Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 198 (2017) 743 – 757

Procedia Engineering

www.elsevier.com/locate/procedia

Urban Transitions Conference, Shanghai, September 2016

The diurnal cycle of urban thermal environment in scale-model street canyons by outdoor field measurement

Q. Wang[a], Y .Li[b], J. Hang[a], L. Peng[b]

[a]Sun Yat-sen University, China

[b]The University of Hong Kong, Hong Kong

Abstract

Building thermal mass is significant to influence urban climate. We performed scale-model field measurement of thermal environment and turbulence in summer of 2015 in Guangzhou, China. Two types of scale-model were used to arrange north-south street canyons $(H = W = 1.2m)$ (the 'empty' model with wall thickness of 1.5cm and the 'sand model' in which all buildings are filled with sand producing bigger heat capacity) to conduct measurement over three days.

The urban roughness layer turbulence and temperature characteristics in such idealized street canyons were investigated by using several instruments such as ultrasonic anemometer, temperature and humidity sensors, four component radiometers, infrared camera. We study velocity distribution, air temperature and basic characteristics of radiation in the idealized city. Especially focus on the different building heat storage impact on the thermal environment.

The thermal mass in the empty model is much smaller than the sand model. Therefore, the measurements show that, during daytime wall temperature (T_{wall}) and air temperature (T_{air}) of empty model reached its peak earlier and this peak value is much higher than those of the sand model. After sunset, result is quite contrary. T_{wall} in the sand model are higher than those in the empty model because the thermal storage of the former is much greater than the latter, but T_{air} in these two models are similar because the measured location of T_{air} is at the centre of street canyon and far from building walls $(L = 0.5H = 0.6m)$.

The street canyons were subjected to differential wall heating and overlying wind. As overlying wind is relatively weak, the heating of building walls may induce thermally driven circulation. A buoyancy parameter, $B = g\alpha\Delta TH / U_{ref}^2 \left[1 + (H/L)^2\right]$, was used to demarcate thermal and inertial circulation regimes. When the street canyon was dominant by the wind, and the canyon velocities scaled by u_0 are approximately constant.

Peer-review under responsibility of the organizing committee of the Urban Transitions Conference

doi:10.1016/j.proeng.2017.07.126

When the thermal circulation becomes important, velocity in canyon and buoyancy parameter shows a relationship: $u(z=0.25H)/U_{ref}(z=2H) \approx \gamma_1 + \gamma_2 B^{1/2}$.

Keywords: diurnal cycle、*thermal storage*、*thermal environment*、*scale model*

1. Introduction

According to statistics, the proportion of the world's urban population in 2000 is 47% and is expected to reach 69% by 2050. Rapid urbanization process has led to a lot of urban environmental issues, such as urban ventilation deteriorates, urban air pollution and urban heat island. The city is not only harmful to the health of residents, but also the increase in summer air conditioning energy consumption. Urban heat island will occur throughout the year, and related with city warming, for example, over the past 135 years, the average temperature in Tokyo rose by 2.8ºC, far higher than the global warming of 0.9ºC. In some larger cities, urban and rural temperature difference can exceed 10ºC. Fung et al. found that if the outdoor temperature increased by 1ºC, , the annual power consumption in the domestic, commercial and industrial will increase 9.3%, 3.0% and 2.4% respectively in Hong Kong [1]. Lam et al. also found that the cooling effect of the city will cause energy consumption increasing by approximately 4.5% [2]. In addition to reducing emissions of air pollutants and anthropogenic heat, healthy, energy-efficient urban environment construction should also take full advantages of the wind, the sun, the city itself and other natural factors. Reasonable layout and urban planning will improve the thermal properties of the city, the relevant mechanism of atmospheric environment for sustainable urban design is important

Because it may be difficult to meet the thermal similarity in wind tunnel experiments, the use of meteorological tower, aircraft and satellite observations are also faced with complexity of the underlying surface, the observation accuracy and data inversion problem. Near full-scale field experiment is a good method to find out mechanism. MUST experiment used container as a model to build an ideal city to fully meet the dynamic similarity requirements, mainly discussed the urban turbulence characteristics and the spread of contamination issues, summed up the upstream and downstream wind profile, pollutant distribution in the horizontal and vertical direction, compared with pollutant dispersion model, achieve mutual verification purposes [3-5]. The COSMO field observation experiments carried out in 2005, in Japan using 512 uniform concrete models to build up a mocked urban to study urban energy balance characteristics through a long period. Thermal storage of the mocked urban and urban energy balance feature based on experimental data, were summarized, they also provide data to verify SUMM numeric model. At the same time, COSMO experiments were also concerned about the late effects of natural convection in a vertical wall, vegetation on the urban environment [6-9], what