Journal of Civil Engineering and Urban Planning (2023)
Clausius Scientific Press, Canada

DOI: 10.23977/jceup.2023.050803
ISSN 2616-3969 Vol. 5 Num. 8

Practical Research on External Space Design of Primary and Secondary Schools in Damp and Hot Areas

Ying Bao[1,2,3,a], Shaomei Li[1,2,b], Yue Pei[2,c,*]

[1]School of Architecture, South China University of Technology, Guangzhou, China
[2]Architectural Design and Research Institute of SCUT, Guangzhou, China
[3]State Key Laboratory of Subtropical Building and Urbanscience, Guangzhou, China
[a]arbaoy@scut.edu.cn, [b]lyshaome@gmail.com, [c]peiyue2309@gmail.com
**Corresponding author*

Keywords: External space of primary and secondary school campuses; Green campus; Humid and hot areas

Abstract: Regional climate, site planning, and architectural design are important factors that affect the external spatial environment of buildings[1]. Creating a comfortable microclimate environment has always been one of the basic goals of architecture, and improving the microclimate environment on campus can enhance the overall comfort of the campus[2]. This article takes Haikou Experimental School, an affiliated high school of Renmin University of China, as an example. By using computer simulation methods, it is hoped that reasonable planning and design can be carried out in terms of site planning, external space layout of buildings, and details of enclosure structures, in order to create a pleasant campus external space environment, which can not only save energy and reduce carbon, but also improve the comfort of teachers and students in the campus external space.

1. Project Overview

1.1. Project Introduction

Figure 1: Aerial View (Architectural Design Research Institute of SCUT)

The Haikou Experimental School Project of Renmin University of China Affiliated High School (Figure 1, 2) is located in Haikou City, Hainan Province, China. The land area of the plot is 129703.44 square meters, with a total construction area of approximately 129990 square meters. The above ground construction area is approximately 122565.85 square meters, the underground construction area is 7424.1 square meters, and the project building height is 5.4-36.8 meters.

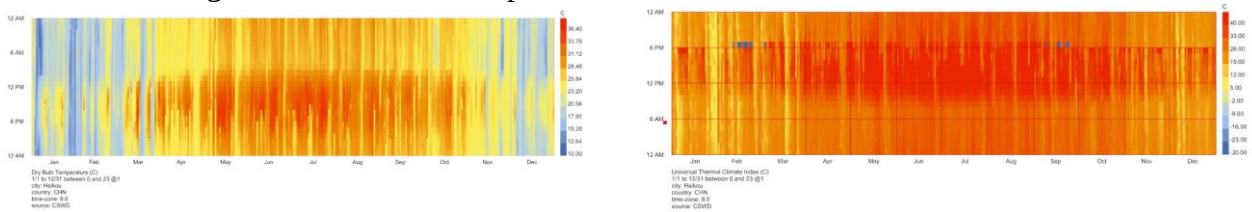
The project is divided into a comprehensive area (auditorium, library, art building, sports hall), a logistics area (dormitory building, cafeteria), and a teaching area (teaching building, experimental building). The overall campus utilizes various energy-saving and carbon reduction design methods to create a green and low-carbon comfortable campus. (Figure 2)

Figure 2: Perspective View of the School (Author Self Taken)

1.2. Climate in humid and hot regions

Haikou is located in the northern part of Hainan Island, between latitude 19 °31 '-20 °04' north and longitude 110 ° 07 '-110 ° 42' east. It belongs to a tropical marine climate, with high temperatures and abundant rainfall throughout the year. During winter, cold air currents invade with occasional cold spells. The annual sunshine duration is long, with a large amount of sunshine radiation. The average annual sunshine hours are 2225 hours, and the solar radiation amount can reach 110000 to 120000 calories per year; The annual average temperature is 23.8 ℃, with the highest average temperature around 28 ℃ and the lowest average temperature around 18 ℃. The wind is mainly northeast and easterly all year round, with an average annual wind speed of 3.4m/s.

Using the Grasshopper plugin ladybug tools to extract and analyze meteorological data in Haikou City, outdoor thermal environment analysis was conducted according to the Universal Thermal Climate Index (UTCI), and the following data were obtained (Figure 3). From the figure, it can be seen that the temperature in Haikou City is generally high throughout the year. Therefore, when conducting overall campus planning and architectural design, in order to reduce building energy consumption, it is necessary to consider building climate adaptability design strategies in addition to shading, ventilation, and heat prevention.



a. Annual dry bulb temperature in Haikou City b. Outdoor thermal comfort in Haikou City

Figure 3: Climate Analysis Map of Haikou City (Image Source: Author's Self drawn)

2. Project Planning Layout

2.1. Site Design

The main entrance of the school is planned to be located on Changbin West 10th Street Road on the south side of the base, with secondary entrances set up on Changbin 12th Road on the east side and Haitao West Road on the west side to facilitate the entry and exit of vehicles on the campus. In the overall planning, the layout has a certain order and flexibility. The building adopts a north-south layout form, with reasonable spacing between individual buildings on the site, forming effective ventilation streamline, improving the outdoor environment of downstream wind direction building groups. Different functional areas are connected by flexible curved corridors, making the overall campus layout more lively while providing shading and rain protection for outdoor activities of teachers and students, Improved outdoor space comfort. (Figure 4)

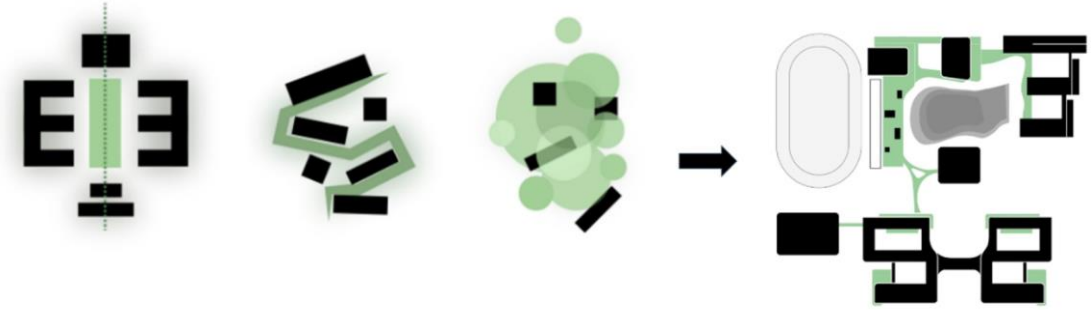


Figure 4: Overall Planning Layout ((Architectural Design Research Institute of SCUT))

The campus is divided into reasonable functional blocks, with a strong enclosure and centripetal architectural layout, forming multiple inner courtyards as outdoor activity spaces for students. (Figure 5)The campus buildings are arranged in a north-south direction, with functional areas divided into teaching areas, comprehensive areas, and logistics areas. (Figure 6)Each area is connected by a corridor, and the entire campus is unified and orderly, while also having fun. The bottom of the corridor is a transportation space, and the roof activity space at its top effectively enriches the architectural space hierarchy and improves land use efficiency.

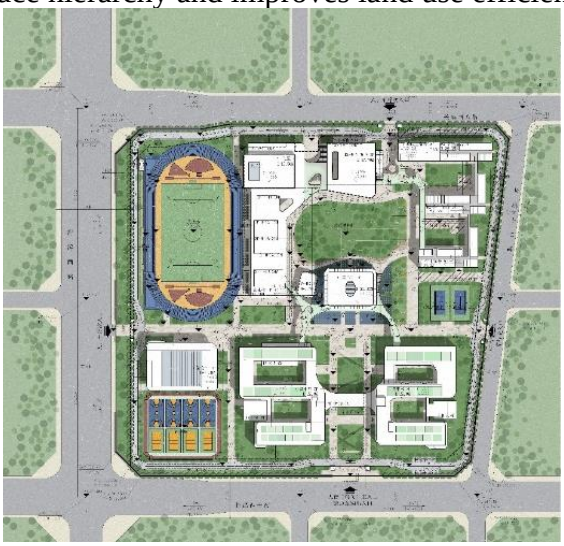


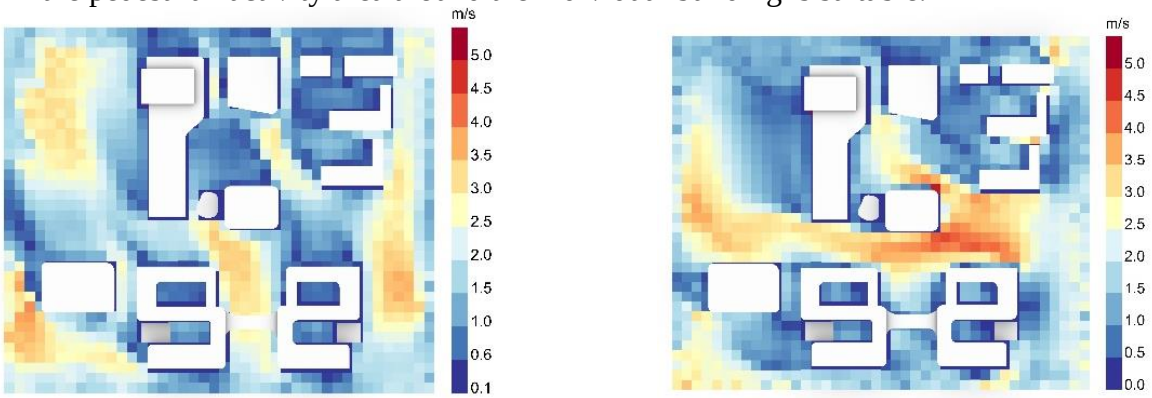
Figure 5: General Plan (Architectural Design Research Institute of SCUT)

Figure 6: Functional analysis (Architectural Design Research Institute of SCUT)

2.2. Site Wind Environment

The dominant wind direction in Haikou City in summer is southeast wind (Figure 7a). A teaching building is set in the southeast direction, and the bottom of the building is elevated to ensure the entry of southeast wind; The dominant wind direction in winter is northeast wind (Figure 7b), with higher buildings arranged in the northeast direction to form a wind barrier, reducing the impact of winter wind on the external space of the campus, and improving the comfort of the external space of the campus in winter.

Simulate and analyze the overall outdoor ventilation situation at a height of 2 meters above the ground using the Grasshopper plugin eddy3d. The calculation results are as follows: the summer wind speed is distributed between 0.1~3.5 m/s, forming a ventilation streamline at the central axis of the overall building site, effectively improving the wind environment of the downstream wind direction. In winter wind conditions, the spacing between buildings is reasonably arranged, with wind speeds between approximately 0.25~4.5m/s. There are no strong wind areas, and the wind speed in the pedestrian activity area around the individual building is suitable.



a. Analysis of Summer Monsoon Environment b. Analysis of Winter Wind Environment

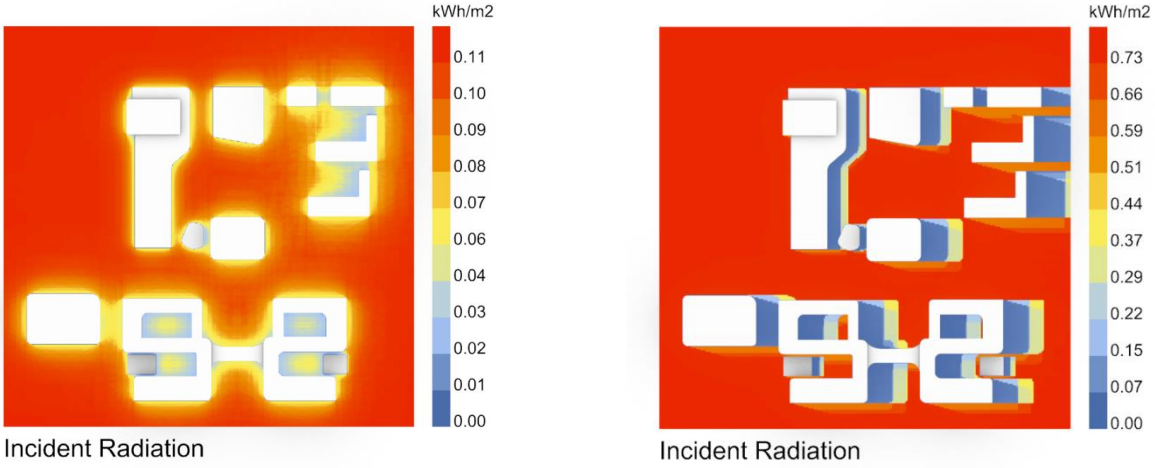
Figure 7: Wind Environment Simulation Diagram (Author's Self drawn)

2.3. Geothermal Environment

The thermal environment refers to an environment that is influenced by a combination of factors

such as temperature, solar radiation, air flow rate, and relative humidity, affecting people's sense of warmth and comfort. [3] The thermal environment of the external space of the campus is composed of factors such as air temperature and humidity, solar radiation, and wind speed.

Based on the characteristics of student activity time, the article uses the Grasshopper plugin Ladybug tools to simulate the amount of sunlight radiation in the internal and external space of the school. The simulation time is 10:00 am on April 22nd, and the solar radiation of the activity areas around the building is 0.06-0.07kWh/㎡; The sports field and campus roads are around 0.1-0.11 kWh/㎡. The overall solar radiation at 16:00 pm is higher than at 10:00 am, and the solar radiation in the activity areas around the building is between 0.2~0.3 kWh/㎡; The sports field and campus roads are around 0.6~0.7 kWh/㎡. (Figure 8)In comparison, the activity areas around the building on that day were relatively comfortable and suitable for outdoor activities by teachers and students.



a. Sunlight radiation at 10:00 am on April 22nd b. Sunshine radiation at 16:00 on April 22nd

Figure 8: School Sunshine Time and Sunshine Radiation (Author's Self drawn)

Green plants that adapt to the local climate can create a good external activity space environment on campus. Planting plants that adapt to the local climate and soil conditions in Haikou can block direct sunlight and increase the thermal comfort of the external environment.

3. External Space Design of Buildings

3.1. Outward oriented square space

The square space is an indispensable part of the external space of the school, and factors such as school building groups, vegetation greening, and road traffic can all affect the spatial form of the campus square[4]. Therefore, the spatial design of the campus square directly affects the microclimate environment of the external space of the school, as well as the comfort of teachers and students in the external space.

The design techniques of elevated floors, external corridors, and wind and rain corridors are extensively used in buildings (Figure 9). The overhead ground floor of the school teaching building is combined with the school square as the main entrance and exit of the campus. The overhead space at the bottom not only ensures effective ventilation of the site, but also reduces solar radiation, thereby improving the overall comfort of the space. The wind and rain corridor and overhanging eaves not only connect different building functions, but also provide shading and rain protection for external space activities of teachers and students, increasing their comfort.

Figure 9: Externally oriented square space (self-drawn by the author)

The large-scale greening of the external space of a building can effectively reduce the impact of environmental temperature rise on the surrounding temperature of the building, reduce the heat island effect, and regulate the microclimate of the campus. Choose local plants that match the climate of Haikou area for campus greening, and use multiple layers of trees and shrubs for greening. The outdoor ground is mainly paved with permeable bricks and green plants to absorb water, which can reduce surface temperature and improve the outdoor thermal environment.

3.2. Introverted courtyard space

Figure 10: Introverted Courtyard Space (Author's Self drawn)

The cohesive centripetal space inside the teaching area and dormitory area, as well as the comprehensive area and dormitory area, are mostly the main spaces for outdoor activities of

teachers and students. Climate adaptive external space design can meet students' learning, living, and entertainment needs, and improve outdoor activity comfort. Building components such as eaves, corridors, and elevated floors can provide an effective shading environment for outdoor activities and improve thermal comfort (Figure 10); Planting trees with dense canopy and leaf area index>3 in the courtyard can effectively block solar radiation and achieve shading effect [5]; Laying permeable bricks and other materials on the ground can allow rainwater to quickly penetrate into the ground, absorb moisture and heat, regulate the temperature and humidity of the ground, and improve the comfort of external spaces.

4. Maintenance Structure Climate Adaptability Design

4.1. Building walls

The transportation space and public space included in campus buildings are also external spaces, so the thermal insulation performance of the exterior walls directly affects their comfort. The roof of this project is insulated with extruded polystyrene board, ordinary exterior walls are self-insulated with aerated concrete blocks, prefabricated exterior walls are insulated with precast concrete slabs and ALC aerated concrete slabs, suspended floor slabs are insulated with 30 thick rock wool slabs, single external windows in teaching buildings and canteens are insulated with Low-E hollow glass, and external windows in dormitories are insulated with ordinary hollow glass.

4.2. Building Roofs

The insulation material for the roof of the building is extruded polystyrene board, and a roof garden is also set up on the roof to create external activity space for teachers and students, while also having the function of insulation.

4.3. Sunshade components

Corridors, hallways, and other gray spaces are often used by teachers and students for after-school entertainment and learning. A comfortable and good light and thermal environment can provide a comfortable environment, allowing teachers and students to relax their spirits. By taking measures such as sunshades and blinds, the impact of sunlight radiation on the area can be effectively reduced, and the comfort of the external space can be improved.

5. Conclusions

With the development of basic education, the importance of physical and mental health for primary and secondary school students continues to increase, and outdoor activities for students continue to increase. As a result, the requirements for the quality of the external activity space environment on campus have also increased. This article simulates and analyzes the wind environment and thermal environment of Haikou Experimental School, an affiliated high school of Renmin University of China, as well as the planning and layout of the campus, the external space of the building, and the building envelope structure. It comprehensively utilizes various design strategies to improve the comfort of the external space on the campus and create a more comfortable external space environment for teachers and students.

Acknowledgements

I would like to thank South China University of Technology Architectural Design and Research

Institute Co., Ltd. He Jingtang Architectural Creation Research Institute for the information provided for this article.

References

[1] Wang Jianguo, Wei Feng. The Environmental Benefits of "Microclimate Shell" - Inspiration from the Renovation Project of the Rulmensenis Mining Area in Germany [J]. Journal of Architecture, 2003 (12): 63-66
[2] Zhang Jiacheng. General Introduction to Climate in China [M]. Beijing: Meteorological Publishing House, 1991
[3] Li Weizhen. Research on the Outdoor Thermal Environment of Urban Residential Areas in Cold Regions in Winter [D]. Xi'an University of Architecture and Technology, 2015
[4] Li Jingwei, Hu Yan'an. Research on the Microclimate Environment of Campus Square Space in Severe Cold Regions in Winter: A Case Study of Daqing City [J]. Science and Technology Innovation, 2019 (22): 1-3
[5] Liu Jing. Research on the Impact of Outdoor Environmental Shading on the Thermal Environment of Residential Areas [D]. South China University of Technology, 2012