

# Evaluation of RANS turbulence models for simulating wind-induced mean pressures and dispersions around a complex-shaped high-rise building

Xiaoping Liu<sup>1,2</sup>, Jianlei Niu<sup>1</sup> (✉), Kenny C.S. Kwok<sup>1</sup>

1. Department of Building Services Engineering, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong, China

2. State Key Laboratory of Fire Science, University of Science and Technology of China, Hefei 230027, China

## Abstract

Re-ingestion of the contaminated exhaust air from the same building is a concern in high-rise residential buildings, and can be serious depending on wind conditions and contaminant source locations. In this paper, we aim to assess the prediction accuracy of three  $k$ - $\varepsilon$  turbulence models, in numerically simulating the wind-induced pressure and indoor-originated air pollutant dispersion around a complex-shaped high-rise building, by comparing with our earlier wind tunnel test results. The building modeled is a typical, 33-story tower-like building consisting of 8-household units on each floor, and 4 semi-open, vertical re-entrant spaces are formed, with opposite household units facing each other in very close proximity. It was found that the predicted surface pressure distributions by the two revised  $k$ - $\varepsilon$  models, namely the renormalized and realizable  $k$ - $\varepsilon$  models agree reasonably with experimental data. However, with regard to the vertical pollutant concentration distribution in the windward re-entrance space, obvious differences were found between the three turbulence models, and the simulation result using the realizable  $k$ - $\varepsilon$  model agreed the best with the experiment. On the other hand, with regard to the vertical pollutant concentration distribution in the re-entrant space oblique to the wind, all the three models gave acceptable predictions at the concentration level above the source location, but severely underestimated the downward dispersion. The effects of modifying the value of the turbulent Schmidt number in the realizable  $k$ - $\varepsilon$  model were also examined for oblique-wind case. It was confirmed that the numerical results, especially the downward dispersion, are quite sensitive to the value of turbulent Schmidt number.

## Keywords

high-rise building, computational fluid dynamics, pollutant dispersion, air cross-contamination

## Article History

Received: 8 June 2012

Revised: 5 November 2012

Accepted: 12 November 2012

© Tsinghua University Press and Springer-Verlag Berlin Heidelberg 2012

## 1 Introduction

Pollutant dispersion in urban environment has been the subject of extended research in recent years, as it is thought to be directly associated with human health and air quality concerns in built-up areas (Brunekreef and Holgate 2002; Bernstein et al. 2004; Haghighat and Mirzaei 2011; Leung et al. 2012). If the pollutants are re-ingested either via the open windows or through the intakes of the ventilation system, the health of people living in the building may be severely influenced. An improved understanding of pollutant transport will facilitate the assessment of the contamination risk to occupants, and help identify and evaluate ways to reduce occupant exposure to airborne pollutants.

The prediction of pollutant dispersion in urban environment is a difficult task due to the strong interaction between a building and the external boundary layer flow. Britter and Hanna (2003) provided an extensive review about flow and dispersion in urban areas by considering the problem at different scales, ranging from regional, city, neighborhood to street. Street-scale flow and dispersion are particularly studied, because the distribution of pollutant concentrations on and near buildings is a main concern of building engineers that design the ventilation inlets and outlets on building facades. A large body of work has been conducted to study the flow and dispersion around buildings, by means of experimental and numerical approaches. Meroney (2004) compiled a very comprehensive review of