Paper ID APEN-MIT-2019_112
Applied Energy Symposium: MIT A+B
May 22-24, 2019 • Boston, USA

Study on simulation and optimization of physical environment in Jinan new city of China

1st Wenjing He
Shandong Jianzhu University
Jinan,China
hewenjing@sdjzu.edu.cn

2nd Pei Li
Jinan City Planning and Design Institute
Jinan,China
line 4: City, Country
hwjarc@163.com

Abstract—With rapid urbanization and climate change, urban physical environment and energy demand are drawing greater attention. This paper conducts an empirical study on the new urban core zone of Jinan, China. Under the greater background of replacing old growth drivers with new ones, as the capital of Shandong Province, Jinan constructs a Prior Zone in this regard. This core zone occupies an area of 13km2 and will be built into a people-oriented green new town. In the urban design process, the author conducts a simulation analysis on urban physical environment and proposes optimization suggestions on urban design based on analysis results to eventually ensure construction of a new green and habit*able urban area.*

Keywords—Wind environment, thermal environment, light environment, computational simulation

I. Project Overview

Jinan Prior Zone for Replacing Old Growth Drivers with New Ones (hereinafter referred to as the Prior Zone) is the pioneer in national comprehensive pilot zones with a total planned area of about 1,000m2. It's aimed to build a green, habitable and sharing international intelligent city. The project, launched in 2017, is expected to be preliminarily completed in 2035. The Prior Zone will promote intelligentized industry, industrialized intelligence, integration of cross borders and high-end brands with new technology, new industry, new type of operation and new model. It will focus on ten industries including big data and new generation of information technology, smart manufacturing and sophisticated equipment, quantum science & technology, biological medicine, advanced materials, industrial financing, modern logistics, medical treatment & health preservation, cultural tourism and technological services. The detonating area of the currently developed core zone occupies an area of 13km2. It's adjoined to the Yellow River with a smooth terrain and basically without buildings, thus providing favorable construction conditions.

II. Urban Design

The detonating area solution highlights a functional layout with such characteristics as series connection in central axis, embedded loops and great mix. With urban central axis as the command, it connects the future green field, high-speed rail station, CBD, public service axis and administrative center from south to north, thus forming a central axis functional sequence. Besides, it radiates from the urban center with functional loops distributed, ranging from functional core to comprehensive development and then peripheral clusters in a neat order. Different modules are closely linked and interact in space and function, thus realizing balanced development.(Figure 1)

Figure 1. Bird's eye view of urban design

III. Urban Physical Environment Simulation Conditions and Requirement

Based on the urban design solution, a computational simulation is conducted on outdoor wind environment, thermal environment, acoustic environment and light environment to study the rationality of the design solution.

Jinan is located at 116°98'E and 36°67'N, a middle latitude region with its weather falling in the warm temperate zone and semi-humid monsoon type. It's mainly characterized by four distinct seasons and obvious monsoon features. In winter, influenced by dry and cold airflow from west Siberia, it's cold with less snowfall and prevailing northerly wind. In summer, affected by warm and humid airflow from the Pacific, it's damp and hot with concentrated rainfall and prevailing southerly wind. The spring and autumn are transitional seasons for monsoon. Therefore, the weather is dry with a low amount of rainfall and changeable wind directions.

The prevailing wind in Jinan is quite concentrated around the year. The wind speed is relatively fast in February, March and April and the most frequent wind direction of the year is south by southwest (S-S-W), followed by east by northeast (E-N-E), southwest (S-W) and northeast (N-E).

The instant wind caused by constant changes in atmospheric flow field is of no reference value except under extreme weather such as typhoon or windstorm. Therefore, an average wind velocity is adopted for studying the wind environment. According to wind direction and frequency data, it's concluded that the predominant wind direction of Jinan in winter is E-N-E while it's S-S-W in summer. The wind frequency in the transition season is not studied in that its wind frequency is chaotic. Wind velocity parameters are determined based on data of Jinan Meteorological Bureau. The daily average wind velocity in summer is 3.5m/s while it's 3.4m/s in winter and it's 4.1m/s in the transition season.

In terms of acoustic environment, it's simulated and verified on the basis of such factors as road network setting, traffic flow data and functional layout of buildings.(Table 1)

As for light environment, Jinan is a big city which belongs to Type II climate zone. The accumulated sunlight time of the bottom windows with full sunlight on the Great Cold Day shall be no more than 2 hours according to architectural sunlight standards. Moreover, every set of residence shall have at least one living space which can gain sunlight and the effective sunlight time period is from 8:00 to 16:00.

IV. Simulation Analysis of Wind and Thermal Environment and Optimized Design

In accordance with requirements of Assessment Standard for Green Building and Code for Green Design of Civil Buildings, the wind velocity at the height of 1.5m from the ground in the pedestrian area is v>5m/s, which is the strong wind area. It's the comfort area when 1.0m/s ≤ v ≤ 5.0m/s and it's the calm wind area when v<1.0m/s.

Based on the large-scale numerical simulation method for urban wind environment, PHOENICS of CFD is applied to conduct a simulation on the wind environment of summer. The outdoor temperature is 32.3℃; the wind velocity is 3.5m/s; the wind direction is S-S-W; the solar radiation is 800w/m2; the scattered solar radiation is 300w/m2; time 14h.

The urban design solution complies with the main wind direction of Jinan and forms an effective wind corridor, which is conducive to natural ventilation in the urban area. It can be seen from the simulated wind velocity chart under prevailing wind of summer that the average wind velocity in the area is about 2.99m/s. The red area is the strong wind area where people outdoors may feel physically or mentally uncomfortable. Therefore, outdoor activities cannot proceed. With a wind velocity ≥5m/s, it's mainly concentrated outside several high-rise buildings in the center of the slot and corners of buildings. The green and yellow areas are comfortable areas which can meet the psychological and physiological needs of people outdoors. People can have rest or walk outside. Its wind velocity is between 1.0-5.0m/s, mainly located in the south-north wind corridor and central green field; the blue zone is the calm wind area. In summer, the wind velocity is excessively low, which will make people outdoors feel out of sorts, thus affecting their activity time. Its wind velocity is smaller than 1.0m/s, mainly distributed in places with dense buildings, buildings with large south-north distance and places where street intervals are small. (Figure 2)

PHOENICS is used to simulate the summer thermal environment of the area where the average temperature is 37.93℃ with complicated changes in space form and large surface temperature. On the whole, the red zone is a high-temperature zone with a temperature ≥41 ℃ , mainly concentrated around buildings, enclosed spaces and places with dense buildings; the temperature of the blue and green zones is the most pleasant, being the comfortable zone whose temperature is between 28 and 31℃, mainly located in the central green field and green areas enclosed by buildings. (Figure 3)

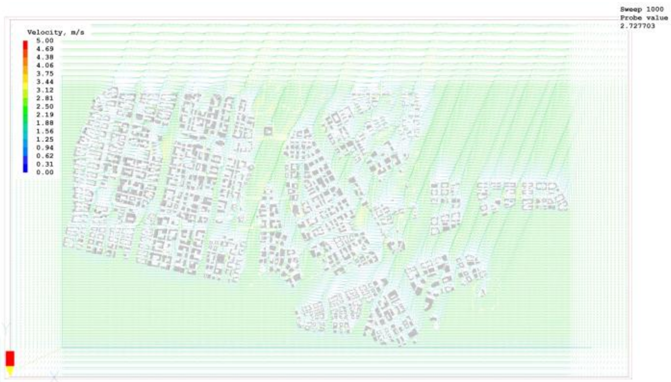

Fig.2. Wind velocity distribution vector diagram over the pedestrian area in summer

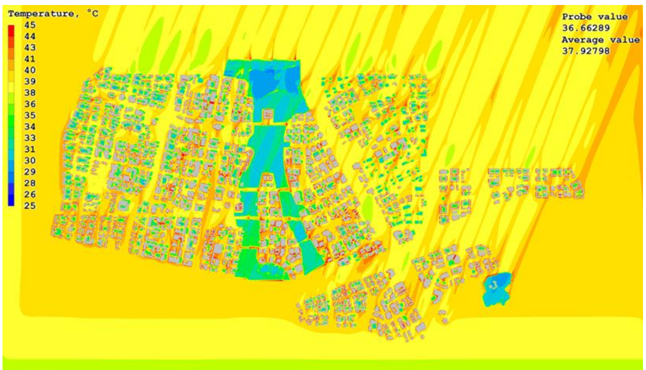

Fig.3. Heat island distribution cloud chart over the pedestrian area in summer

As a whole, the design can be optimized in different aspects to enhance the wind and thermal environment of the city such as urban planning, architectural design and landscape design.

In terms of overall planning, a green field can be developed at the windward point and wedged into the internal city so that the cold air can enter; a water and green corridor can be designed to conform to the prevailing wind direction and dots of green field can be evenly arranged in urban areas with high density; regional park green space and water system should be increased as the former can improve surrounding thermal environment via airflow exchange at night. Regards to urban design, it should comply with the main wind direction of Jinan to form an effective wind corridor and facilitate natural ventilation; a proper street depth-width ratio shall be controlled and ventilation corridor fragmented building blocks can be added to establish more wind corridors of buildings, thus helping ventilation and cooling of buildings; the green field rate shall be raised in enclosed spaces and inside streets so as to release heat through vegetation; a necessary concession shall be made in front of buildings on main streets in order to spread heat; building height should be controlled at the windward point so as not to prevent cold air from entering the city. In light of road traffic, the street direction should conform to the prevailing wind direction; underground parking lot or three-dimensional parking should be established surface temperature. Sunshade design is encouraged for ground parking lot.

For buildings, ventilation and heat dissipation can be promoted through designs such as opening in the middle of building masses and wing walls; a ventilated courtyard design can avoid bevel static wind area and passive ventilation such as ventilation opening and wind hat; arcade or stilt building design can be utilized to block sunlight and ventilate. Buildings which are perpendicular to the main wind direction of summer affect internal ventilation and cooling of the slot because of their degree of enclosure and density. Therefore, scattered buildings are helpful to creating better ventilation conditions and further spreading internal heat. The direction can be rotated to some extent to conform to the main wind direction, which is a satisfying design strategy.

V. Simulation Analysis of Acoustic Environment and Optimized Design

As shown by the calculation outcome, the noise along the urban road especially railway and expressway is loud. The noise on both sides of the railway is up to 70dBA in the day and 60dBA in the night while it's respectively 68dBA in the day and 55dBA in the night along the urban expressway. The noise on both sides of the arterial road reaches 65dBA in the day and 55dBA in the night while it's 58dBA in the day and 54dBA in the night along branch roads. The noise along the urban railway has gone beyond the standard set in Environmental Standard Quality for Noise (GB3096-2008) which stipulates that the noise shall be no more than 70dBA in the day and 55dBA in the night for area of category four.（Figure 4,5）

Much as the noise along the expressway and arterial road can meet the aforementioned regulation, its noise value is still large. Therefore, noise sensitive buildings should not be set, which means residential buildings, schools and hospitals, etc. which are demanding for the acoustic environment should not be built near the railway, expressway and arterial road. The noise inside the enclosed spaces of buildings is 45dBA, thus creating a quiet space.

To protect the quiet acoustic environment at the rear sensitive points, the height of buildings which are not sensitive to noise along traffic trunk lines can be appropriately increased to serve as a screen and block noise.

A green space with a sufficient width along the arterial road should be kept to prolong the noise decline space and reduce the noise impact.

When conducting acoustic environment design for the central green belt, acoustic landscape design approach can be adopted to reduce the interference of road noise in different areas. For instance, different sounds of water landscape such as waterfall, falling water and brook can be placed in different positions to introduce natural sound, or the sound of natural living beings such as chirping of birds and insects in garden landscape. While reducing noise, it can build a desirable urban acoustic landscape environment.

Fig. 4. Sound contour map with road traffic impact in the day

Fig. 5. Sound contour map with road traffic ilmpact in the night

VI. Simulation Analysis of Light Environment and Optimized Design

According to Code of Urban Residential Areas Planning & Design (GBJ50180－93) (edition of 2002), the sunlight standard of residence shall be in line with Table 5.0.2-1. Under special circumstances, it shall meet the following requirements: The original sunlight of adjoining residence shall not be reduced when extra facilities regardless of their type are constructed. The sunlight standard for new residence in transformed old projects can be lowered according to the circumstances but it shall be no less than 1 hour on the Great Cold Day.

The sunlight duration of the south elevation, southwest evaluation and shadow surface along the building outline in b to i areas or nearby areas is 2 hours, which is up to standard; the sunlight duration of the south elevation and shadow surface along the building outline in a area or nearby areas is less than 2 hours; it's suggested that public construction on ground floor can be appropriately increased based on combination of commercial and residential mix to optimize the test residence surface. (Figure 6,7)

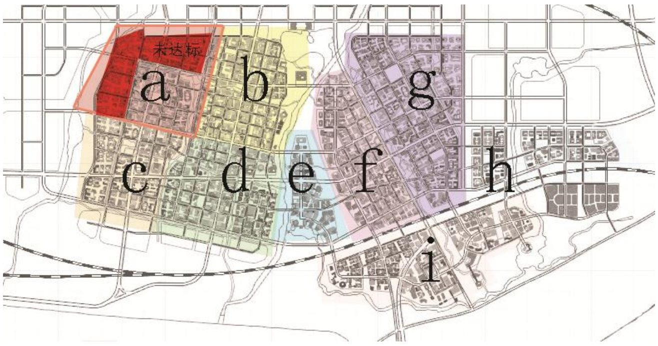

Fig. 6. Simulated partition of light environment

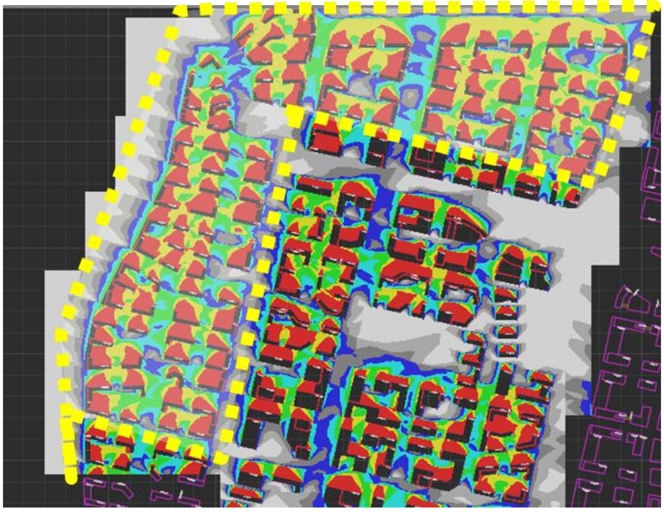

Fig. 7. Disqualified area in light environment simulation

VII. CONCLUSIONSIMULATION ANALYSIS OF LIGHT ENVIRONMENT AND OPTIMIZED DESIGN

The simulation analysis of physical environment such as wind, thermal and light environment based on the urban design solution can help find out areas where physical experience is unsatisfying, locate causes and work out improvement measures in such aspects as urban planning, architectural layout and landscape design, thus eventually optimizing outdoor physical environment. Therefore, it can be noted that the simulation of urban physical environment is of great significance at the urban design stage and is vital in the process of constructing green urban areas.

ACKNOWLEDGMENT

This work was financially supported by the Natural Science Foundation of Shandong Province, China (ZR2014JL034)

REFERENCES

[1] Assessment Standard for Green Building and Code for Green Design of Civil Buildings Environmental Standard Quality for Noise (GB3096-2008)

[2] Code of Urban Residential Areas Planning & Design (GBJ50180－93)