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A Review of the Research on Architectural Design and Microclimate Collaborative Optimization of High-Density Blocks

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Abstract. In the context of the continuous acceleration of global urbanization, according to the statistics of the United Nations Human Settlements Programme, the proportion of global urban population has exceeded 55% by 2025. The concentration of population in urban core areas has prompted high-density communities to become the dominant form of urban space development. High-density communities, due to their advantage of intensive utilization of land resources, effectively alleviate the contradiction of tight urban construction land. They are in line with the land use efficiency goals of sustainable urban development. However, due to the high building density, natural ventilation is often blocked and the heat island effect intensifies, thereby affecting the quality of the living environment. This paper focuses on the collaborative optimization of architectural design for high-density blocks and the microclimate environment, and discusses the related concepts and theoretical foundations of high-density blocks and microclimate environment, including urban climatology and human environmental comfort. By analyzing the mechanism of the impact of urban architectural forms on wind environment, thermal environment and radiation environment, it explores the path of improving residents' comfort by improving the urban form, providing theoretical basis and practical reference for alleviating the contradiction between high-density urban development and livability.

Keywords: High-density blocks; Architectural design; Microclimate; Mollaborative optimization; Environmental regulation.

1. Introduction

Global urbanization is advancing at an unprecedented rate, with the proportion of the global urban population currently exceeding 55% and expected to climb to nearly 70% by 2050, according to United Nations data. The high concentration of population in cities has made high-density neighborhoods the core form of urban spatial organization. It achieves intensive land utilization through high floor area ratio and mixed functions, effectively alleviating the contradiction of urban land resource shortage. However, high-density development also raises a series of complex problems. For example, dense building clusters lead to shrinking green spaces and reducing water bodies, which directly interfere with the balance of urban microclimate. Coupled with global warming, urban heat island effects and poor local ventilation are becoming more and more prominent, seriously affecting the quality of the living environment.

Danish architect Jan Gehr once pointed out that "microclimate conditions directly determine the duration and frequency of people's outdoor activities", highlighting the key role of microclimate in urban space vitality. As the main carrier of human activities, the microclimate environment and comfort of external spaces have become the core considerations of urban planning and design [1]. Domestic and foreign studies have confirmed that there is a significant coupling relationship between building layout and urban microclimate. By optimizing the building form, texture and spatial structure, the local wind, heat and light environment can be effectively adjusted, thereby improving spatial comfort and reducing building energy consumption [2].

our country has always placed sustainable urban development and climate change response at the core of the strategy, and a series of policy documents such as the National Climate Change Adaptation Strategy 2035 and the "14th Five-Year Plan for Scientific and Technological Innovation in

Urbanization and Urban Development" provide solutions to the existing problems of high-density blocks from the perspectives of territorial spatial planning system, optimization of urban heat island effect, and improvement of urban ecological environment quality, which further highlights the urgency and strategic necessity of carrying out research on architectural design and microclimate collaborative optimization [3].

Therefore, systematically analyzing the collaborative optimization path of architectural design and microclimate in high-density blocks can provide new ideas for alleviating the problem of livability attenuation in the process of urban high-density development, and is also expected to become a potential direction for promoting the theoretical and practical innovation of sustainable urban development. This paper has a certain degree of compatibility with the national policy orientation such as new urbanization and green and low-carbon development, and to a certain extent, it also responds to the practical needs of balancing spatial efficiency and ecological quality in contemporary urban construction.

2. Research on building groups and urban microclimate theory

2.1. Basic concept of high-density block building complex

2.1.1. Delineation of high-density building clusters

Fig.1 shows that they use the hierarchical structure of historical geography and typology to study urban form, and their results are relatively complete and widely cited. The Conzien school believes that urban forms mainly include buildings, plots, and streets. From a more refined perspective, Carnigia not only set the road as a path, but also added the road with traffic attributes and the functional plates on both sides, and on the next floor, the rooms, structures and materials together constitute the construction requirements of the building [4]. On this basis, high-density building clusters meet the comprehensive delineation of floor area ratio, building density, population density, spatial form and functional mix.

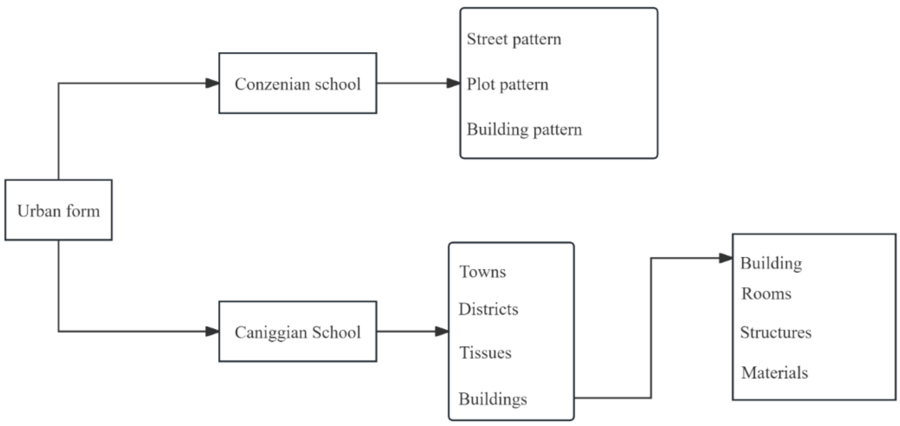

Figure 1. Urban form and structure diagram

2.1.2. Development of high-density building complexes

At present, the urban population agglomeration index has doubled, land resources are becoming more and more tight, and the demand for building groups has gradually shifted from a single building to the development of complex building groups. The most representative of them is the development of residential building complexes, from traditional villages to commercial towns that concentrate various resources. The building complex achieves a vertical expansion, which not only enhances land utilization and alleviates population growth, but also boosts the economic agglomeration effect. Currently, high-density buildings are not only enhancing economic benefits but also shifting their development focus towards sustainability and livability. The related explorations and practices are receiving increasing attention from all sectors of society. Fig.2 can visually demonstrate the improved livability and sustainable development of the buildings.

Figure 2. Urban development and transformation map

2.2. Definition of microclimate and urban building regulation of microclimate elements

2.2.1. Microclimate definition

Italian scholar Barry proposed that the climate system is divided into global wind zone climate, regional macroclimate, local climate and microgas [5]. Landsburg's definition of "microclimate" is the part of the atmospheric boundary layer in which the microclimate environment is affected by topography, soil, and vegetation [6]. Liu Nianxiong et al. define the microclimate as the climatic characteristics and climate change of the atmosphere of the surface (generally referring to the soil surface) of 1.5 to 2.0 meters, where the surface is determined by the tectonic characteristics of the fine underlying surface and has the greatest impact on human activities [7]. Although these scholars have different expressions, it can be summarized as microclimate is influenced by natural factors, such as buildings, vegetation, underlying surfaces and environmental heat exchange in cities, which greatly affect the microclimate conditions of the region

Table 1. Table of climate systems

system	Approximate range of climatic characteristics		Time frame
	Horizontal range (km)	Vertical range (km)	
Global wind band climate	2000	3~10	1~6 months
Regional macroclimate	500~1000	1~10	1~6 months
Local climate and weather	1~10	0.01~1	1~24 hours
Microclimate	0.1~1	0.1	24 hours

2.2.2. Urban buildings regulate microclimate

The spatial form of the building group directly affects the solar radiation reception, airflow organization and light environment, and the local heat island effect is easy to form in high-density building groups. In addition, the building window opening method and ventilation system design affect the natural ventilation efficiency. Therefore, the local microclimate can be reasonably changed through the adjustment of building form and layout

2.3. Relevant theoretical basis

2.3.1. Urban climatology

Urban climatology is a discipline that studies the impact of urban form, space and human activities on the surrounding climate. The China Meteorological Administration pointed out that in the process of urbanization, the high population density, special underlying surface, and high-intensity economic activities have changed the original climate conditions of the region and formed a unique urban climate. Many scholars believe that urban climatology focuses on the urban regional climate system and deeply explores its formation mechanism and characteristic laws [8]. At the same time, the regulatory effect of urban morphology, land use and other planning methods on the climate system is also the focus of urban climatology. From the perspective of discipline attributes, urban climatology integrates multidisciplinary knowledge such as atmospheric science, urban planning, and ecology. Its research is of great significance, as many experts agree, and it provides solid theoretical support for optimizing urban climate resilience design, improving the quality of human settlements, and formulating sustainable development strategies.

2.3.2. Comfort of living environment

The comfort of the living environment is a comprehensive indicator of the quality of human settlement space, and is an important factor in evaluating the livability of a city and the perceived quality of open space. At present, the research on the comfort of the living environment mainly focuses on the evaluation indicators, models, and influencing factors of human comfort [9]. Studies have shown that changing the microclimate of the city can greatly improve the comfort of the local environment and improve the life happiness index of urban residents [10]. At present, the evaluation of the comfort of the living environment is based on the values of various climatic indicators including human comfort index, temperature and humidity index, wind efficiency index, and clothing index. Among them, the human comfort index is mainly affected by meteorological factors such as temperature, relative humidity, and wind speed. The calculation formula is:

$$B = (1.8t + 32) - 0.55(1 - r)(1.8t - 26) - 3.2\sqrt{v} \quad (1)$$

In v, B is the human comfort index, t is the daily average temperature (°C), r is the daily average relative humidity (%), and v is the daily average wind speed (m/s). The table of human comfort index grading standards is omitted [11] Other indicators can be seen in Table 2.

Table 2. Grading standards and corresponding assignments of temperature and humidity index, wind efficiency index and clothing index [7]

Temperature and humidity index		Wind efficiency index		Clothing index		Assignment criteria
index	Human body sensations	index	Human body sensations	index	Appropriate clothing	
>80	So hot	≥160	Extremely uncomfortable hot air	<0.1	Skirt	1
75 ~ 80	hot	160 ~80	Uncomfortable hot air	0.1 ~ 0.3	Tropical clothing	3
70 ~ 75	Warm and hot	80 ~ 50	There is no obvious wind	0.3 ~ 0.5	Short-sleeved cardigan shirt	5
65 ~ 70	warm	−50~−200	Warm	0.5 ~ 0.7	Lightweight summer clothes	7
60 ~ 65	comfortable	−200~−300	Comfortable wind	0.7 ~ 1.3	Add shirts and casual clothes	9
55 ~ 60	cool	−300~−600	Cool breeze	1.3 ~ 1.5	Cotton coat and casual clothes	7
45 ~ 55	Cool and cold	−600~−800	A little cooler	1.5 ~ 1.8	Commonly used clothing in winter	5
40 ~ 45	cold	−800~−1000	Cold	1.8 ~ 2.5	Casual wear thickened coat	3
<40	So cold	≤ −1000	It's very cold	>2.5	Down or fur jacket	1

3. Parameter indicators of building form regulation microclimate

3.1. Urban form and wind environment

The evaluation of wind environment mainly covers physical environment indicators, human comfort indicators, outdoor air quality and other aspects, and the evaluation system is relatively complex and involves many elements and standards [12, 13]. Through the systematic review of relevant literature and research results at home and abroad, it is found that the wind speed and wind pressure in the wind environment have a significant impact on the microclimate of the block, especially the wind speed in the pedestrian height range, which has the most significant impact on human comfort [14]. This paper finds that there is a close coupling relationship between the wind environment and the urban spatial form. The urban spatial form shapes the wind environment through the plane pattern, three-dimensional structure and interface features. At the same time, the wind environment acts on the urban spatial form. Factors affecting the wind environment of urban form:

(1) The increase of building density and floor area ratio will compress the airflow channel, and some studies have shown that when the building density exceeds 50%, the wind speed inside the block is reduced by 40%-60% compared with the open area; and for every 1.0 increase in floor area ratio, if there is no reasonable ventilation corridor design, the local static wind frequency may increase by 15%-20% [15].

(2) The angle between the street direction and the dominant wind direction directly affects the ventilation efficiency. Streets parallel to the dominant wind direction can form a "wind funnel" effect, increasing the wind speed by 20%-30%; Streets perpendicular to the dominant wind direction are prone to forming eddy current zones, resulting in obstructed ventilation [16].

When the building height difference reaches more than 30%, it can promote vertical airflow exchange and increase the wind speed inside the block by 10%-15%. In addition, the "drafting effect" of high-rise buildings can guide the upward diffusion of hot air by setting a height difference of 15%-20% [17].

3.2. Urban form and solar radiation thermal environment

According to the analysis of domestic and foreign literatures, it is found that the vertical shape of space affects heat exchange by changing the airflow movement path, and the layout of high and low can promote air convection and enhance heat dissipation. The closed space is prone to the formation of local high temperature zones due to poor air mobility. In addition, the indirect effect of spatial shape on the temperature distribution of the underlying surface further aggravates the spatial heterogeneity of the thermal environment.

The urban form has a significant impact on the thermal environment by regulating the radiation budget, airflow movement and thermal characteristics of the underlying surface. From the perspective of long-wave and short-wave radiation regulation, the layout of high-density buildings changes the sky viewing factor (SVF), which in turn affects the long-wave radiation exchange. For example, in some cities, the long-wave radiation interception is obvious in the low SVF area, and the local temperature is 2-3°C higher than that in the high SVF area. Reasonable building spacing and determinant layout can promote the formation of ventilation corridors and accelerate the convective transmission of heat radiation. It has been measured that the retention time of heat radiation is shortened by about 30% compared to poorly ventilated blocks [18]. From the perspective of building morphological parameters, the street aspect ratio (H/W) has a significant impact on the thermal environment. The average temperature on narrow canyon (high H/W) streets in the summer afternoon is 1 - 3°C higher than that of wide canyon streets, as they are prone to radiation traps that hinder the escape of long-wave radiation. At the same time, areas where the street trend is well coupled to the dominant wind direction have enhanced airflow disturbances, which can increase the efficiency of heat radiation transfer by 20% to 30% [19].

4. Conclusion

Through theoretical combing and mechanism analysis, combined with the characteristics of high-density blocks, the following conclusions are drawn:

(1) There is a significant coupling relationship between the architectural design of high-density blocks and the microclimate, and the building morphological parameters (density, height, layout, etc.) directly affect and change the living comfort through the synergy of wind, heat and radiation environment.

(2) The key control parameters have clear quantitative characteristics: the width-to-height ratio of ventilation corridors is ≥1/3, and the building height difference ≥30% can effectively increase the

wind speed; high-reflectivity materials and green coverage of more than 30% can significantly reduce the accumulation of radiant heat; the spacing that meets the sunshine standards and the compact building size can optimize the light environment and thermal balance.

This paper further reveals that the improvement of livability in high-density blocks requires a coupling relationship of "form-climate-comfort "As the core, the balance between intensive land use and ecological environment quality through multi- factor collaborative design provides a theoretical basis and technical path for solving the contradiction between "high-density development and livability attenuation", and also provides a specific starting point for responding to strategic needs such as green and low-carbon and climate adaptation in urban planning practice. Although some progress has been made in this paper, I believe that it is still necessary to strengthen the multi-scale coupling mechanism, connect the optimization of block form with the city-level macro system, build a hierarchical response system, and reveal the transmission law of architectural form and microclimate.

References

[1] Zhang Qiang. Research on the influence and improvement of external space elements on comfort from the perspective of microclimate: A case study of Tianjin universities [D]. Tianjin University, 2019.

[2] Zhang Wenzhong. The Core Framework of Livable City Construction [J]. Geographical research, 2016, 35 (02): 205-213.

[3] Wang Lihui. Research on the optimization strategy of green space pattern in the central area of Harbin to cope with the heat island effect [D]. Harbin: Harbin Institute of Technology, 2017.

[4] She Xinyi. Research on the morphology of building complexes based on urban microclimate regulation [D]. Jiangsu: Southeast University, 2025.

[5] Wei Ri Yao. Research on the Optimization of Public Space Form in Traditional Island Villages of Yantai Based on Microclimate Comfort [D]. Shandong: Yantai University, 2025.

[6] Pag K. Application of building climatology to the proble ms of housing and building for human settlements, World Meteorological Organization, WMO-NO, 1976: 441.

[7] Liu Nianxiong, Qin Youguo, Building Thermal Environment [M]. Tsinghua University Press, 2005: 47.

[8] Zhou Shuzhen, Zhang Chao. Introduction to Urban Climatology [M]. Shanghai: East China Normal University Press, 1985.

[9] Tan Kaiyan, Min Qingwen, Wang Peijuan. A climate comfort index model based on China's climate characteristics and human comfort [J]. Meteorology, 2022, 48 (7): 913-924.

[10] Yang Yujun, Zhou Dian, Wang Yupeng, et al. Planning method of centralized greening in high-rise residential blocks based on improvement of thermal comfort in summer [J]. Sustainable Cities and Society, 2022, 80: 103802.

[11] Zhang Renxing. Analysis of climate comfort of human settlements in Xingyi City, Guizhou Province [J]. Heilongjiang Science, 2025, 295 (16).

[12] Li Jun, Rong Ying. Design guidelines for urban air ducts and their construction control [J]. Urban Issues, 2014, (9): 42-47.

[13] Zhang Li, Li Xingrong, Yang Lin, Qiu Zongxu. Analysis of Shenzhen Solar Radiation Meteorological Conditions from the Change of Radiation Intensity. Journal of Solar Energy 3 (2019).

[14] Han Banglong. Quantitative Research on Spatial Morphology Indicators of Urban Blocks Based on Wind Environment Evaluation [D]. Shenyang: Jianzhu University, 2021.

[15] ZHANG Tao. Coupling of wind environment and spatial morphology in urban central areas [D]. Southeast University, 2015.

[16] Chen Hong, Li Baofeng, Zhang Weining. Correlation between urban microclimate regulation and block morphological elements [J]. Urban Architecture, 2015 (31): 41- 43.

[17] Guan Binrong, Ma Guoxin. Architectural Design and Wind Environment [J]. Journal of Architecture, 1995 (11): 44-48.

[18] Hu Anna. Research on street space compensation model in urban high-density environment [D]. Changsha: Hunan University, 2022.

[19] Yuan Ye, Guo Binbin, Xu Zongwu, et al. Coupling design of photothermal performance of building shapes: A case study of university teaching buildings in cold regions [J]. Architects, 2022 (2): 76-82.