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Flow past a building with surface greening: comparison of PIV and LDV in two wind tunnels

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Abstract

In the context of studying vegetation effects on flow in the urban environment, twin studies of the flow past a cube shaped building (H=110 mm) were performed in the wind tunnels of the Karlsruhe Institute of Technology (KIT), (cross section 2x1m) and the National Technical University of Athens (NTUA), (cross section 3.5x2.5m). Identically shaped buildings were used, exposed to comparable upstream atmospheric boundary layer (ABL) profiles in terms of mean velocity, turbulence intensity and integral length scales. Simulated vegetation was placed on the building's upstream face or roof. Measurements were performed with Laser Doppler Velocimetry (LDV) at KIT and 2D-3C (and 2D-2C) Particle Image Velocimetry (PIV) at NTUA.

For characterising the upstream flow in both wind tunnels, hot wire anemometry was used to measure mean and fluctuating quantities and the integral length scales were calculated. Results are presented in Figure 1, along with the indicative regions of the turbulence intensity for moderately rough and rough terrains (VDI, 2000). The agreement of the vertical distribution of the ABL quantities in the two wind tunnels is notable, at least up to twice the building height (z_{ref}=H). The slight differences in the profiles lead to Reynolds numbers (based on building height and upstream velocity at the same height) of Re_H=23,500 at KIT and Re_H=16,500 at NTUA, both above the reported $Re_{H,crit}=10^4$ limit for Re number independence (VDI, 2000).

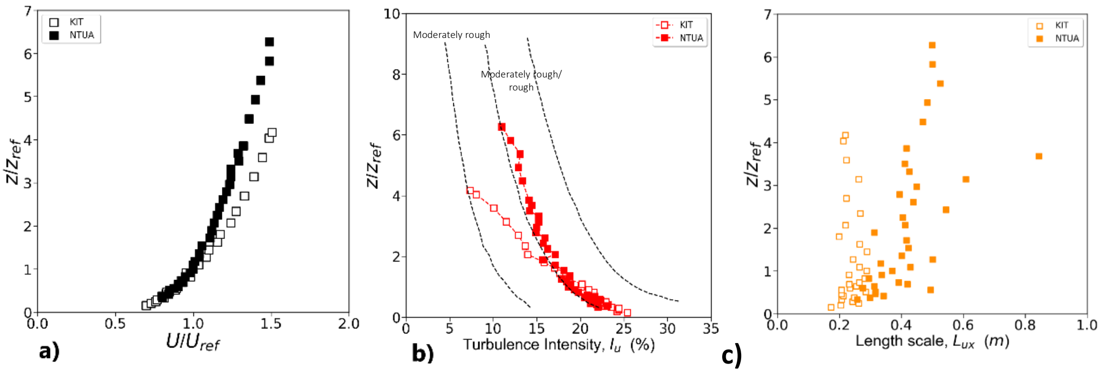

Figure 1: Boundary layer properties in the KIT and NTUA wind tunnels, calculated from the streamwise velocity component a) mean velocity, b) turbulence intensity, c) integral length scale

Vegetation on the building surfaces was modelled with reticulated, open cell foam of varying density (10-60 PPI), whose pressure loss coefficient was independently measured at KIT and NTUA and corresponds to dense hedges or ivy, based on dynamic similarity (Gromke, 2011) at a scale of 1:300.

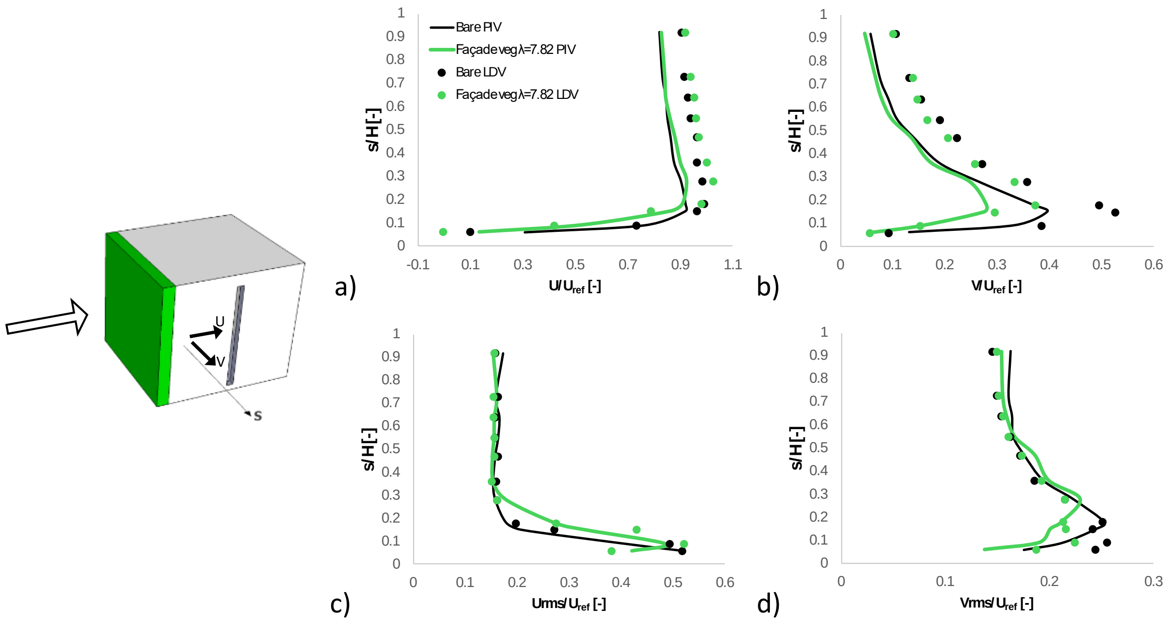

Figure 2: PIV and LDV results, with and without vegetation, along a horizontal profile (s) halfway up the sidewall and 0.1H from the leading edge: streamwise a) mean, c) rms and lateral b) mean, d) rms

Indicative results from LDV and PIV are presented in Figure 2 along a horizontal profile outside the building (s/H=0 at the wall), 0.1H from the leading edge and halfway up the building's side wall. The differences in the measured mean and rms velocities among the two methods are less than 10% of the upstream velocity at the building height ($U_{ref} = U_H$) with or without facade vegetation. It is important to note that the two measurement sets both show that upstream facade vegetation reduces the lateral mean velocity next to the side wall (Figure 2b) and dampens lateral velocity fluctuations (Figure 2d). The effect on the streamwise component is present mainly in an increase of the rms values (Figure 2c) near the wall.

Overall, the two measurement sets indicate the same qualitative trends of flow structure while vegetation effects and quantitative results are in close agreement. The full set of data is publicly available (Pappa et al. 2023) and provides an opportunity to analyse the effects of building outer surface vegetation on the flow field as well as differences arising from measurement techniques, experimental conditions and wind tunnel configurations.

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References

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