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Wind Tunnel Study on Flows over Various Two-dimensional Idealized Urban-liked Surfaces

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Extensive human activities (e.g. increased traffic emissions) emit a wide range of pollutants resulting in poor urban area air quality. Unlike open, flat and homogenous rural terrain, urban surface is complicated by the presence of buildings, obstacles and narrow streets. The irregular urban surfaces thus form a random roughness that further modifies the near-surface flows and pollutant dispersion.

In this study, a physical modelling approach is employed to commence a series of wind tunnel experiments to study the urban-area air pollution problems. The flow characteristics over different hypothetical urban roughness surfaces were studied in a wind tunnel in isothermal conditions. Preliminary experiments were conducted based on six types of idealized two-dimensional (2D) street canyon models with various building-height-to-street-width (aspect) ratios (ARs) 1, 1/2, 1/4, 1/8, 1/10 and 1/12. The main instrumentation is an in-house 90o X-hotwire anemometry. In each set of configuration, a sampling street canyon was selected near the end of the streamwise domain. Its roof level, i.e. the transverse between the mid points of the upstream and downstream buildings, was divided into eight segments. The measurements were then recorded on the mid-plane of the spannwise domain along the vertical profile (from building roof level to the ceiling of wind tunnel) of the eight segments. All the data acquisition processes were handled by the NI data acquisition modules, NI 9239 and CompactDAQ-9188 hardware. Velocity calculation was carried out in the post-processing stage on a digital computer.

The two-component flow velocities and velocity fluctuations were calculated at each sampling points, therefore, for each model, a streamwise average of eight vertical profiles of mean velocity and velocity fluctuations was presented. A plot of air-exchange rate (ACH) against ARs was also presented in order to examine the ventilation performance of different tested models. Preliminary results show that the near-ground turbulence behaviour (2 to 5 times of the building height) is relatively sensitive to the changes in ARs. The wider the streets (decrease in AR), the higher the turbulence level was observed. A similar behaviour is observed on the ventilation performance in which the ACH was increased with decreasing AR. Interestingly, a peak ACH value was observed around AR = 1/10 and was slightly dropped thereafter at AR = 1/12. The observation is in line with our previous large-eddy simulation (LES) results. These findings indicate that variability of urban-like surfaces is important to the near-ground turbulent boundary layer structure. Additional measurements on the flows and dispersions over building surfaces will be undertaken on a variety of ARs and building height variations to elucidate the complex transport and pollutant dispersion mechanism in urban areas.