Numerical simulation on Wind flow in Street canyon with changes of the Aspect Ratio and Wind Direction

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Abstract numerical simulation on wind flow in a street canyon were investigated under changes of the aspect ratio and wind direction using CD models. The diffusion flow field in the atmospheric boundary layer within the street canyon was studied for different aspect ratios (W/H = ½, ¾, and 1) and wind directions (θ = 90°, 112.5°, 135°, and 157.5°). The simulation demonstrated that the wind velocity and turbulence intensity increase as the aspect ratio and wind direction increase.

1. INTRODUCTION

Air quality in an urban environment has attracted much attention owing to increasing traffic emissions and their negative effects on human health. Urban street canyons, where both pedestrian density and traffic density are usually high, are common urban areas. The main parameters that determine the air flow patterns and distribution of the pollutant concentration within street canyons are a focus of air pollution research. The parameters include both geometrical and meteorological conditions. The geometrical parameters include the building shape, orientation, and aspect ratio (W/H), which is defined as the ratio of the building height (H) to the width between buildings (W). The meteorological parameters include the ambient wind speed and direction and thermal stability. The building aspect ratio and ambient wind direction are of particular importance in that they determine the flow patterns and dispersion processes within street canyons. Yassin et al. [1] studied flow and dispersion at a street intersection using numerical and experimental methods. Yassin [2] studied the effects of the variability in the height and shape of a building roof on the flow and pollutant dispersion within a street canyon using the standard k-ε turbulence model. The results obtained indicate that the pollutant concentration increases as the roof height decreases. Additionally, the pollutant concentration was lower for slanted and trapezoid-shaped roofs and higher for flat roofs.

Despite our understanding of the various parameters and processes responsible for the wind field process within street canyons gained in previous studies, there appears to be some controversy regarding the process responsible. There is still a strong demand for greater understanding of the effects of the parameters to improve our knowledge of mechanisms that govern flow within street canyons and thus assess and optimally respond to traffic emissions. Thus, the aim of the present work was to investigate numerically the flow field within the street canyon under changes of the aspect ratio and wind direction. To accomplish this aim, three-dimensional numerical models based on the Reynolds-averaged Navier–Stokes (RANS) equations coupled with the standard, Renormalized-Group (RNG), and realizable k–ε turbulence models were used to further explore the pollutant dispersion characteristics of a street canyon. Three-dimensional models of a street canyon were considered and gaseous pollutants emitted from traffic exhaust were analyzed. The results of the model were validated using extensive experimental data obtained in a detailed wind-tunnel study by Yassin and Ohba [3].

2. NUMERICAL MODEL

The commercial CFD package ANSYS FLUENT Version 6.3.26 (ANSYS Inc., 2010) was used to simulate the wind flow and pollutant dispersion within the street canyon. The CFD modeling was configured to solve the pseudo-steady-state incompressible Average Navier Stokes (RANS) equations equipped with κ-ε turbulence models (κ is turbulent kinetic energy and ε is dissipation rate of kinetic energy) for the mean flow within street canyons for different building aspect ratios and wind directions. Three separate κ-ε turbulence models; the standard, RNG and Realizable were used. The conservation equation for the species concentration of pollutants must also be solved together with the above-mentioned equations that describe the flow characteristics. In modeling urban flow and dispersion, a finer grid is desirable within/around street canyon models to better resolve flow and dispersion fields, whereas a coarser grid is allowable away from the street canyon model. The above set of governing equations was numerically solved on a staggered grid using the finite volume following the Semi-Implicit Method for Pressure-Linked Equation (SIMPLE) algorithm

3. RESULTS AND DISCUSSION

The following discussion and analysis considers only the results obtained with the standard κ-ε turbulence model, which gave the same results as the wind-tunnel experiments in the validation tests. The results of numerical simulation using the standard κ-ε turbulence model for the street canyon are presented and analyzed in terms of the flow field and pollutant dispersion characteristics. To investigate the effect of the wind direction (θ = 90°, 112.5°, 135°, and 157.5°)

and building aspect ratio (W/H = ½, ¾, and 1.0), 12 cases for the street canyon were considered. Figure 5 shows contours, vectors, and path lines of normalized longitudinal velocities for street canyons having different aspect ratios and wind directions. These figures show that the wind direction and aspect ratio greatly affect the flow patterns near the roof and ground levels. The flow was most intense near the upper region of the central street. The flow patterns above the street cannot be parallel to the ground because the flow separates at the upwind edge of the upwind building. Hence, the flow patterns above the street can have streamline curvature. The airflow exchange between the outer flow and canyon interior for wind directions θ = 112.5° and 135° was stronger than that for wind directions θ = 90° and 157.5°. The airflow exchange between the outer flow and canyon interior for the aspect ratio W/H = ½ was stronger than that for aspect ratios W/H = ¾ and 1. This is due to the flow close to roof level being oblique to the street axis. The distributions of the turbulence intensity within street canyons having different aspect ratios and wind directions are shown in Fig. 2. The turbulence intensity distribution was observed to be similar near roof level for all canyons. The turbulence intensity was found to be fairly uniform within the street canyon, and it decreased in the vicinity of walls as expected. There was an increase with height on the windward side and a decrease with height on the leeward side, although the variations were not great. Additionally, there were slightly higher values in the core of the vortex. The turbulence intensity was found to be high near mid-height of the street canyon and it decreased downward to ground level and upward to roof level.

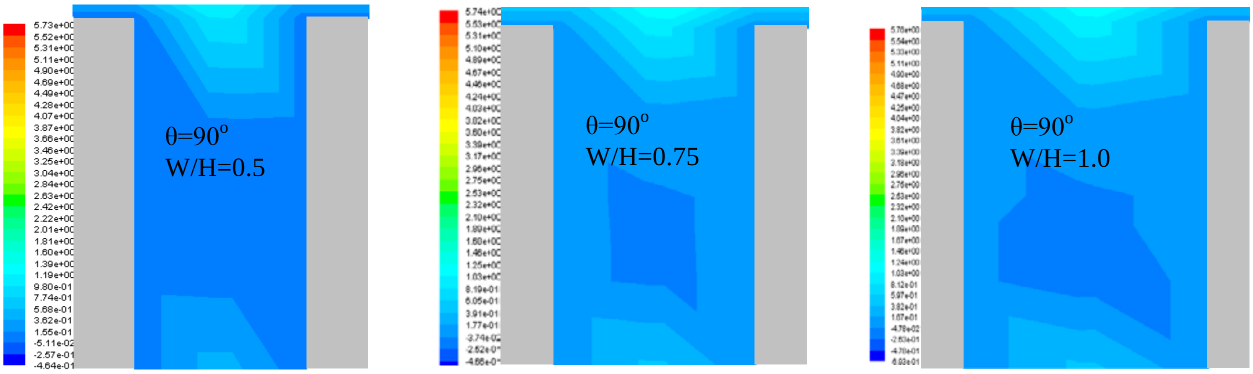

Fig. 1 Contours of longitudinal mean velocity of the different aspect ratios and wind directions in the *x-z* at *Y/H*=0.0

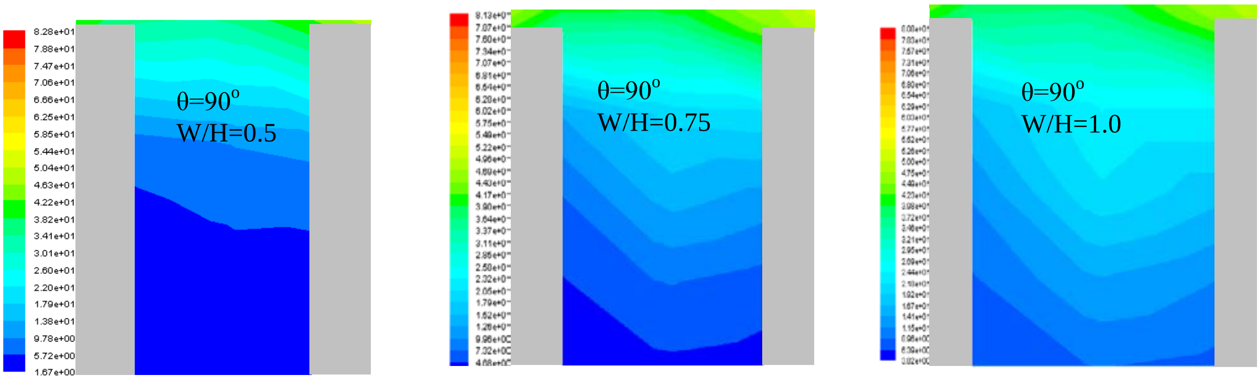

Fig. 1 Contours of turbulence intensity of the different aspect ratios and wind directions in the *x-z* at *Y/H*=0.0

References

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