Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 205 (2017) 2401–2406

Procedia Engineering

www.elsevier.com/locate/procedia

10th International Symposium on Heating, Ventilation and Air Conditioning, ISHVAC2017, 19-22 October 2017, Jinan, China

Urban morphology on heat island and building energy consumption

Yan Zhou[a], Zhi Zhuang[a,*], FengYang[a], Yao Yu[b], Xiaohong Xie[c]

[a]*Tongji University, Shanghai, China, 200092*
[b]*North Dakota State University, Fargo, USA, 58102*
[c]*MCC Huatian Engineering and Technology Corporation, Nanjing, China, 210019*

Abstract

With the rapid urbanization of cities, the morphology of urban blocks develops from a single and low-density type to a diversified and high-density one, which has great influence on the underlying ground surface conditionings, ventilating performance and heat gain at a district scale, thus enhancing urban heat island effect and increasing building energy consumption. In this paper, the distinct urban attributes (greening rate, building density, and volume ratio) of ten districts around the county meteorological stations of Shanghai were collected to explore the relationships between the urban heat island effect and the urban morphology attributes. In addition, an energy model for a typical office building was setup to investigate the quantity effect of these distinct urban attributes on the energy performance of the buildings located around these ten county meteorological stations. The results show that the correlations between the urban island effect and distinct urban attributes exist. The heating load indexes of the buildings located in downtown are 1.5-5% less than those in the suburbs. As the heat island intensity raises by 1℃, the average heating energy consumption will decrease 5.04%.

Peer-review under responsibility of the scientific committee of the 10th International Symposium on Heating, Ventilation and Air Conditioning.

Keywords: urban morphology, heat island, building energy consumption, heating load

Nomenclature

g	greening rate, %
Bd	building density, %
p	floor area ratio
UHI	average heat island intensity, ℃
UHIF	frequency of urban heat island, kh
Tu	average temperature of urban observation stations, ℃
Tc	average temperature of suburban stations, ℃
tu	the hourly average temperatures of urban observation stations, ℃
tc	the hourly average temperatures of suburban stations, ℃

* Corresponding author. Tel.: +86-21-6958-4738; fax: +86-21-65981102.
E-mail address: zhuangzhi@tongji.edu.cn

1877-7058
Peer-review under responsibility of the scientific committee of the 10th International Symposium on Heating, Ventilation and Air Conditioning.
10.1016/j.proeng.2017.09.862

1. Introduction

The effect of urban morphology on building energy performance draws more and more attentions nowadays as building energy use accounts for more than a quarter of the total energy use by cities. With the rapid urbanization of cities, the morphology of urban blocks develops from the single and low-density type to the diversified and high-density one, which has great influence on the underlying ground surface conditionings, ventilating performance and heat gain at a district scale, thus enhancing urban heat island effect and increasing building energy consumption. Studies on urban heat island effect have rapidly increased in the last decade, while the urban morphology impacts on mitigating heat island effect and decreasing building energy consumption are still lack of further studies.

Ewing and Rong [1] pointed out that the urban form can affect the residential energy use through the three major approaches, i.e. the building heating and cooling energy demand of the transmission and distribution loss, the energy demand of different residential stocks, and the urban heat island. In Singapore, Wong et al. [2] analysed the effect of the parameters, such as floor area ratio, greening rate, sky visual field factor, and building density, on local temperatures and building energy consumption at a block scale. The results show that the local temperature changed by as high as 2°C due to the change of floor area ratio, and the building energy consumption can be saved by 4.5% by improving the urban form. In 2014, Hou et al. [3] analysed the average temperature and daily electricity consumption in Shanghai from 2003 to 2007, and the results show that the acceleration of the urbanization process has a significant effect on the spatial distribution of the numbers of cooling and heating degree days. According to the simulation data of outdoor air temperatures in residential areas, it was found that the summer cooling loads of residential buildings in urban residential areas are increased by 10%-35%, while the winter heating loads are not significantly affected by the urbanization [4].

In this paper, the distinct urban attributes (greening rate, building density, and volume ratio) of ten districts around the county meteorological stations of Shanghai were collected, and the dynamic weather data streams across the county meteorological stations were used to explore the relationships between the urban heat island effect and these distinct urban attributes. An energy model for a typical office building was established, as a case study, to investigate the quantity effect of the distinct urban attributes on the energy performance of the buildings around these ten county meteorological stations.

2. Study area and datasets

In this study, ten blocks/districts around ten meteorological sites in Shanghai were selected as the target research areas. The blocks with different morphology patterns and characteristics not only consist of high-density urban areas but also suburban buildings. The distribution of each site is shown in Fig.1.

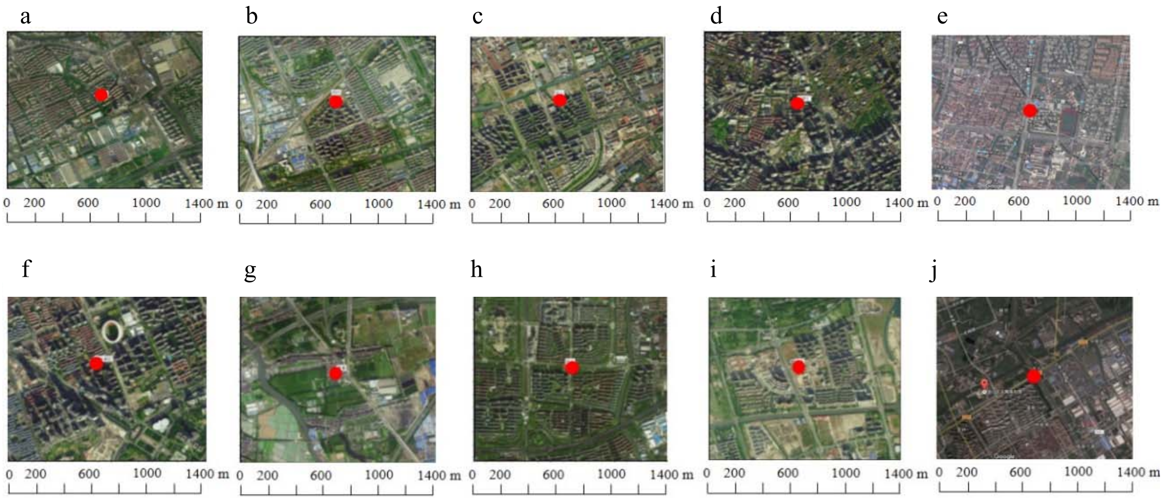

Fig.1. Districts around the county meteorological stations of Shanghai (a)Jiading, (b)Minhang, (c)Baoshan, (d)Xujiahui, (e)Chongming, (f)Pudong, (g)Qingpu, (h)Songjiang, (i) Fengxian and (j) Jinshan

Previous studies show that the characteristic parameters, such as building density, volume rate, greening rate, open space rate, body shape coefficient, sky angle factor, street aspect ratio and altitude, can reflect the microclimate of a city block [5]. Hence, the greening rate, building density and floor area ratio were used in this study to reflect the microclimate feature, which are denoted by “g”, “Bd” and “p” respectively in the following text. The data shown in Table 1 was determined based on the field survey and the Baidu Streetview that is an online view tool with more abundant data for Chinese cities.