Available online at www.sciencedirect.com
ScienceDirect
Journal of Hydrodynamics
2016,28(5):801-810
DOI: 10.1016/S1001-6058(16)60683-2
www.sciencedirect.com/
science/journal/10016058

Wind tunnel simulation of pollutant dispersion inside street canyons with galleries and multi-level flat roofs*

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(Received July 6, 2015, Revised March 23, 2016)

Abstract: In this study, the pollutant dispersion within street canyons is studied by experiments conducted in an environmental wind tunnel. The vehicular exhaust emissions are modeled using a line source. The pollutant (smoke) concentrations inside the canyons are measured based on a light scattering technique. The pollutant concentrations within the four different street canyons containing the galleries and the three-level flat-roofs under both the isolated and urban environments are obtained and discussed. For each of the four canyon configurations investigated, it is found that there is an obvious discrepancy between the pollutant dispersion patterns under the isolated environment and the urban environment. The three-level flat roof is found to significantly influence the pollutant distribution pattern in a street canyon. In order to clarify the impacts of the wedge-shaped roofs on the pollutant dispersion inside an urban street canyon of an aspect ratio of 1.0, the pollutant distributions inside urban street canyons of three different wedge-shaped roof combinations are measured and analyzed. It is revealed that the pollutant distribution pattern inside the urban street canyon of an aspect ratio of 1.0 is influenced greatly by the wedge-shaped roof, especially, when an upward wedge-shaped roof is placed on the upstream building of the canyon. Images from this study may be utilized for a rough evaluation of the computational fluid dynamics (CFD) models and for helping architects and urban planners to select the canyon configurations with a minimum negative impact on the local air quality.

Key words: street canyon, pollutant dispersion, wind tunnel experiments, three-level flat roof, line source

Introduction

A "street canyon" generally refers to a relatively narrow street in-between buildings that line up continuously along both sides[1]. Within the street canyons, the pollutants emitted from motor vehicles have adverse impacts on the health of pedestrians, cyclists, drivers, vehicle passengers and nearby residents[2]. Since the traffic emissions constitute a major source of air pollution in most urban areas, the dispersion of vehicular exhausts inside and over street canyons becomes an important aspect of urban air-quality studies.

So far, full-scale field measurements, wind tunnel experiments, and computational fluid dynamics (CFD) simulations were widely used to investigate the wind flow and the pollutant distributions in street canyons. These studies focused primarily on the effects of the street-canyon geometry[3-5], the ambient wind[5-7], the thermal conditions[8-10] and the traffic-induced turbulence[11-13] on the wind flow pattern and the pollutant distributions inside street canyons. In the investigation of the effects of the canyon geometry on the flow and the dispersion within street canyons, the previous considerations focused on the street width to building height aspect ratios, the symmetric and asymmetric building placements (for even, step-up and step-down canyons), as well as the building roof shapes. In those considerations, the rectangular buildings are commonly assumed and the roof shapes applied are the vaulted, trapezoidal, slanted and wedged roofs. In the real urban environments, some street canyons may have complicated geometries with galleries and multi-level flat

* Project supported by the National Natural Science Foundation of China (Grant No. 51536006), the Innovation Program of Shanghai Municipal Education Commission (Grant No.10ZZ95) and the Hujiang Foundation of China (Grant No. B14003).
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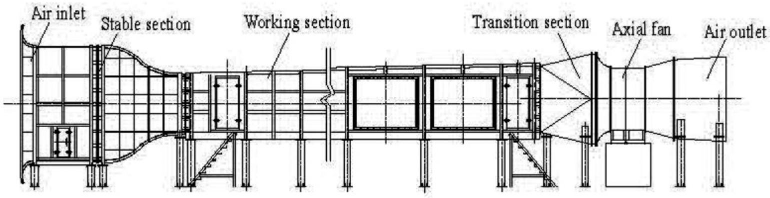

(a) Components of the wind tunnel

(b) Exterior photo of the wind tunnel

Fig.1 Wind tunnel at the School of Environment and Architecture, University of Shanghai for Science and Technology

roofs[14,15], which, up to now, have not been well studied. In recent years, the pollutant dispersion within urban street canyons formed by wedge-shaped roof buildings was investigated systematically by CFD approaches[16,17] but no wind tunnel experimental results were reported. The findings from the CFD simulations need to be validated by the wind tunnel measurements.

The aim of the present study is to reveal the effects of multi-level flat roofs and galleries on the pollutant distributions inside both the isolated and urban street canyons and to clarify the impacts of wedge-shaped roofs on the pollutant distributions inside urban street canyons by means of the wind tunnel experiments. The wind tunnel models of street canyons with galleries and three-level flat roofs as well as the wind tunnel models of urban street canyons with wedge-shaped roofs are constructed at a geometric scale of 1:100. A line source emitting smoke (pollutant) is designed for simulating the vehicular exhaust emissions. The pollutant concentrations inside the wind tunnel models of the street canyons are obtained using a light scattering technique[18,19]. The images from the light scattering technique are processed to reveal the pollutant distribution pattern inside each street canyon studied.

1. Experimental set-up and measurement techniques

1.1 *Introduction to the wind tunnel facility*

The experiments are performed in the environmental wind tunnel at the School of Environment and Architecture, University of Shanghai for Science and Technology. This facility is an open circuit wind tunnel of suction type with a total length of approximately 33 m. It consists of an air inlet fitted with honeycombs and meshes, a stable section, a contraction section with a contraction ratio of 4:1, a working section, a transition section, an axial fan and an air outlet (Fig.1). The dimension of the working section is 18 m long, 2.5 m wide and 1.8 m-2.1 m high (the ceiling of the working section has a slope of 1:60 allowing the compensation of pressure losses in the direction of the stream). The air speed in the working section can be adjusted in the range of 0.5 m/s-20 m/s. The six spires installed at the entrance of the working section and the coarse roughness elements across the working Section 2 m downstream the spires are utilized to initiate the atmospheric boundary-layer flow (Fig.2).

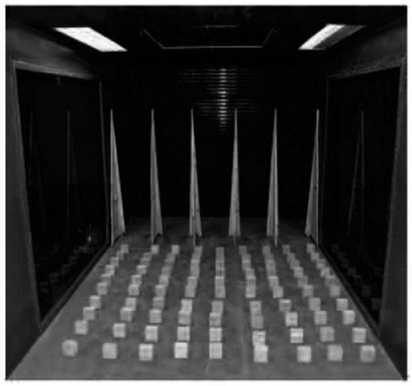

Fig.2 Spires and coarse roughness elements in the wind tunnel