TOWARDS A QUANTITATIVE ASSESSMENT OF PEDESTRIAN WIND COMFORT IN WIND TUNNELS BY SAND EROSION

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Urban microclimate and pedestrian wind comfort gained prominence in the recent decades. It has received special attention due to concern by architects and planners since more than 50% of the population of the developed countries live in urban conglomerates. The quality of life in these areas strongly depends on the comfort feeling in the everyday activities such as going to work, strolling in a shopping street, waiting for a bus, sitting in a park, etc. As Penwarden remarks in 1973: for hundreds of years town dwellers have been sheltered from the wind by closely grouped buildings of more or less uniform height. This situation has changed since tall buildings rise above the roof-top level of its surrounding. Tall buildings can significantly disturb airflows over urban areas, and by deflecting the wind to the street level, can cause unfavourable wind conditions at pedestrian height.
A number of tools allow experimental assessment of pedestrian wind comfort. Up to now the so-called sand erosion technique is used as a visualisation tool. However, some trials were done to gain quantitative information from it but till now it remained a merely qualitative tool. Livesey & al., 1990, raised two important questions concerning the sand erosion technique: "what does the sand scour technique measure?" and "how do wind speeds inferred from scour patterns relate to measurements obtained with other instruments?" These are the questions the present study is aiming to answer.
When covering with sand particles the spaces between buildings on an urban microclimate model and exposing it to a high enough wind speed in the wind tunnel, zones of erosion can be observed at certain places of the model. The spaces where grains are removed are assumed to be "windier" than other zones, where the sand has not been removed.
It is a well established knowledge (e.g. Bagnold, 1941; Williams, 1986), that given particles resting on an aerodynamically smooth, flat surface or on a bed of alike particles are always dislodged at a certain shear stress exerted by the turbulent boundary layer of the flow above the bed. This fact together with the above-mentioned procedure of visualizing windier zones would implicate that the eroded zones around the model building are in fact zones of constant shear stress. It seems, however, that turbulent features of the complex flow around the model play an important role in shaping the sand patterns and therefore drawing this conclusion is not correct.
The present study investigates the phenomena of sand erosion downstream of a backward facing step through wind tunnel experiments and a computational model in MATLAB. The experimental methods of investigation are High Speed Imaging, Particle Image Velocimetry and "traditional" sand erosion for comparative studies. The computational model involves ordinary differential equation solver for the equations of motion and several stochastic elements to simulate turbulent features and aeolian particle entrainment and rebound. By linking the local mean wall shear stress to the so called "erosion time" (the time needed for the sand to leave), a quantitative measurement tool is proposed. The study gives guidelines / recommendations to users of the sand erosion technique for microclimate studies.

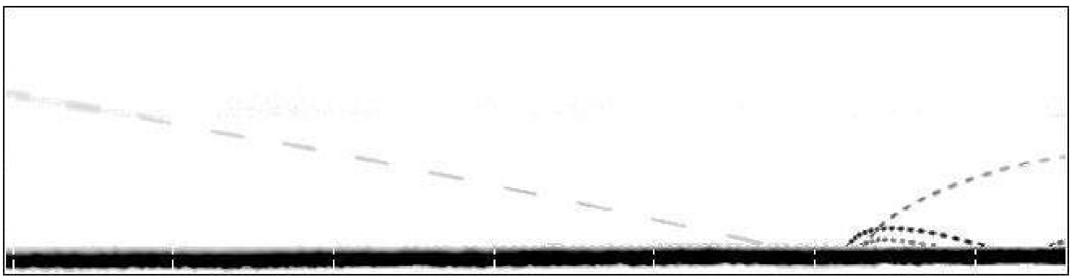

Figure 1: Saltating sand grain initiating two other particles to move. The flow is from left to right, free stream velocity 15 m/s, high speed imaging framerate 500/s

[1]*BAGNOLD, R.A.: The Physics of blown sand and desert dunes, Methuen & Co. Ltd. London, first published 1941*
[2]*LIVESEY, F, INCULET D., ISYUMOV N., DAVENPORT A.G.: A scour technique for the evaluation of pedestrian winds, Journal of Wind Engineering and Industrial Aerodynamics, vol. 36, pp. 779-789, 1990*
[3]*PENWARDEN, A.D. : Acceptable wind speeds in towns. Building Science, vol. 8, pp. 259-267, 1973*
[4]*WILLIAMS, J.J.: Aeolian entrainment thresholds in a developing boundary layer, PhD thesis, Univ. of London, 1986*