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Procedia Engineering 169 (2016) 44 – 54

Procedia Engineering

www.elsevier.com/locate/procedia

4th International Conference on Countermeasures to Urban Heat Island (UHI) 2016

The Study of the Effects of Building Arrangement on Microclimate and Energy Demand of CBD in Nanjing, China

Ji-Yu Deng[a]*, Nyuk Hien Wong[b], Xin Zheng[a]

[a]*School of Architecture, Southeast University, No.2 Sipailou, Nanjing 210096, China*
[b]*Department of Building, National University of Singapore, 4 Architecture Drive, Singapore 117566, Singapore*

Abstract

This study aims to investigate the impact of building arrangement on the urban microclimate and energy consumption of buildings in central commercial and business district by using simulation tools, including ENVI-met and HTB2. In order to achieve this goal, a series of numerical calculations and building energy simulations are utilized to evaluate a total of 12 urban scenarios with various building arrangements. The results indicate a quantitative correlation between building arrangement and the microclimate and building energy performance at urban design scale. Furthermore, several recommendations have been provided for urban planners and designers as strategies and methods to mitigate the UHI effect and to reduce the energy consumption.

Peer-review under responsibility of the organizing committee of the 4th IC2UHI2016

Keywords: Urban heat island; Building arrangement; Urban microclimate; Energy consumption; Plot ratio

1. Introduction

The urban heat islands (UHI) is known as the significant differences in microclimate between urban and rural areas [1]. Especially in the central area of city, the microclimate parameters in outdoor spaces, including the air temperature, wind speed, relative humidity, solar radiation etc., are significantly influenced by various configurations of urban texture, such as plot ratio, site coverage, building height, and building arrangement etc. Consequently, the microclimate parameters affect the outdoor thermal comfort and building energy demand considerably and correspondingly.

* Corresponding author. Tel.: +86 153 8098 5151.
E-mail address: jiyudeng@gmail.com (Ji-Yu Deng).

Peer-review under responsibility of the organizing committee of the 4th IC2UHI2016
doi:10.1016/j.proeng.2016.10.006

Over the past few decades, a large number of studies have been carried out to investigate the impact of urban morphology on microclimate condition. Basically, some researches were conducted by numerical models [2–4], while some others were based on field measurements [5–7]. These studies have validated how the urban geometry had certain effects in relation to urban microclimate condition.

Due to the climate change, building energy consumption will become increasingly sensitive to the effects of surrounding buildings. Therefore, building energy performance analysis should be considered in neighborhood context instead of an isolate building [8]. Moreover, most of the correlative studies were conducted to validate the relationship between urban morphology and building energy consumption by using an energy simulation tool [9–11].

Reference to above literature review, the parameters of urban morphologies involved in most of the studies are concerned with the street geometries, including aspect ratios, orientations, plot ratios and density. However, only a few literatures focused on the effects of building arrangement which create the various streets and canyons [12, 13].

This study aims to detect the effects of building arrangement variations on outdoor thermal conditions and building energy performance in CBD area under the local climate of Nanjing city. In order to achieve this goal, a series of numerical simulations were conducted to evaluate several urban scenarios with various building arrangements derived from two building prototypes and different parameter combinations. Finally, comprehensive and effective solutions for optimizing the guidelines and strategies of urban planning and design have been proposed.

2. Site Description

This study is carried out for typical summer conditions in Nanjing city located at 32.05°N, 118.48°E, and 22 m altitude above sea level. This city is characterized by a humid subtropical climate which is hot and humid in summer with an average maximum temperature of 32°C and a humidity of about 75%. The prevailing winds are from east and southeast, with average speed ranging from 2 to 3 m/s. All these climate conditions contribute to the typical climate of the middle and lower reaches of Yangtze River region.

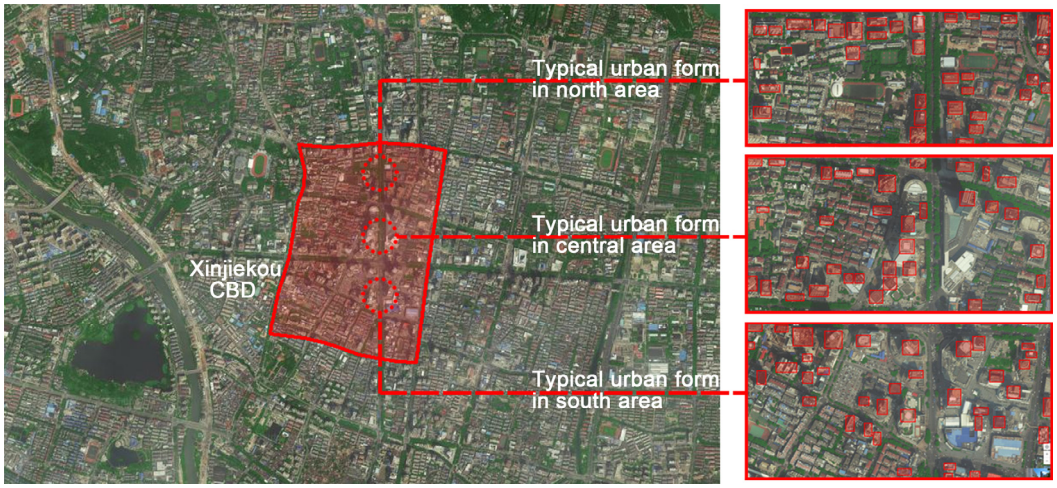

Fig. 1. The location of the reference site.

The study area is located in the central area of the city, called Xinjiekou, which is a famous CBD with a dense urban morphology, as is shown in Fig. 1. The reference site is characterized by high-rise buildings, narrow streets and less vegetation. The block shape in this area can be classified into two types: point one and slab one. In addition, most of the streets have the E-W and N-S orientations, and some of them are with intermediate orientations while the terrain of the site location is flat. The outdoor space formed by variations of building arrangements has been adopted as the object of analysis in this research for the microclimate simulation.