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Assessment on seasonal variations of outdoor thermal comfort with on-site monitoring in a precinct

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Abstract

City residents desire to enjoy more outdoor recreational activities, such as walking, cycling and picnicking. The authors' earlier study reported that thermally comfortable environment could be generated in a local space at hot summer in a subtropical city. The present study aims to further assess the variations of the thermal perceptions for the temperate autumn and cool winter in the two same outdoor sites on an campus via on-site monitoring at the pedestrian level winds and thermal parameters at two sample days (sunny and cloudy) in a precinct. The daytime wind directions were also recorded from a nearby urban weather station and used for the analysis on the differences of wind and thermal comfort between the two surveying sites. The instantaneous thermal perceptions were assessed using PET (Physiological Equivalent Temperature) and the PET based index, normalized environmental parameter differences. Results indicate that the wind speed differences become smaller between the two sites due to their different building designs and the changes of wind directions in summer and winter. Not as the hot summer, the PET results note that the space without shading, directly subject to solar radiation, which can provide a thermally comfortable area at a sunny day in the cool seasons. Specifically in winter, wind speed difference is not contributed significantly to improve the thermal comfort while adaptive sunshine can obtain better thermal perception. The results reconfirm the possibility that a local outdoor thermal comfort zone can be built at selected urban spots even in cool seasons and provide a reminder for planners to consider the seasonal impacts in precinct planning within high dense city.

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Keywords: Outdoor thermal comfort, Microclimate, Wind direction, PET (Physiological Equivalent Temperature);

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1. Introduction

City residents are willing to have more outdoor recreational activities in a livable urban environment. Making the city more favorable becomes a significant issue for the urban planning and built environment design in a high dense city, with severe urban heat island (UHI). Hong Kong is such a typical example with the long and hot summer, short transitional seasons and cool winter, so that, the building energy consumptions are large and most of them are costed for the air conditioning systems. The exhausted indoor heat to the outside environment would enhance the UHI effect, which lower the averaged pedestrian wind speed. The Hong Kong government conducted the Air Ventilation Assessment (AVA) scheme (also called microclimate design) [1] and recommended in urban projects to establish the wind amplification/ attenuation environment in some local built sites.

Nomenclature

T_a	air temperature
T_g	globe temperature
V_a	wind speed
RH	relative humidity
T_{mrt}	mean radiant temperature
I_{clo}	heat resistance of clothing
d	diameter of the black globe
ε	emissivity of the black globe
$\Delta V_{a,0.5}$	thermally perceivable wind speed differences
$\Delta T_{mrt,0.5}$	thermally perceivable mean radiant temperature differences
$\Delta T_{a,0.5}$	thermally perceivable air temperature differences
$\Delta\theta_{Va,2\text{-}1}$	normalized wind speed differences
$\Delta\theta_{Tmrt,2\text{-}1}$	normalized mean radiant temperature differences
$\Delta\theta_{Ta,2\text{-}1}$	normalized air temperature differences

The outdoor thermal comfort is such a key part in microclimate study, and field measurement and questionnaire survey are the two frequently using methods in the outdoor thermal comfort area, especially for the hot and humid climate regions. Some developments and findings [2, 3] were reported on the recent outdoor thermal comfort measurements and the use of outdoor spaces. Lin et al. [4] presented the shading effect should be well considered for the long term outdoor thermal perceptions in subtropical Taiwan. Hwang and Lin [5] investigated the thermal environments of some semi-outdoor spaces via field survey and indicated that considering the requirements of occupants were essential in the hot and humid regions. The urban scale human thermal comfort was surveyed by Ng and Cheng [6] and revealed the neutral PET (Physiological Equivalent Temperature) in summer Hong Kong was around 28 ℃. The authors' earlier study [7] also conducted on-site measurement and proofed that thermally comfortable condition could be generated in a local space at hot summer in a subtropical city. Moreover, a combined method for outdoor thermal comfort prediction was published recently, which was based on the measured environmental parameters [8]. In addition, Yang et al. [9] carried outdoor thermal study and explored the effect of thermal adaptation on human thermal sensation in outdoor spaces of tropical Singapore. Trindade da Silva and Engel de Alvarez [10] evaluated the ventilation's effects on the outdoor thermal comfort in a given location and indicated that the wind direction had the relationship with the local thermal perceptions though it was not clear enough. Some researchers in Yangtze river delta with hot summer were also active, such as Yang and Chen [11] presented a thermal atlas system to assess the thermal environment at the urban district and illustrated the Lujiazui CBD in Shanghai for an example.

Our previous results only revealed the possibility in summer that the local thermally comfortable space beneath an elevated building block could be built in a precinct of a city, while the thermal perceptions in other seasons as autumn and winter were not clear enough. Meanwhile, the impact of wind directions was not well considered in the thermal comfort assessment for the authors' knowledge. In the present study, the hypothesis is that one space feels