Green Walls for Sustainable Buildings and Cities: Aerodynamic Characterization of Vegetation

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Abstract

Air pollution due to particulate matter (PM) is the number one cause of premature mortality in urban environments [2]. It is known that local peaks in atmospheric PM concentration can be reduced by urban green via deposition on the leaves [1]. Green walls (Figure 1) are particularly interesting in this concept because, in contrast to e.g. urban trees, they do not obstruct ventilation in street canyons, they can be installed at locations where space is limited and they allow much more flexibility in terms of thoughtful planning. Furthermore they provide additional ecosystem services, such as urban heath island effect mitigation, increase in biodiversity (including pollination facilitation), increase in life quality of citizens, etc.

The primary objective of this study is to acquire a clear and total view on how and to what extend green walls capture PM (and thus contribute to cleaner air).

For estimation of PM removal efficiency it is important to know how urban airflows interact with vegetation, and what characteristics are determinative for PM deposition. To address these questions, firstly a wind tunnel experiment was conducted in order to measure the pressure drop caused by typical green wall vegetation in an air flow. Subsequently the experiments were simulated with COMSOL Multiphysics® software.

Several plant species were brought into a simple closed circuit wind tunnel (Figure 2) of 6 m in length and 10 cm diameter. Air flow was created by an internal fan which could induce flow speeds varying from 1.14 m/s to 4.4 m/s. Using the Darcy-Forchheimer law, permeability and a Forchheimer drag could be determined, as the pressure drop over the vegetation and wind speed were measured. Utilizing additional techniques, other (plant) parameters such as Plant Area Density (one sided plant area per volume), porosity, Specific Leaf Area (plant area per dry matter), etc. could be determined. All of these parameters will be analyzed for correlation using statistical methods.

The experiments were simulated in COMSOL Multiphysics. A k-ω turbulence model was considered and the Brinkman equation was used to model air flow through the porous vegetation section. Permeability, Forchheimer drag and porosity, determined from the experiments, were necessary input parameters in this approach. The fan was modelled as an interior fan, using the fan characteristic as the only boundary condition. First test already show significant agreement between experiments and model approach for wind speed (Figure 3) and pressure difference (Figure 4). The model will later be extended in order to include a PM deposition model, linking the deposition efficiency with several of the above mentioned parameters. This will allow us to test the PM deposition capacity of several green wall configurations.

Reference

[1] K. P. Beckett et al., Urban Woodlands: Their Role in Reducing the Effects of Particulate Pollution, Environmental Pollution, Vol. 99(3), p. 347 (1998)
[2] World Health Statistics, EEA Air Quality in Europe — 2014, Report (2014)

Figures used in the abstract

Figure 1: Two types of green walls.

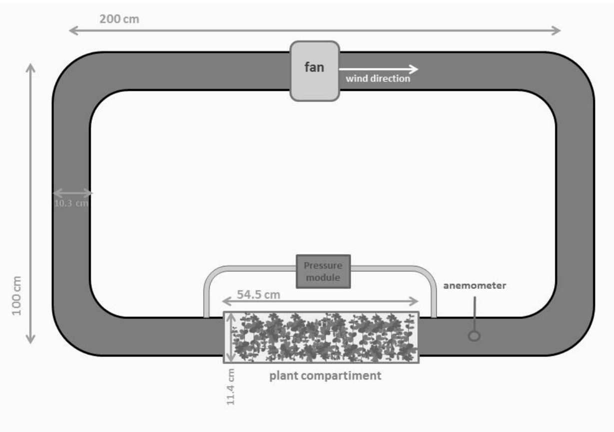

Figure 2: Setup of the wind tunnel experiment.

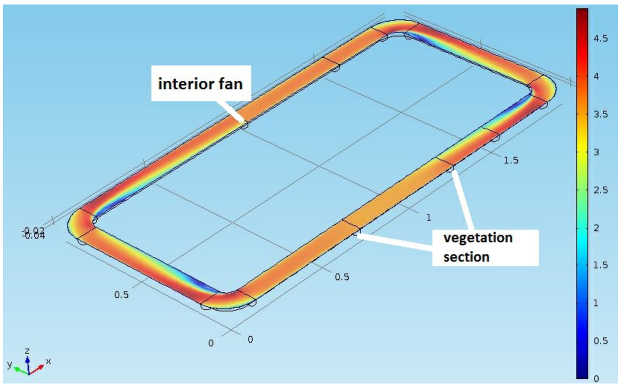

Figure 3: Simulation of air flow through a wind tunnel.

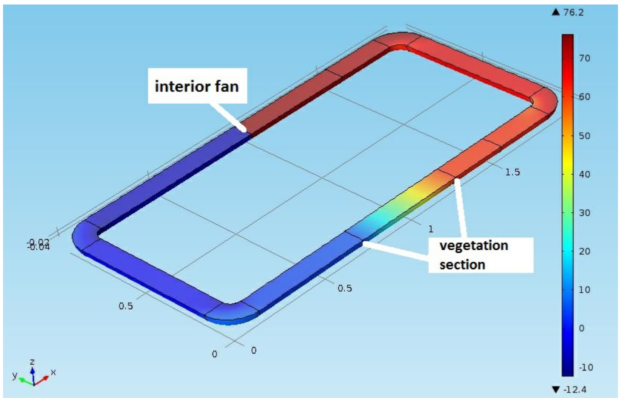

Figure 4: Simulation of pressure drop.