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# Study on the thermal performance and wind environment in a residential community

Huawei Chang [a], Can Xiang [a], Chen Duan [b], Zhongmin Wan [a,c,*], Yuting Liu [d], Yao Zheng [a], Yan Shang [a], Mengling Liu [a], Shuiming Shu [a,**]

[a] School of Energy and Power Engineering, Huazhong University of Science and Technology, Wuhan 430074, China
[b] Wuhan Second Ship Design and Research Institute, Wuhan 430064, China
[c] College of Information and Communication Engineering, Hunan Institution of Science and Technology, Yueyang 414006, China
[d] China-EU Institute for Clean and Renewable Energy, Huazhong University of Science and Technology, Wuhan 430074, China

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ABSTRACT

In situ measurements are conducted on the thermal performance and wind environment in a residential community. The relationship between the community thermal performance and the tested parameters including the air temperature, relative humidity, underlying surface temperature is also presented. The results indicate that the lawns and tree shade in the community help to reduce the ambient temperature and enhance the relative humidity which means that the green ratio of a building cluster makes a significant contribution to the thermal performance. Furthermore, a numerical simulation is performed with the experimental results as the boundary conditions to get the airflow field and pressure field of the whole community to improve the architectural layout. The numerical results indicate that staggered arrangement of the building groups seems to be more beneficial to eliminating the laneway wind effects compared to aligned arrangement.
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## Introduction

Presently, building energy consumption accounts for approximately 25%–40% of the total energy consumption, and residential consumption accounts for 60% [1–3]. Renewable energy, especially solar energy is widely used to decrease building energy consumption [3–5]. In China, driven by rapid urbanization and increasing demand for building services and comfort levels, building energy consumption will continue to increase, which must be considered during construction design [1,6]. As groups of buildings arise, the urban thermal performance is getting worse and attracting more attention due to the changes of the underlying surface [6].

Not only is the whole urban thermal performance affected, but also the residential micro thermal performance should be taken into consideration. The wind speed dead band and the local high temperature, for example, will directly lead to the

* *Corresponding author*. College of Information and Communication Engineering, Hunan Institution of Science and Technology, Yueyang 414006, China. Tel.: +86 730 8648870.
** *Corresponding author*. Tel.: +86 27 87542718.
E-mail addresses: zhongminwan.hust@gmail.com (Z. Wan), fei@hust.edu.cn (S. Shu).
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deterioration of the air quality of the entire community, thereby bringing adverse effects on residential health. As a result, further study on the thermal performance and wind environment of residential community is needed. At present, there are four main methods to study the thermal and wind environment of a residential community: in situ measurements, numerical simulations, wind tunnel experiments and remote sensing observations.

The main parameters of in situ measurement in residential community include air temperature, humidity, underlying surface temperature, wind speed and direction and solar radiation intensity. Focusing on parameters observed by the Micro Weather Station, Bonan [7], in Colorado, the influence on the residential community thermal performance caused by building layout was analyzed. Bourbia [8] measured the residential community temperature and building surface temperature then studied the relationships between them. To obtain the index of the residential community thermal comfort, the humidity, wind speed and surface temperature of the floor tile and shadow were measured, respectively [9,10]. Li et al. [11] conducted comprehensive tests on the community and found the dominant factors influencing the district thermal performance. These dominant factors not only include such parameters as humidity but also involve the construction layout, the heat transfer characteristics of the walls, the greening rate and the water coverage rate. Through a one year temperature test, Sonne et al. [12] validated and partly quantified the effect of shade on the relieving local Urban Heat Island (UHI). Ghali et al. [13] conducted field experiments and developed statistical correlations for thermal sensation and thermal comfort of people in the outdoors, numerical study on wind speed and frequency was also presented. The results showed that the increasing of wind velocity and frequency can make positive contribution to people's tolerance of outdoor conditions while it may make negative contributions with the increase in air temperature and relative humidity. Bourbia et al. [14] conducted a series of in situ measurements of the air temperature on different streets to assess the impact of the design of street on the built environment. Sun et al. [15] studied the influence of time lag and the decrement factor of building materials on building energy conservation. Peng et al. [16] measured the diurnal and seasonal variation of the surface urban heat island intensity (SUHII) defined as the surface temperature difference between urban and suburban areas measured from 419 large global cities. With the utilization of remote sensing, only the water and green surfaces are capable of reducing the UHI effect [17].

Numerical simulation is not only a popular method to simulate and predict community thermal performance but also a test method to examine the reasonability of architectural planning and design. It is common to take in situ measurements of the surface temperature as a boundary condition for numerical calculation; the results of which are usually compared with the measured data for analysis and optimization. There is much research in this field, among which one research is aimed at the radiation budget for the polluted layers of the urban environment and for estimating the influence of urbanization to the local thermal performance [18]. Some researchers applied Computational Fluid Dynamics (CFD) to simulate a community outdoor thermal performance to find the air and underlying surface temperature, the relative humidity, and the wind speed and direction in the whole community; then, researchers studied the community thermal performance based on the numerical results [19–24]. An energy-balanced analytic model validated for the H/D = 1.0 canyon was set up to predict the temperature of the facades, the ground, and the local air mass of the urban areas [25]. Ryu and Baik [26] employed a mesoscale atmospheric model to elaborate and quantify the relative contributions of the vertical walls, the radiation trapping, and the wind speed reduction to the UHI intensity and interactions between these factors. Murata et al. [27] demonstrated that UHI intensity can be estimated by comparing the observational data and the outputs of a well-developed, high-resolution, non-hydrostatic regional climate model. Srebric proposed multi-scale modeling to identify the influence of urban neighborhood properties on the energy and airflow, and found the emerging properties of urban neighborhoods directly affect (1) the mitigation strategies for a better adaptation, (2) design performance metrics of neighborhoods for the green building rating systems, and (3) socio-environmental factors [28].

In order to find out the influences of different factor on the thermal performance and wind environment, this study applies in situ measurement and numerical simulation to study the temperature and wind environment in a residential community. The thermal performance and wind environment under the conditions of different temperatures and wind directions has been analyzed to achieve a reasonable optimization layout of the building groups according to simulation results.

## General description

The residential community chosen to conduct the study is located in Wuhan, China (114.33° east longitude, 30.50° north latitude). This residential community consists of 35 high-rise buildings and uses aerated concrete as its main building materials with rigid extruded PS foam board as its thermal insulation material. The buildings surrounding this community are dwarf enough and there is a sufficiently large amount of vacant land behind the building cluster against a mountain. Therefore, when modeling, the circumjacent buildings could be ignored. To facilitate the study, some minor buildings and functional buildings are excluded from the modeling and simplified treatment is applied for those complex architectural configurations. This paper applied a relatively large domain for sufficient consideration of the ambient environment impact.

## Experimental study

### Experiment summary

Twelve typical measuring points were selected to study the wind environment and thermal performance of this residential community. These experiments lasted for six months, from June to November. The parameters of each point were measured every two hours from 9:00 to 21:00, thus 7 times a

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