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# Evaluating the performance of porous screens as an urban wind mitigation measure through multi-scale modelling

Alex Lang [a], Aidan McLoughlin [b], Salvatore Manuel Renda [c], Andrew Nicoli [d], Stefano Cammelli [e]

[a]*WSP, Manchester, UK, alex.lang@wsp.com*
[b]*WSP, Manchester, UK, aidan.mcloughlin@wsp.com*
[c]*ENGYS UK, London, s.renda@engys.com*
[d]*WSP, London, UK, andrew.nicoli@wsp.com*
[e]*WSP, London, UK, stefano.cammelli@wsp.com*

## SUMMARY

This study investigates the effectiveness of porous screens as a wind mitigation strategy using a multi-scale computational fluid dynamics (CFD) approach. Firstly, detailed numerical simulations of a typical porous screen are conducted, and the observed pressure losses are compared against benchmark wind tunnel experiments. The resulting pressure drop characteristics are then used as the basis to evaluate the full-scale aerodynamic performance of isolated screens for different wind directions using Darcy-Forchheimer porosity models. City-scale simulations are subsequently performed, employing a standard pedestrian level wind assessment methodology, to highlight the impact of the porous modelling methods on the resulting pedestrian comfort and safety metrics. The limitations and uncertainties associated with CFD modelling of porous materials in pedestrian level wind studies are discussed, with a comprehensive evaluation of current methods and some practical suggestions for best practices provided.

***Keywords:*** *Porous Screens, Pedestrian Level Wind, Wind Microclimate, Computational Fluid Dynamics*

## 1. INTRODUCTION

Porous screens are widely used as a mitigation measure in pedestrian level wind (PLW) studies of urban areas. This is based on the principle that porous obstructions can be used to locally improve wind conditions by reducing the velocity and turbulent kinetic energy of the flow in the downstream region. Porous screens are increasingly being relied upon to ensure urban areas meet pedestrian comfort and safety criteria at the design stage, particularly in the planning of tall and/or densely grouped buildings where strong downdraft and funnelling effects are expected. Furthermore, where problematic wind conditions are observed after the construction phase of a building, retrofitted porous screens may be installed as a relatively simple mitigation measure to improve the local wind microclimate.

Pedestrian level wind studies for the design of buildings and urban areas are typically performed using scaled wind tunnel experiments or computational fluid dynamics (CFD) simulations. In both methods, simplifications and uncertainties are inherent in the modelling of porous elements. The most significant limitations of both methods are summarised in Table 1.

Table 1: Comparison of limitations and sources of uncertainty in wind tunnel and CFD modelling of porous screens.

| CFD Simulations | Wind Tunnel Testing |
|---|---|
| Idealised screen geometries | Idealised screen geometries |
| Mesh resolution limitations in porous regions | Scale effects |
| Turbulence modelling deficiencies | Discrete measurement points |

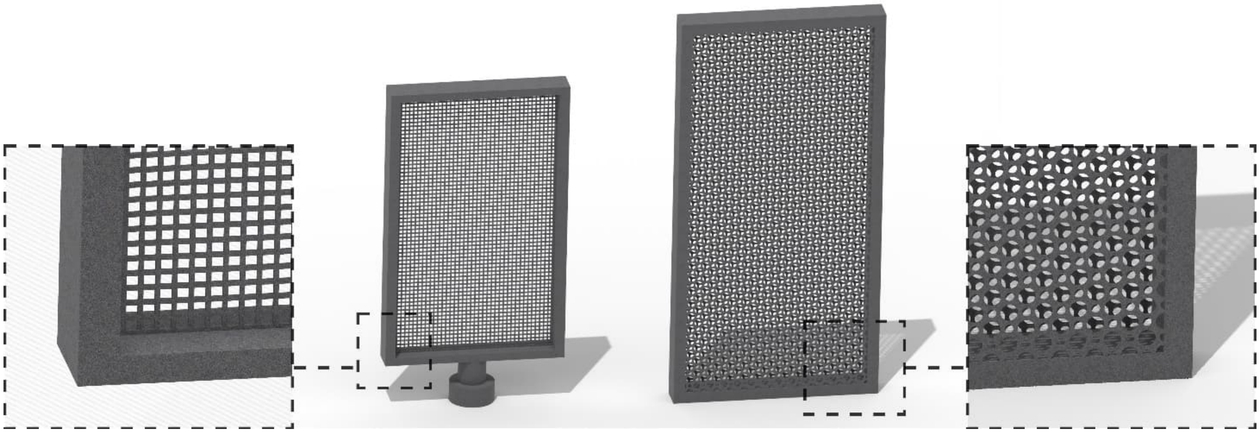

Figure 1: Examples of porous screen types used as pedestrian level wind mitigation measures.

A wide variety of porous screen configurations have been used in urban developments to date, some representative examples of which are shown in Figure 1. The screens often feature single or double skin panels, bespoke perforation patterns, and thick solid stands/framing. For design-stage PLW studies, the exact configuration of a porous screen is often unknown at the time of modelling. Therefore, a generalised model is typically used with a specified open area ratio, which is then matched for the installed screen. In practice, however, the pressure drop performance of the installed screen will also be dependent on the specific geometry of the perforations and on the frame geometry.

This work aims to evaluate the reliability of CFD modelling methods for porous screens in PLW studies, bridging the gap between the resolution of small-scale wind tunnel models and the full-scale performance of realistic screen geometries. Practical guidelines for CFD modelling are presented as a conclusion of the simulated results.

## 2. APPROACH AND METHODOLOGY

In this study, a multi-scale approach is taken to validate the computational methods used to evaluate the performance of porous screens in pedestrian level wind analysis. The workflow of the study is summarised in Figure 2. The following three scales of simulation are performed:

1. *Pore-scale:* Detailed analysis of the flow through subsections of a porous screen geometry, which is used to derive pressure drop characteristics. These simulations are validated against benchmark wind tunnel data available in literature.

2. *Screen-scale:* Simulations of isolated full-scale porous screens in typical atmospheric boundary layer (ABL) flows for a range of wind directions. Porous effects are included using Darcy-Forchheimer porosity models based on the pore-scale results, with a focus on comparing the most common porous modelling methods, i.e.:
    - 2D porous baffles
    - 3D isotropic porous zones
    - 3D anisotropic porous zones with custom reference frames
3. *City-scale:* A representative pedestrian level wind study, assessing the influence of the porous modelling methods with the interaction of multiple screens and buildings. Again, the computational results are compared to wind tunnel data for the same PLW case.

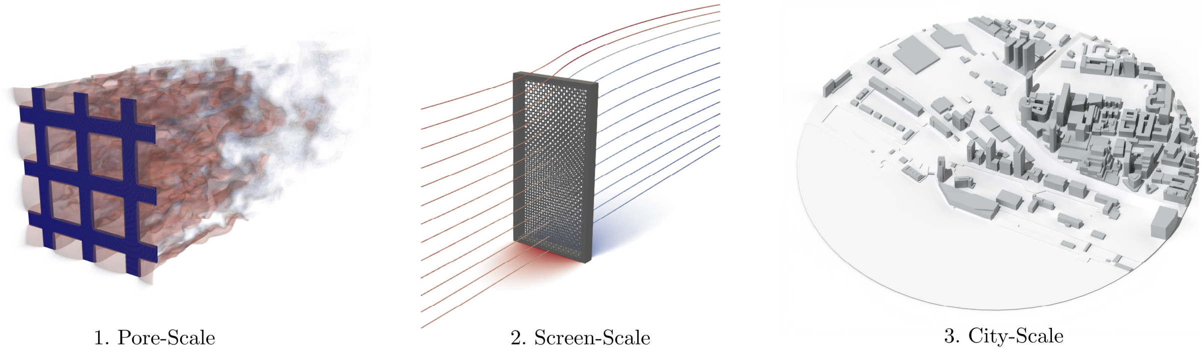
1. Pore-Scale
2. Screen-Scale
3. City-Scale

Figure 2: Scales of simulation in the study.

## 2.1. Pore-scale modelling

The first stage of the modelling involves CFD simulations of a representative section of a porous screen that would be used in a wind tunnel PLW model. The study aims at replicating the experiment carried out by Méry & Sebbane at the ONERA B2A Test Bench (Méry & Sebbane, 2023). The simulations are performed using a steady-state finite volume RANS solver and the k-ω SST turbulence model (Menter, 1994). The computational domain, shown in Figure 3, consists of a 10 million cell hex-dominant mesh. No-slip wall boundary conditions are applied to the two surfaces of the channel used in the numerical simulations as well as to the surface of the screen itself. Symmetry boundaries are used on two sides of the domain to reduce the simulation to a quarter of the 50mm × 50mm test section of the channel. A velocity inlet condition is set at the entrance of the channel, whereas the pressure is fixed at its outlet.

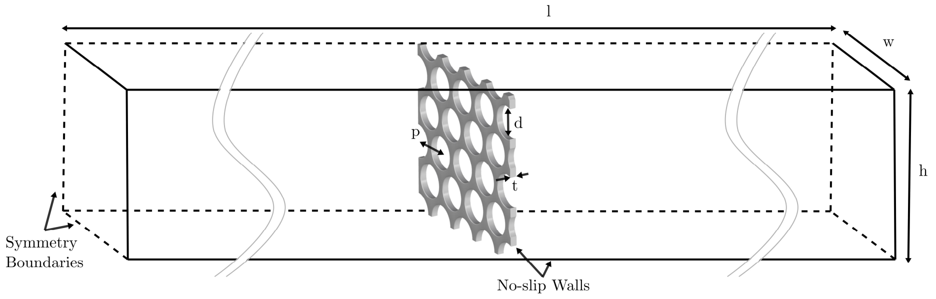

Figure 3: Domain setup for the detailed sub-model. Perforation diameter *d* = 5mm, pitch *p* = 6mm, thickness *t* = 1mm, domain height *h* = 25mm, width *w* = 25mm and length *l* = 2.6m. The open area of the sample screen is 63%.

## 3. INITIAL FINDINGS

The numerical pressure drop results for the pore-scale modelling are shown in Figure 4. It is seen that the numerical results give close agreement with the experimental wind tunnel results, with the greatest deviation for the highest velocity tested. The 0m/s - 36m/s velocity range covers the full range of wind speeds expected in both wind tunnel and full-scale pedestrian level scenarios.

The pressure coefficient, defined as the pressure drop normalised by the dynamic pressure at the inlet, shows a relatively flat profile for the simulated results. In particular, the simulated results above 12m/s are almost uniform, showing that the pressure drop coefficient is invariant with respect to Reynolds number. In the experimental results, a slight drop in pressure coefficient is observed at the highest tested wind speed.

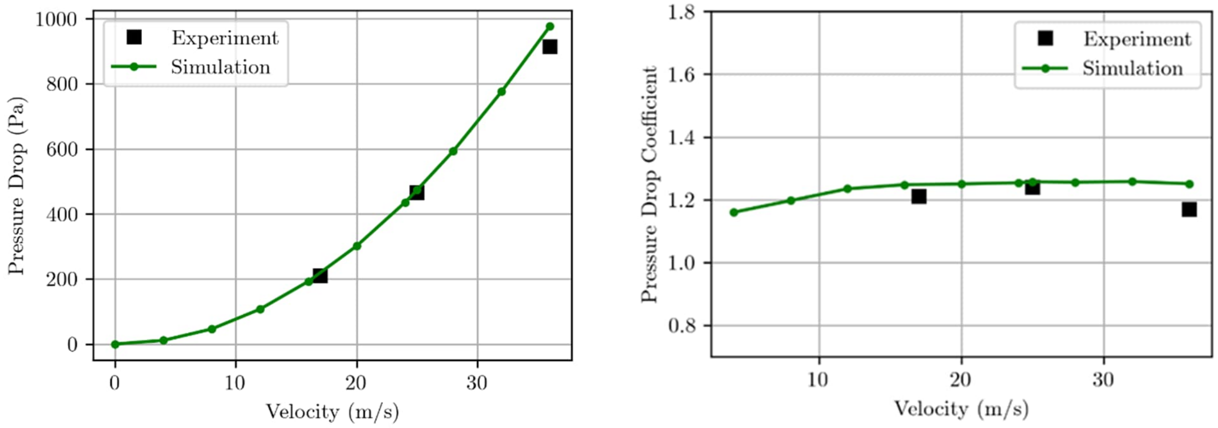

Figure 4: Pressure drop results for the detailed sub-model, with comparison to the experimental wind tunnel data of Méry & Sebbane (2023).

## 4. CONCLUSIONS AND FUTURE PROSPECTS

Pore-scale resolved CFD simulations are shown to accurately capture the pressure drop across a representative porous screen section. This setup can now be tested with varying screen orientations relative to the oncoming flow, with the resulting pressure drop characteristics used as the basis for porosity modelling at the screen-scale and city-scale.

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