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# LABORATORY MEASUREMENTS OF WIND VELOCITY FIELD BEHIND WINDBREAK SCREENS

BY

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**Abstract.** Often tall buildings and other large constructions affect unfavourably the wind comfort conditions at pedestrian level on the adjacent areas. In their attempt to ameliorate these negative effects of wind action, urban professionals use for some cases flat-type protection systems. This paper presents some data on the characteristics and effectiveness of such windbreak screens, resulting from the study of physical models in wind tunnel located in turbulent boundary layer.

**Key words:** tall buildings; large constructions; negative effects; wind action; wind comfort; windbreak screens.

## 1. Introductions

The thickening of urban areas with new tall buildings located near existing buildings determines the addition of very different built-up volumes and forms. Wind flow in urban areas depends on local whether characteristics, on the upstream land roughness and on the surrounding buildings arrangement. Wind action is often

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influenced by the presence of these new buildings, and air flow conditions along the streets and generally at reduced height, gains importance. Therefore, the pedestrian comfort, the wind loads on low levelled building roofs or nearby traffic conditions, could be affected negatively.

In this context, as they aware of presence and importance of these phenomena, authorities from more and more countries develop criteria for acceptability and local decisions, regarding environmental conditions due to wind flow around the buildings. For these reasons, designers, builders, specialists in urban planning and systematization requires the presence of general rules and guides that offer practical solutions applicable in this field.

In the Department of Civil and Industrial Engineering from the Faculty of Civil Engineering and Building Services is operable a Laboratory of Buildings Aerodynamics which enables the activity of a research team consisting of teachers, PhD students and technical specialist staff.

Among the concerns of this research team, regarding the pedestrian level wind action, can be considered the development of a wind tunnel testing program to develop some practical means by which professionals can intercede through various local facilities to improve the wind comfort conditions.

The devices that should offer protection against wind action will have to fulfill several functions (to be effective) namely

1. To slow down the movement of the average air stream in areas of fast flow.
2. To reduce the turbulence scale of the flow. “Shredding” the turbulence and breaking large vortexes through special devices, will determine the attenuation and smoothing (by viscous dissipation) of the air churning.
3. The attenuation of horizontal or vertical gradient of the average wind speed, using fairing systems (aerodynamic profiling) or local permeability (sieve, vegetation, etc.).
4. Deviation of the (mean) fluid “threads” and channelling the airflow to achieve certain areas of calm.

It is preferable, that in most wind flow management steps, to combine the average speed control with the turbulence control. This way actions can conjugate deviation of the flow trajectory with the dissipation of the dynamic energy.

Such means of reducing wind speed are generally called *wind barrier* or *windbreak*, and is commonly associated with a natural vegetative barrier against wind, or *windscreen* and refers to any artificial barrier, be it synthetic or mechanical, obstructing wind flow. The *wind barrier* can be designed as a flat screen or fence placed perpendicularly or inclined with an angle to the main flow direction.

Windscreen or windbreak efficiency is expressed as a protection factor, which is a dimensionless quantity and for any point, *i*, is expressed by the relation

$$F_i = \frac{|U_i| + \sigma_i}{U_{\text{ref}} + \sigma_{\text{ref}}}, \tag{1}$$

where: $U_{\text{ref}}$ is the reference speed, $|U_i|$ – the average speed measured in point, $i$, and $\sigma_{\text{ref}}$, $\sigma_i$ – standard deviation of the gust speed in the same points, reference and, respectively, $i$; all are expressed in m/s (s. Fig. 1 ).

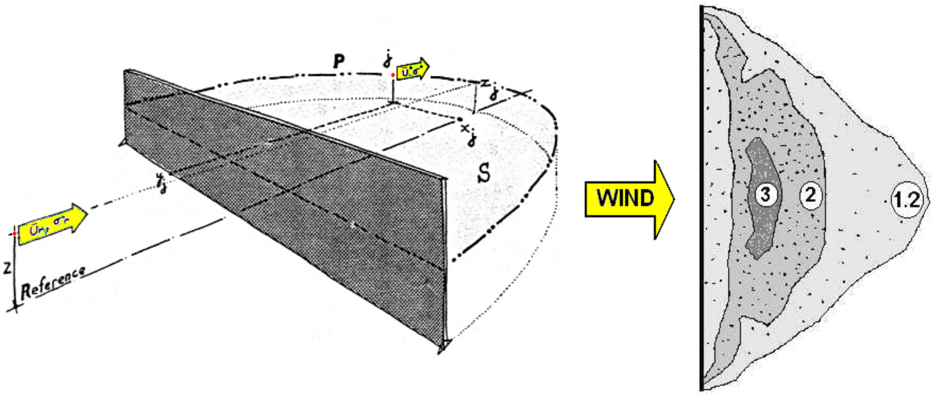


Fig. 1 – Flat windscreen and the distribution of protected areas from downstream.

On the protected area located downstream from the windbreak screen (marked $S$ in Fig. 1), the values of the protection coefficient which are considered characteristic are $F_i \cong 3$; 2; 1.2. These values correspond to a reduction in frequency of the pedestrian level wind discomfort, with 99%, 80% and, respectively, 30%. The discomfort threshold used in the studies described below was adopted from the literature (Gandemer & Guyot). It is given by the sum of the average speed value, $U_s \cong 5$ m/s and standard deviation, $\sigma_s \cong$ $\cong 1$ m/s, measured at a height $z = 1.5$ m from ground level.

## 2. Experimental Conditions

The experiments were carried out in SECO2 – an open jet Eiffel type – boundary layer wind tunnel with a working section of 10 m long and 1.4 × × 1.4 $\text{m}^2$ cross-section.

The atmospheric boundary layer was reproduced in the wind tunnel at the scale 1/100 (based on the scale of flow turbulence). In this case the variation of the vertical profile for the average wind speed (longitudinal component) follows the power law $V_{(z)} = V_G(z/z_G)^{\alpha}$, with $\alpha \cong 0.183$, specific for wind flow over suburban areas (site type II) . For this type of flow the longitudinal and transverse scale of turbulence (at 10 cm above the tunnel floor) is $\lambda_x \cong 88$ cm, respectively $\lambda_y \cong 40$ cm, corresponding to the values of ~88 m and ~40 m at natural scale.

The studied windscreens are generally flat and thin obstacles, more or less porous, replicated at a scale of 1/100 and placed in the type II atmospheric boundary layer, reproduced in the wind tunnel. Some wind barriers reproduces the vegetable texture of a hedge or of a tree plantation. Following the change in turbulence intensity, it can be seen that the models with $H \cong 9...10$ cm are completely immersed in the boundary layer, fulfilling this condition of similarity.

## 3. Description of the Flow Around an Windbreak Obstacle

When the air flow meets a windbreak, some streams will be deflected sideways and over the top of the screen, as long as the degree of screen permeability will be reduced (or if the loss in bends by friction, as it passes through the screen perforations, would be important). If the windbreak screen has a higher permeability (assuming air passage generates lower energy loss) than an important part of the incident air flux will cross through the barrier.

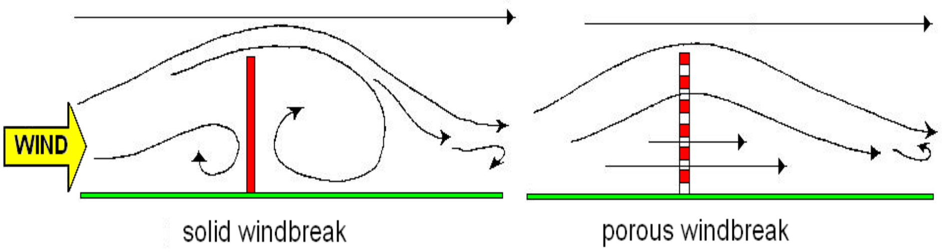


Fig. 2 – Schematic view of the air flow around the windbreak/windscreen.

To highlight the pattern of wind flow passing over these wind barriers, flow field visualization were made near some windbreak models. The types of windbreak used for analysis are: a) opaque screen, b) perforated (with the “permeability” of 50%), c) inclined bladed screen (blades angle at 45$^{o}$). He could see vortex organization associated with high turbulence, which greatly attenuates with the increasing degree of perforation (the permeability of the bladed system is smaller than the permeability of perforated screen).

It was found that behind obstacles the original parameters of the flow (the distribution average speed and turbulence) are changed over a distance equal to several times windbreak’s height (in the order of 10 times). The area affected is related to the characteristics of the windbreak and of the incident wind.

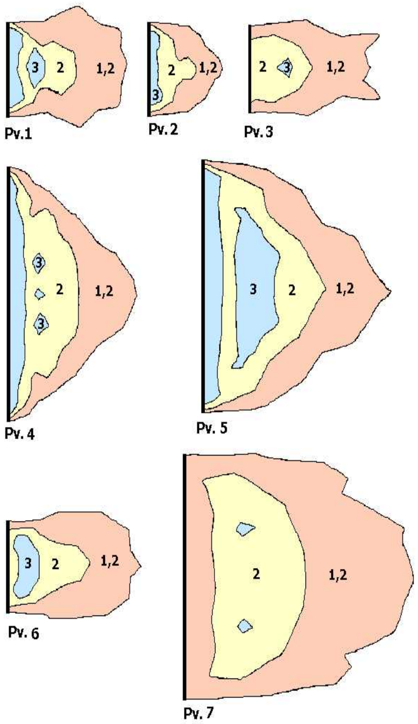
### 3.1. Measurement Results

The seven windbreaks studied are reproduced at the scale 1/100 in the boundary layer wind tunnel. The longitudinal and transversal scale of the boundary layer turbulence (at 10 cm above the tunnel floor) is $\lambda_x \cong 88$ cm, respectively $\lambda_y \cong \lambda_z \cong 40$ cm, corresponding to the values of 88 m and, respectively, 40 m in the natural scale. Below are presented synthetically the characteristics of the areas protected by each studied windbreak, implemented at the natural scale.

**Table 1**

*Protected Areas Behind the Windbreaks*

| Windbreak type | Specific dimensions | Protected areas |
|---|---|---|
| Pv. 1 | $L = 40$ m<br>$h = 10$ m<br>$\phi = 0$ | $S_{1.2} = 3,372\ \text{m}^2$<br>$S_2 = 962\ \text{m}^2$<br>$S_3 = 220\ \text{m}^2$ |
| Pv. 2 | $L = 40$ m<br>$h = 5$ m<br>$\phi = 0$ | $S_{1.2} = 1,357\ \text{m}^2$<br>$S_2 = 559\ \text{m}^2$<br>$S_3 = 124\ \text{m}^2$ |
| Pv. 3 | $L = 40$ m<br>$h = 5$ m<br>$\phi = 50\%$ | $S_{1.2} = 2,691\ \text{m}^2$<br>$S_2 = 889\ \text{m}^2$<br>$S_3 = 41\ \text{m}^2$ |
| Pv. 4 | $L = 120$ m<br>$h = 5$ m<br>$\phi = 0$ | $S_{1.2} = 5,548\ \text{m}^2$<br>$S_2 = 2,854\ \text{m}^2$<br>$S_3 = 658\ \text{m}^2$ |
| Pv. 5 | $L = 120$ m<br>$h = 10$ m<br>$\phi = 0$ | $S_{1.2} = 9,031\ \text{m}^2$<br>$S_2 = 3,924\ \text{m}^2$<br>$S_3 = 855\ \text{m}^2$ |
| Pv. 6 | $L = 40$ m<br>$h = 10$ m<br>$\phi = 20\%$ | $S_{1.2} = 3,472\ \text{m}^2$<br>$S_2 = 1,278\ \text{m}^2$<br>$S_3 = 404\ \text{m}^2$ |
| Pv. 7 | $L = 40$ m<br>$h = 10$ m<br>$\phi = 50\%$ | $S_{1.2} = 4,344\ \text{m}^2$<br>$S_2 = 1,495\ \text{m}^2$<br>$S_3 = 78\ \text{m}^2$ |



Graphical depiction of the protected areas.

## 4. Conclusions

The following conclusions can be underlined:

1. Windbreaks length differently affect flow as $L >> \lambda_y$ or $L \leq \lambda_y$. The geometry of protected areas differs in the two cases. Schematically we can

approximate the form of the protected area with a half-ellipse, but in the first case ($L >> \lambda_y$) the large axis is reflected by the windbreak and in the second case ($L \leq \lambda_y$) the small axis is reproduced by the windbreak.

2. Comparing the surfaces of protected areas for windbreaks with identical aerodynamics but with different lengths, we have seen that the three areas marked with $S_{1.2}$, $S_2$ and $S_3$ evolves differently depending on length of the screen and are found to be approximately in the following ratio with the length ($L$): area $S_{1.2}$ – proportional to $L$, $S_2$ – proportional to $L_{1.3}$ and $S_3$ – proportional to $L_{1.5}$.

3. The variation of screen height do not significantly influence the flow in the downstream area because $h \in [5,...,10]$ m << $\lambda_z \cong 40$ m.

4. In conclusion, laboratory tests have confirmed that the optimal characteristics for the flat windbreaks are: 2.5 m ≤ $h$ ≤ 10 m ; 0 ≤ Ø ≤ 50%; 20 m ≤ $L$ ≤ 120 m.

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## DETERMINĂRI DE LABORATOR ALE CÂMPULUI DE VITEZE EOLIAN ÎN SPATELE UNOR ECRANE PARAVÂNT

(Rezumat)

Adesea clădirile înalte şi alte construcții de dimensiuni mari influențează în mod defavorabil condițiile de confort eolian la nivel pietonal, în zonele adiacente. În încercarea de ameliorare a acestor efecte negative, ale acțiunii vântului, specialiştii urbanişti utilizează, în anumite cazuri, sisteme de protecție tip ecran plat.

Se prezintă unele date privind caracteristicile şi eficiența unor asemenea ecrane paravânt, rezultate în urma studierii pe modele fizice amplasate în tunel aerodinamic cu strat limită turbulent.