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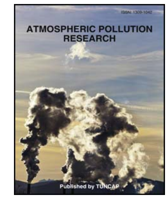

Numerical simulation of pollutant dispersion characteristics in a three-dimensional urban traffic system

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ABSTRACT

A complex three-dimensional (3D) urban traffic system containing roundabouts and tunnels continues to emerge in China's metropolises. Based on this, a mathematical model was established to describe the fluid flow and CO propagation characteristics in a complex 3D traffic system, including a sunken bus stop area, traffic roundabout, viaducts, and tunnels. Features of pollution dispersion in those locations were analyzed under different ambient crosswinds (ACWs). The results showed that the distribution of pollutants in the 3D traffic system was greatly influenced by geometric parameters and their relative positional relationship. Distribution of pollutants in the 3D traffic system is rather complicated and varied. At a sunken bus stop area, changes in ambient wind will cause fluctuating pollution levels upstream and downstream at the bus stop, and symmetrical distribution has been exhibited under parallel wind. The effects of complex road conditions on pollutants are beyond the prevailing winds at the traffic roundabout. In a naturally ventilated municipal double-hole traffic tunnel, contaminants accumulate along the downstream direction, which is more pronounced at low wind speeds. However, dilution effects are enhanced in tunnels' open areas.

1. Introduction

With the rapid growth of China's economy and urbanization, the prevalence of motorized vehicles is gradually increasing. Automobile emissions not only cause the global greenhouse effect (De_Richter et al., 2017) but also impact urban air quality. In fact, vehicle emissions have become one of the most important pollutant sources in the city environment (Liu et al., 2008; Shahbazi et al., 2016), affecting humans' respiratory system, cardiovascular system, and nervous system (Lu et al., 2017; Mcdonald et al., 2004). Consequently, the issue of city traffic pollution has aroused widespread concern.

Several studies have been conducted on pollutant diffusion in idealized urban area models with certain geometrical structures (Krecl et al., 2015; Sabatino et al., 2013; Scungio, 2013; Tsai and Chen, 2004). Previously, scholars believed that ACWs perpendicular to the street exacerbated contaminant spread, and the geometry of roofs and aspect ratio of street canyons had a great influence on vortices (Kastner-Klein and Plate, 1999). Soulhac et al. (2009) investigated pollutant dispersion in a street canyon with road intersection. The results showed that a vortex formed at the beginning of the street, which determined the exchange of pollutants between the street and the intersection; the level of pollutants ranged between a limited long street and an infinite street. Research about traffic roundabout showed that the effect of the complex relationship of road connections on pollutant dispersion went beyond prevalent ambient wind (Pandian et al., 2011).

In addition the above, studies about other aspects of this field have also attracted considerable attention. Firstly, several new simulation models have utilized flourishes, including the first-tested detached eddy simulation (DES) model (Scungio et al., 2015a), which was found to be sufficiently accurate; and the one-equation Spalart-Allmaras turbulence model (Scungio, 2013). Secondly, particle dispersion has piqued researchers' interest (Scungio et al., 2015b; Zhang et al., 2011). Thirdly, measures aimed at improving air quality in street canyons have been developed. Moradpour et al. investigated the effects of green roofs (Moradpour et al., 2017) and urban vegetation design (Moradpour et al., 2016) on the outdoor thermal environment and pollutant levels; both were proved to be effective environmental improvement strategies.

With the rapid development of urbanization in China and the growing size of cities, more 3D traffic systems are being constructed to

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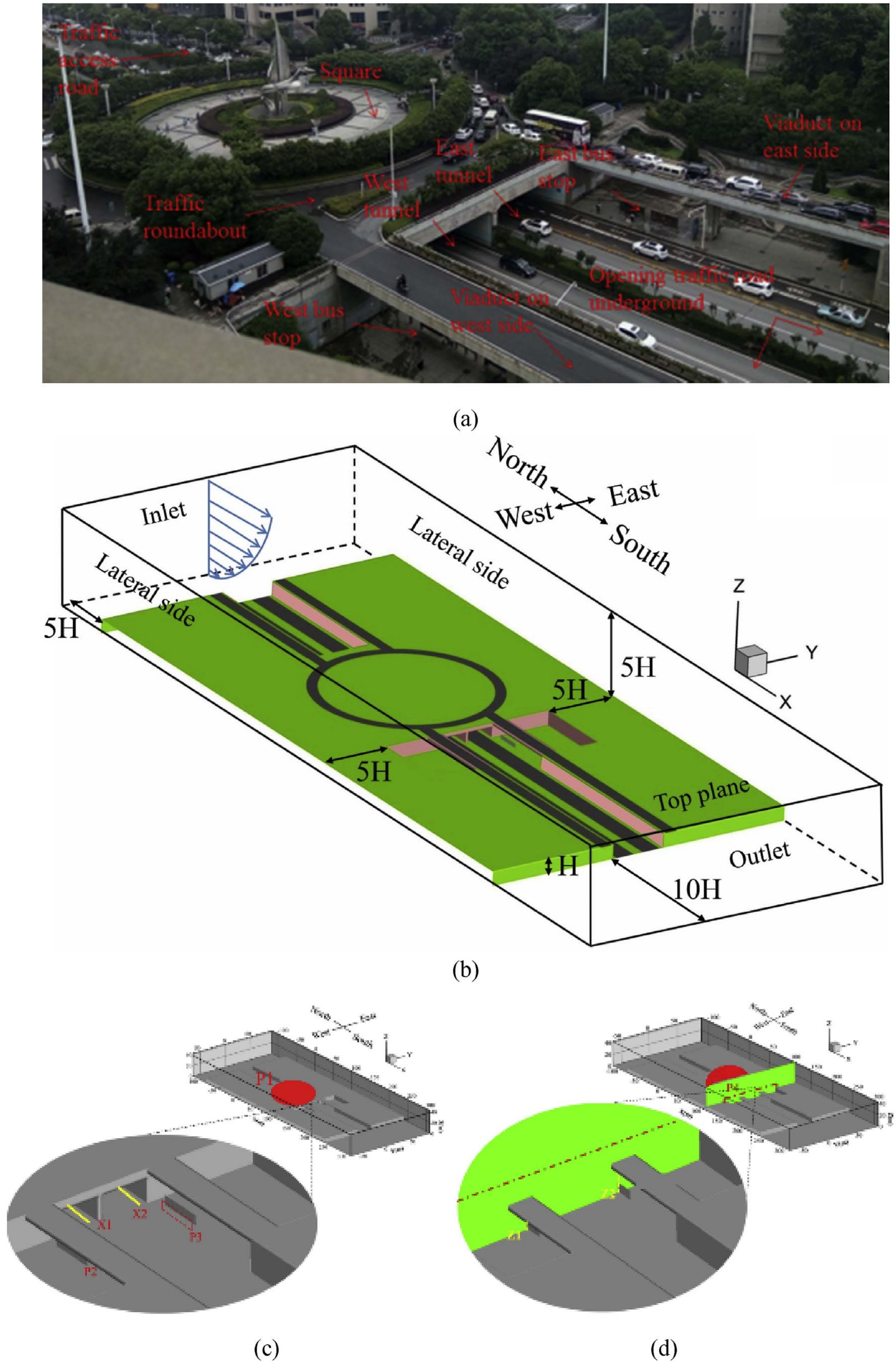

Fig. 1. Real and physical model: (a) the real 3D traffic system contains three major research objects: the bus stop area, the traffic roundabout, and the tunnels; (b) physical model; (c) position of the object region of planes P1, P2, and P3 and lines X1 and X2 in the physical model; (d) position of the object region of plane P4 and lines Z1 and Z2 in the physical model.