Renewable Energy 73 (2015) 3–9

Contents lists available at ScienceDirect

Renewable Energy

journal homepage: www.elsevier.com/locate/renene

A field study of urban microclimates in London

Mehdi Shahrestani [a,*], Runming Yao [a], Zhiwen Luo [a], Erdal Turkbeyler [b], Hywel Davies [c]

[a] School of Construction Management and Engineering, the University of Reading, Whiteknights, PO Box 219, Reading, Berkshire RG6 6AW, United Kingdom
[b] Department of Mechanical and Automotive Engineering, Coventry University, Priory Street, Coventry CV1 5FB, United Kingdom
[c] Chartered Institution of Building Services Engineers, 222 Balham High Road, London SW12 9BS, United Kingdom

ARTICLE INFO

Article history:
Received 18 February 2014
Accepted 29 May 2014
Available online 21 June 2014

Keywords:
Microclimates
Experimental study
Simulation
Wind pattern
Urban context

ABSTRACT

This paper aims to address the characteristics of urban microclimates that affect the building energy performance and implementation of the renewable energy technologies. An experimental campaign was designed to investigate the microclimate parameters including air and surface temperature, direct and diffuse solar irradiation levels on both horizontal and vertical surfaces, wind speed and direction in a dense urban area in London. The outcomes of this research reveal that the climatic parameters are significantly influenced by the attributes of urban textures, which highlight the need for both providing the microclimatic information and using them in buildings design stages. This research provides a valuable set of microclimatic information for a dense urban area in London. According to the outcomes of this research, the feasibility study for implementation of renewable energy technologies and the thermal/energy performance assessment of buildings need to be conducted using the microclimatic information rather than the meteorological weather data mostly collected from non-urban environments.

1. Introduction

An understanding of the characteristics of the urban microclimates allows the city planners, designers, architects and developers to make informed strategic design decisions with respect to, not only the climatic impacts of their buildings, but also the effect of the resulting microclimatic variables on the performance of buildings. Particularly, the urban microclimates will affect passive and low energy designs, including natural or hybrid ventilation and the use of renewable technologies in urban areas, in terms of strategies and performance. The urban wind and solar radiation can be used for developing better design options for renewable energy technologies within urban environment. However, achievement of these solutions in high-rise and dense urban built environments is challenging. This is mainly due to the complex nature of various heat transfer mechanisms within the urban area, leading to the urban climatic parameters significantly different from those recorded and reported by official weather stations located in suburban environments. Hence, the knowledge of microclimatic parameters, particularly air temperature, direct and diffuse solar irradiation, wind direction and speed are of paramount importance for developing better design options for passive building design and renewable energy implementation within urban environment.

In the open literature, the studies of microclimate are addressed through numerical simulation and experiments. Many studies have devoted to the simulation of urban microclimates [1–8]. In terms of experimental studies, most of them are reported mainly in the context of air circulation and temperature distribution within urban street canyons [9–11]. In these studies, the geometric characteristics of the general urban layout are idealized as infinite parallel walls of a street canyon with emphasis on the pedestrian comfort, pollutant dispersion and natural ventilation. Santamouris et al [9] studied the thermal characteristics in a deep ($H/W = 2.5$) pedestrian canyon with a NW–SE axis, under hot weather conditions in Athens. A surface temperature difference of up to 19 °C was observed between opposite building walls. Air temperature difference near the two opposite facades varied by up to 4.5 °C due to the impact of convection heat transfer from adjacent wall surfaces. Niachou et al. [10] reported an experimental study of a typical street canyon ($H/W = 1.7$) orientated in ESE–WNW direction in Athens, again under hot weather conditions. The measured surface temperature difference across the street reached almost 30 °C and this caused overheating at lower air levels. Georgakis and Santamouris carried out detailed experiments in a deep canyon in Athens during the summer period to evaluate the potential of natural ventilation in the urban environment and to better understand the airflow and thermal phenomena in deep urban canyons on the

* Corresponding author.
E-mail address: m.shahrestani@reading.ac.uk (M. Shahrestani).

http://dx.doi.org/10.1016/j.renene.2014.05.061

climatic variables[12]. In addition, Kolokotroni et al [13] studied the urban climate in London in order to develop a model to predict the air temperature and building energy demands. The results of the developed model revealed the influence of urban microclimate conditions on building energy demands. In another study, Radhi et al [14] studied the impact of urban expansion in Bahrain on atmospheric urban heat islands using remote sensing and geographical information system (GIS). However, the experimental study of a group of buildings with the emphasis on measuring the spatial and temporal distribution of microclimatic variables around each building of the complex has not been encountered in the literature. It is therefore the focus of current research. A detailed experimental campaign was carried out in a dense urban area in London to study the urban microclimates and possible renewable energy such as wind and solar radiation for the application in passive building design in urban environment. The main objectives of this experimental investigation are

- to quantify the temporal and spatial distribution of microclimatic variables for a general building complex;
- to study the impact of the layout and orientation of buildings on these variables;
- to understand the airflow and thermal characteristics of a general urban building complex, and;
- to gather data for validating numerical simulation models of an urban microclimate.

2. Experimental setup

The experimental measurement campaign has been carried out in summer 2010 in London. The London site is displayed in Fig. 1. It is a mixture of residential buildings and the institutional buildings of London South Bank University's Southwark campus. Naturally, there is traffic through the London roads, and there is no lawn area, except trees along some roads. Four separate roads are identified to monitor microclimatic variables and the building and road surface temperatures. They are Ontario Street (3), Keyworth Street (4), Thomas Doyle Street (5) and Borough Road (6). The respective features of these streets are listed in the Table 1.

Keyworth Street links Borough Road and Ontario Street and represents a 230 m long urban canyon. While one side of Keyworth Street is a continuous row of attached buildings, including the newly built K2 building of London South Bank University, the buildings on the opposite side is detached at two locations by Thomas Doyle Street (5) and a car park/access road of the university. As is shown schematically in the Fig. 1, the K2 building has replaced low-rise buildings at the same location. The K2 building has a height-to-width ratio of 2.66, and the Keyworth Street canyon has a width of 12 m.

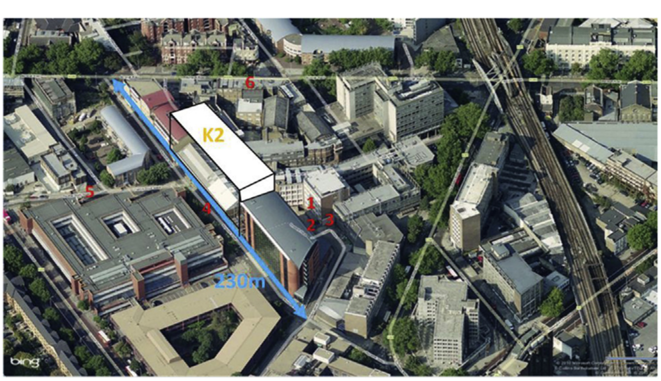

Fig. 1. Field measurement campaign site at Elephant and Castle, London.

Table 1
Street characteristics at the London site

Street	Street orientation	Traffic	Vegetation	Weather Station (WS)
Ontario Street (dead-end)	SSW to NNE	Access only	None	WS1, WS2, WS3
Keyworth Street	SE to NW	One way	Trees at one side	WS4
Thomas Doyle Street	SW to NE	One way	None (but, trees at the joining streets)	WS5
Borough Road	WSW to ENE	Main road	Trees	WS6

At the London site (Fig. 1), as is also presented as a plane view in Fig. 2, the microclimatic variables were measured at four locations, which are on Ontario Street, Keyworth Street, Thomas Doyle Street and Borough Road. These weather stations are labelled as WS3, WS4, WS5 and WS6, respectively. Table 2 shows the characteristics of these roads. The weather station 3 (WS3) was located at the dead-end of the Ontario Street, but the other weather stations (WS4–WS6) were positioned at the mid-distance of the streets. Due to the high-rise buildings at the London site, at the dead-end of the Ontario Street, in addition, two more automatic weather stations (WS1 and 2) were installed to a mobile-trailer mast, respectively, at 10 and 4 m height. Finally, the air temperature was also measured at the height of 1.8 m by the HOBO temperature sensor at each street lighting-column and the mobile mast. In addition, surface temperatures were measured at each street lighting-column location for the road/pavement and immediate building walls. Table 2 summarizes the surface measurement points (e.g., P1) at each location.

The London Measurement Campaign was carried out only for the summer season in 2010. For a period of one month, from 19 July to 16 August 2010, the climatic variables were measured at every 5 min. Also, for the first five days of the London summer campaign, from 19 July to 23 July 2010, the surface temperatures were also measured continuously at every hour. In addition, the surface temperatures of the asphalt road, pavement and building walls were measured at 16 surface locations.

2.1. Measurement parameters and instruments

At each site, the microclimatic variables of the air temperature, the wind speed and direction, the air humidity and the global solar radiation (the total value of the direct and diffused components on a horizontal surface) were measured at a height of 4 m, at several locations which were distributed comparatively within each building complex. The locations of weather stations at the London site are displayed in Fig. 2. These measurement locations were chosen in a way that the microclimates of buildings can be analysed in terms of the different layout of buildings and their orientations. The locations were also, respectively, exposed to any prevailing wind direction depending on weather conditions on a site. Around each climatic measurement point, the surface temperatures of the road and surrounding building walls were also measured.

At each measurement location, an automatic weather station – Davis Wireless Vantage Pro2, was installed to a street lighting-column (which will be referred as a "mast" from now on) at the height of 4 m. For each weather station, on a continuous basis, the climatic measurements were remotely logged to its data logger at every five minutes, which was kept indoors. The accuracy of the integrated sensor suite (ISS) of the weather station for measuring each climatic variable is 0.56 °C for air temperature, ±5% for the wind speed, ±7 degree for the wind direction, ±3% for the air humidity and ±5% for the solar radiation. Also, a second temperature sensor – HOBO Temp Data Logger, was installed at each mast for