 9 m/s.

‘Figure 3 b)’ shows the model of Laser Valley building mounted in the Wind Tunnel TASL 1 with the pressure taps installed on the tour.

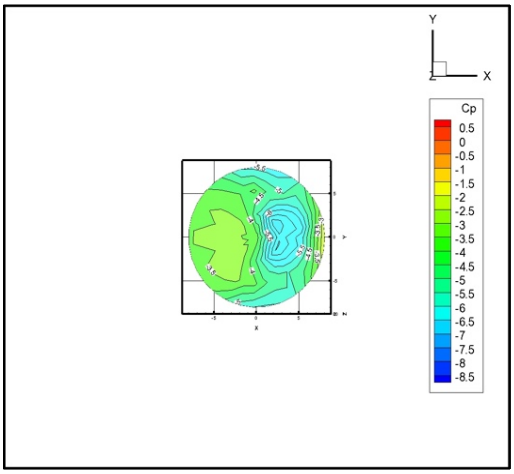


a) b)

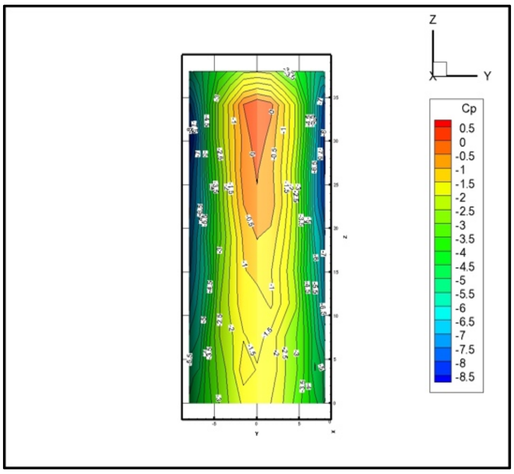
Figure 3. a) pressure measurement in the computer, b) experimental model with the pressure taps in the wind tunnel

4. Results and discussions

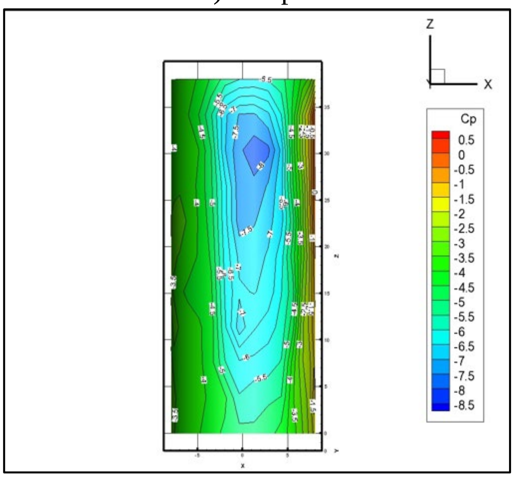
The results of the pressure measurement tests along the tower for the north direction is shown in 'Figure 4'. Pressure coefficients (C_p) are were computed using the velocity and the static pressure measured upwind, in the free stream. High pressure values were acquired on the front side of the tower. However; the lowest pressure values were measured on the two sides. Moreover, as it was expected the pressure remains low and approximately constant over the rearward face of the tower.



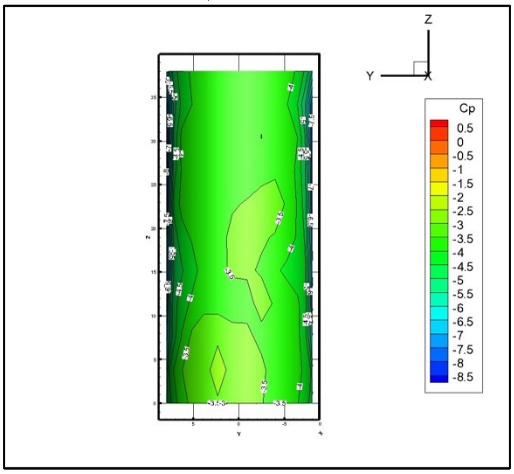
a) Top view



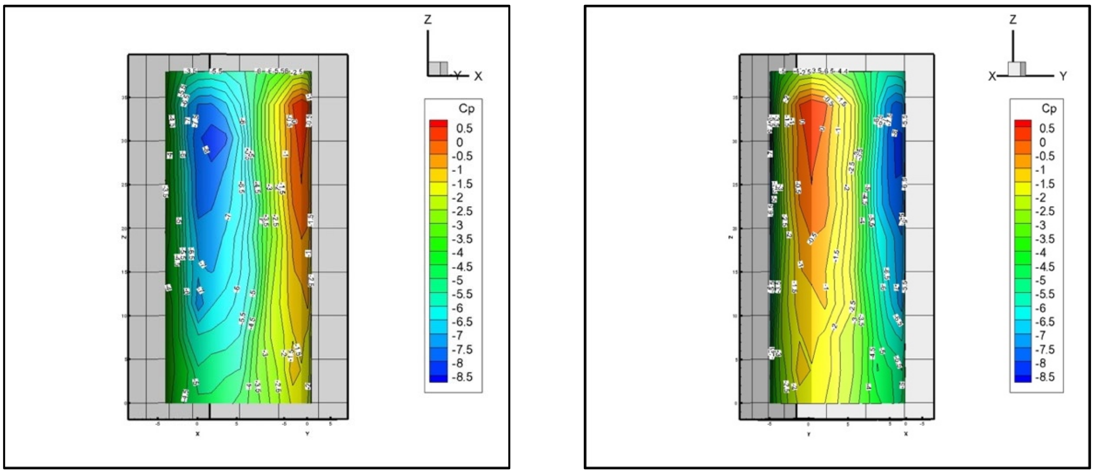
b) Front view



c) Lateral view



d) Wake view



e) Side view f) Side view

Figure 4. Pressure measurement results

5. Conclusions

The pedestrian wind environment is one of factors affecting the wellbeing of a city and its inhabitants.

The absence of the comfort in the outdoor spaces may prevent people from meeting and affect the integration of the society. For that purpose, a series of wind tunnel tests on campus laser valley were carried out in the urban planning design stage in order to provide a comfortable outdoor spaces.

Additional research work should be done. First, we attend to carry velocity measurement by LDA and numerical simulation CFD in order to visualise and analyse the velocity in the study area and to compare the results for a better assessment of the velocity field.

Moreover, architectural design and thermal comfort will be studies in future work in order to provide suitable pedestrian environment and a successful outdoor public spaces. Furthermore, it is more efficient if architects and urban developers include the wind nuisance factor in planning from the very early stage and to be able to study the impact of their design.

Acknowledgment(s)

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