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# Simplified elements for wind-tunnel measurements with type-III-terrain atmospheric boundary layer

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ABSTRACT

In this work, the results of simulating the ABL over a type III suburban terrain in the industrial wind tunnel of the Department of Mechanical Engineering of the *Vrije Universiteit Brussel* (VUB) are presented. Two different Roughness Barrier Mixing Device (RBMD) methods for simulating the ABL have been used (firstly, the well-known combination of Counihan quarter ellipses and roughness elements, and secondly, a new configuration based on truncated Irwin spires and roughness elements). Counihan quarter ellipses are generally considered as the optimal method for ABL simulation. However, its construction is quite complex. Therefore, an alternative setup, using truncated Irwin spires, was experimentally tested. The results of these two simulated ABLs were compared with international standard applicable for type III suburban terrain. Results showed good agreement between standards and experimental results showing that both techniques give a good representation of the ABL. Finally, the proposed truncated Irwin spires method/configuration is confirmed as a proper way to carry out ABL wind-tunnel simulations, as the results are practically the same as the ones obtained with the well-established Counihan method to simulate ABL in wind tunnels.



## 1. Introduction

It is generally accepted that allowing the flow to run over a rough surface producing a natural-growth boundary layer is the best method for simulating the Atmospheric Boundary Layer (ABL) in a wind tunnel [1]. Depending on the surroundings of the studied region, a different roughness must be used. When using this technique, the scale of the simulated ABL depends on the length of the roughness fetch. In order to obtain very large scales for the analysis of wind loads on buildings, a specially constructed wind tunnel with a working section that is much longer than its cross-sectional dimension is required [2–4]. The formation of this turbulent boundary layer tunnel can be enhanced by using obstructions upstream that have the ability to absorb energy from the mean flow without introducing large scale disturbance [5]. Many different techniques have been studied since 1960, for instance using spires in combination with roughness elements [2,6], air jets [7,8], fences in combination with chains [9] and fences [10] or rods [11]. Finally, a good review of the different techniques to simulate the ABL in a wind tunnel can be found in [12].

The Roughness Barrier Mixing Device (RBMD) method proposed by Cook has simulated successfully the lower third of the boundary layer using turbulence grid, plane barrier wall and roughness elements [13]. These RBMD techniques are renowned for reproducing mean and fluctuating parameters of the atmospheric boundary layer. The RBMD method, suggested by Counihan [14], using elliptic wedge generators in combination with a castellated wall and roughness elements [14–18] allows full-depth boundary-layer simulations. This method is widely used for full-depth ABL simulation [19–25]. An alternative for the RBMD method of Counihan is given by Irwin [26]. Irwin uses the flat triangular spires from Standen et al. [2] as a vortex generator and roughness elements to reproduce full-depth boundary layers with a thickness of about 80% of the spire height. The major advantage of the techniques of Irwin [26] compared to the technique of Counihan [14] is the use of triangular spires as vortex generators, the construction of these elements being much easier compared to quarter ellipses. Finally, the use of the flat triangular spires has been referred as Standen method by some authors [27,28].

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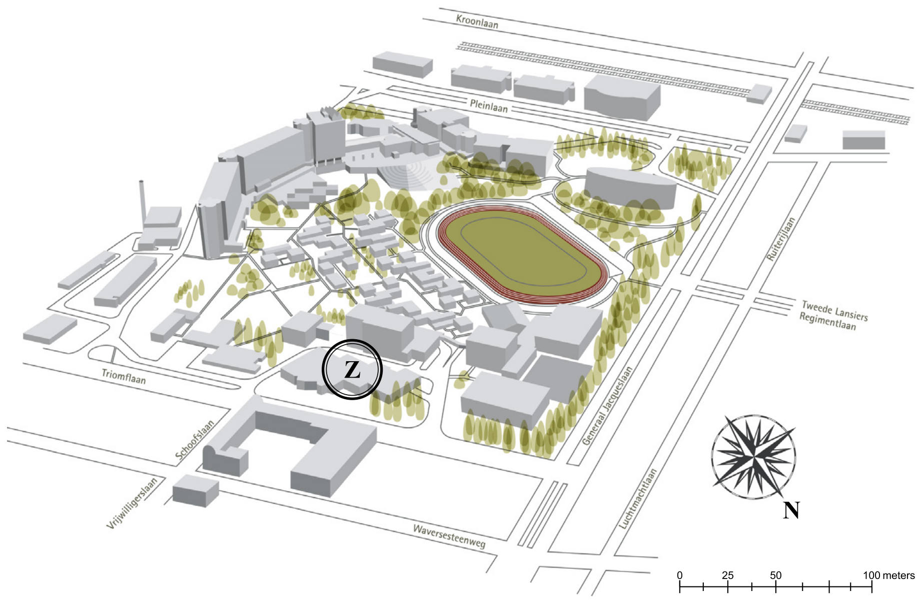


**Fig. 1.** Suburban terrain at Brussels (Elsene/Ixelles) for which the ABL is simulated. The building Z at the VUB campus is indicated in the image.

**Table 1**
Main specifications of the industrial wind tunnel at the Mechanical Engineering Department of the VUB.

| Type | Open circuit |
|---|---|
| Total tunnel length | 25 m |
| Testing chamber length | 12 m |
| Testing chamber height | 1 m |
| Testing chamber width | 2 m |
| Turbine power | 55 kW |
| Maximal wind speed | 20 m/s |

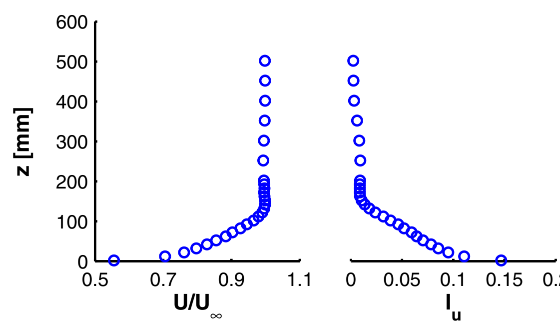


**Fig. 2.** Flow at testing section of the VUB wind tunnel in clear configuration (i.e., without any ABL simulation).

ABL simulations in a wind tunnel represent a quite complex problem. First of all, the researchers have to deal with the length of the wind tunnel, which normally does not allow for a complete development of the required boundary layer. Therefore, spires and vortex generators need to be installed. Also, the ABL simulations can be performed using full-depth simulation or part-depth simulation method [13,14,23,26,29,30]. Other problems are the scaling of the Reynolds numbers [31], or the difficulties to simulate the peak suctions on a wind tunnel even with simulated ABL [32], as the conical vortices are incompressible flow-structures that perform like a suction amplifier for wind turbulence [33,34]. Besides, once the properly scaled ABL simulation has been achieved for a specific wind tunnel, the results of the wind tunnel testing must be carefully scaled, as they are going to be translated to full-scale pressure/forces in a situation where the real boundary layer will never be exactly the same as the one simulated in the wind tunnel. As a consequence, reasonable decisions needs to be taken by researchers when dealing with wind tunnel testing of civil structures, no matter if the facility used is an extremely well-equipped one, or a simple facility, even without ABL simulation, is used [35–39].

In the present work, the design and validation of the simulated ABL in the wind tunnel at the VUB are presented. These ABL simulations were developed in order to find a solution to prevent Exhaust Gas Recirculation (EGR) from happening in a micro Gas Turbine (mGT). That research work [40] required simulation of the local ABL at the Elsene/Ixelles municipality of Brussels, this area being a typical example of a suburban terrain in the Benelux. By simulating the ABL in the industrial wind tunnel of the Vrije Universiteit Brussel (VUB), the wind behaviour around the building where the mGT is located (building Z of the VUB campus, see Fig. 1) was analysed (and more in detail around the stack of the mGT). Wind tunnel experiments with a scale model allowed the authors of the study to find a solution for the recurrent problem of EGR, by properly heightening the stack.

The characterising parameters of the ABL are introduced in Section 2 of this study. These parameters have specific values, defined in international standards on turbulent boundary layers, depending on the roughness of the location to be analysed. The definition of each parameter is presented, together with their specific values, for the ABL around aforementioned building Z of the VUB campus. Out of these values, the dimensions of the experimental wind-tunnel set up are also determined in Section 2. For the simulations carried out, both Irwin [26] and Counihan [14] RBMD methods were used. In Section 3, the simulated ABLs are validated by measuring and calculating its characteristic parameters and comparing them with the values from the standard codes, in order to select the optimal method to use in wind tunnel simulations. Finally, conclusions are summarised in Section 4.

## 2. Design of the ABL

The wind tunnel simulations of the ABL were performed in the industrial wind tunnel at the VUB (Table 1). The wind tunnel has a