STUDY OF MEASUREMENT AND ENVI-MET SIMULATION OF WINTER NIGHT IN NANPING VILLAGE UNDER WET AND COLD MICROCLIMATE BASED ON URBAN ROUGHNESS

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Abstract. This study selects four urban roughness parameters of building density, FAR, building dispersion ratio, and green rate to study the wet and cold microclimate in the winter night. According to the combination of 7 points‘ measurement and 36 grids’ ENVI-met simulation, this study obtains microclimate research data. The significants of the winter night wet and cold microclimate is focused on improving the somatosensory temperature, and this study splits the target into two related directions, one is to extend the duration of comfortable temperature and humidity, another is to expand the comfortable area of temperature and humidity. By coupling analysis of urban roughness and the comfortable ratio, this study found out 11 relationship lines between urban roughness and nighttime microclimate in NanPing village. These laws offer the design strategy for NanPing Village’s future development from three directions. These also provide a solution to achieve a low carbon, sustainable built environment.

Keywords. Urban Roughness; Microclimate; Climate measurement; ENVI-met; Sustainable development.

1. Introduction

China’s latest ”Green Building Evaluation Standard” highlights the concept of people and focuses on the relationship between people and the environment. In response to the principle of green building, Currently, the majority of design lacked forward-looking concept in the early steps, leading to some buildings’ lacking climate-comfortable design in the exterior space. In the actual project, most green design concentrates on the late design or architectural technology. (Johansson E,2006;Asadi S,2014;Yahia MW,2018). Some adjustments in the early stage determine the final result.

Urban Roughness is the data expression of space form and space restrictions in urban design. The design and quantitative optimization of urban roughness could make contributions to the city’s sustainable development.(Emmanuel R, 2006;Johansson E,2013).This study selects four parameters for the settlement characteristics of the village, including building density(C), floor area ratio FAR(R), building dispersion ratio(T), and green rate(D). (Y.K., 2009;Perini K, 2014; Sharmin T, 2017)

PROJECTIONS, Proceedings of the 26th International Conference of the Association for Computer-Aided Architectural Design Research in Asia (CAADRIA) 2021, Volume 2, 427-436.

The microclimate is a meteorological term that is smaller in scope than the surrounding climate range and the recent near-surface climate (Zhang X, 2016). Some researchers conducted a correlation study between urban design and microclimate and proposed the expression of urban roughness in urban design(Ding wowo 2012).Microclimate can be studied through on-site measurement of climate data and small-scale construction virtual model. ENVI-met is a microclimate simulation software based on the principles of thermodynamics and fluid mechanics.ENVI-met dynamically simulates the interaction between surface, air, and vegetation within a small scale of the city. (Jendritzky G,1981; Bruse M, 1998; Wiener, J.M., 2005;Zhang,H.2011; Lo L,2013;Karakounos I,2018)

2. Research object

2.1. NANPING VILLAGE

China constantly devotes to explore new approaches of sustainable development in rural areas, which helps to balance development between urban and rural area. NanPing village is facing the challenges of urbanization and sustainable development. It is located in the northeast of Guangzhou and far from high-density cities.NanPing village has the basic characteristics of ordinary Chinese villages. Majority of the houses in the core area of NanPing Village are traditional brick-walled buildings with 1˜2 floor.(Fig. 1)

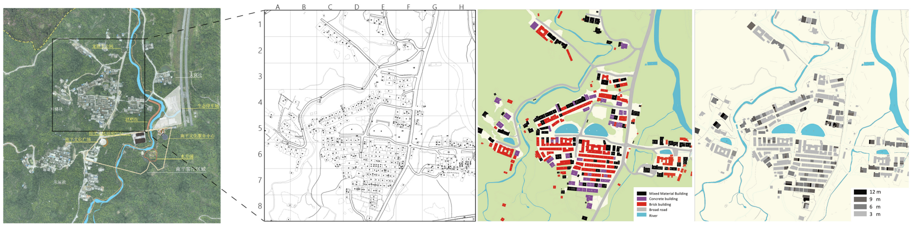


Figure 1. The research scope and surrounding status of NanPing Village.

The average winter temperature in this village is about 17° C.Through questionnaire survey, more than 73% of people feel cold every night because of the Wet and Cold microclimate. they usually keep warm by burning charcoal wood. Due to the young go out for work, the residents in NanPing are mostly children and the older over 50 years old. For the elderly population, it is more sensitive and uncomfortable under the wet and cold microclimate at night.

2.2. URBAN ROUGHNESS GRIDS IN NANPING VILLAGE

Since the study of urban roughness is based on the discussion of urban texture level, the size of the grid still needs to reflect the basic dimensions of the street contour. This experiment uses a simple comparison of 150*150m. (Bottema M, 1998)Common urban roughness research units are used as research units for each grid. This study selected 8*8 small blocks to cut 400*400m for 64 small squares, and each small quare is 50*50m,and each 9 small square block formed a 150*150m grid. Each grid area is 2.25ha, and a total of 36 grids can be obtained.

The urban roughness values of 36 grids were differentiated by depth to obtain four distribution maps. According to the distribution, it is obvious that building density(C), FAR(R), building dispersion ratio(T)are positively correlated. The three are negatively correlated with green rate(D). (Fig. 2)

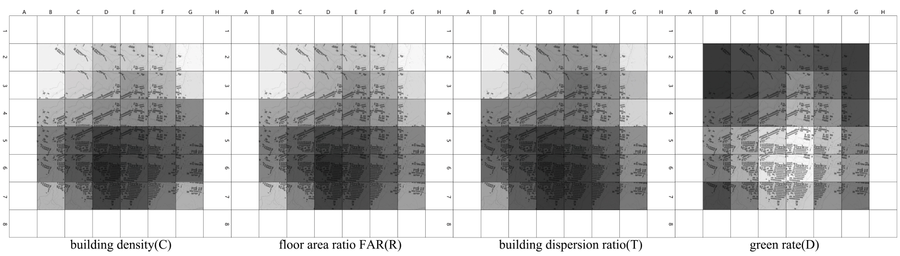


Figure 2. Urban roughness color distribution map of 150*150m grid.

3. Measurement

3.1. MEASUREMENT CONTENT AND POINT DISTRIBUTION

The study uses a fixed-point observation method to set up 7 observation instruments (HD 32.3). The air temperature and relative humidity of the test area at different measuring points were recorded every 15 minutes. The test time is from 14:30 on January 18th(2020) to 8:30 on January 19th(2020).The appropriate air temperature and relative humidity are mainly concentrated in the first half of the night, which is 17:00 to 21:00 on January 18th.

According to the characteristics of the settlement of NanPing Village, the study selects four measuring grid points of B5, C5, D2, and F4 with significantly different urban roughness. Among four indoor points and three outdoor points, the experiments try to eliminate the influence of the underlying surface and water. According to the measurement result, the indoor and outdoor temperature difference is small, changes were not evident. Air temperature at 20:00 starts to a lower stable value and heats the following morning at 6:00. Seven measuring points showed that the relative humidity maintained a high value from 20:00, and the relative humidity began to decrease after 6:00. (Fig.3)

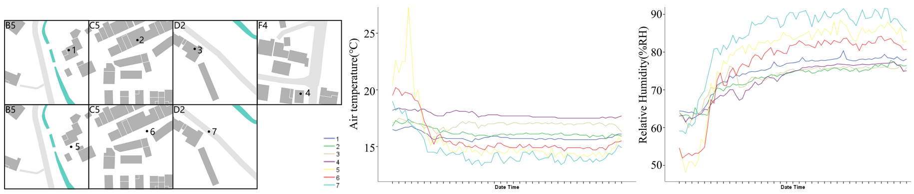


Figure 3. Air temperature and relative humidity change chart (1.4m) .

3.2. RELATIONSHIP BETWEEN URBAN ROUGHNESS AND MICROCLIMATE IN 7 MEASUREMENT POINTS

Other experiments show that the most comfortable indoor temperature and humidity: the winter comfort air temperature is 15.2 ˜ 23.3°C, the appropriate relative humidity limit is 30 to 80% (Li Yaya.2013;Xu Kunlun.2016), Indoor humidity combined with the average humidity value of the night is set to 45 to 75%. The study calculates the proportion of time that the air temperature and relative humidity reached the comfort standard at night. (Table 1).

Table 1. Comparison of measuring point humidity compliance rate and urban roughness.

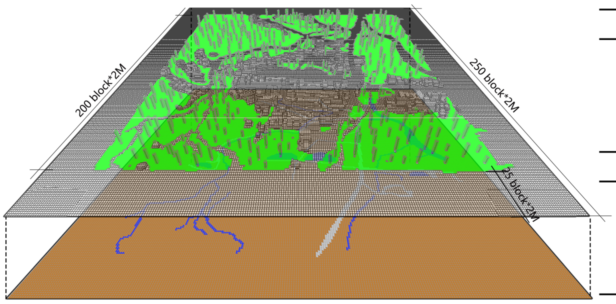
Object	B5（1,5）	C5（2,6）	D2（3,7）	F4（4）
Average indoor air temperature（℃）	15.69	16.07	16.95	17.70
Indoor air temperature comfortable time ratio at 15.2-23.3℃	100%	100%	100%	100%
Average outdoor air temperature（℃）	14.56	15.03	13.99	/
Outdoor air temperature comfortable time ratio at 15.2-23.3℃	12.70%	23.81%	1.59%	/
Average indoor relative humidity（%RH）	76.87	74.38	74.82	74.42
Indoor relative humidity comfortable time ratio at 45~75%	22.64%	58.49%	37.74%	43.40%
Average outdoor relative humidity（%RH）	83.95	80.60	88.28	/
Outdoor relative humidity comfortable time ratio at 30%~80%	9.43%	32.08%	0.00%	/
Building density（C）	0.18	0.25	0.08	0.17
FAR（R）	0.26	0.34	0.13	0.20
Building dispersion ratio（T）	6.77	7.64	4.68	4.65
Green rate（D）	0.46	0.39	0.67	0.46

According to the relationship between urban roughness and time ratio, the urban roughness data has a certain correlation with the temperature and humidity changes in NanPing. However, due to the limited data of the seven measuring points, it is impossible to obtain clear correlation data and related functions. It is necessary to carry out the microclimate simulation of the entire NanPing through ENVI-met. Then coupling analysis with the relationship between microclimate situation and further scientific conclusions in 36 grids.

4. ENVI-met simulation

4.1. COMPUTATIONAL DOMAIN AND BLOCK SIZE

The study uses ENVI-met modeling the core area of NanPing Village (36ha). The overall horizontal modeling block is 250*250 (the horizontal area is 500*500m, core area is 400*400m), the vertical block is 15 equidistant blocks (vertical height is 30m, the highest building in the site is 12 m). (Fig. 4)



Spaces settings	
Block	250*250*15
Block element	X/Y/Z=2.00m/block;
Coordinate	China Standard Time GMT+8
ConfigWizard settings	
Start simulation date	18.01.2020(Winter)
wind speed(10m)	South Wind 0.2m/s
Start simulation time	12：00(5 hours in advance model preheating)

Figure 4. 3D model and settings in ENVI-met.

4.2. COMPARISON BETWEEN MEASURED AND SIMULATED VERIFICATION

To verify the reliability of the simulation, the study uses the simulation data of the same position measurement point to carry ENVI-met simulation and compares the changes of air temperature and relative humidity data of point (5, 6, 7) at 1.4m height on a time-by-time basis. (Fig. 5)

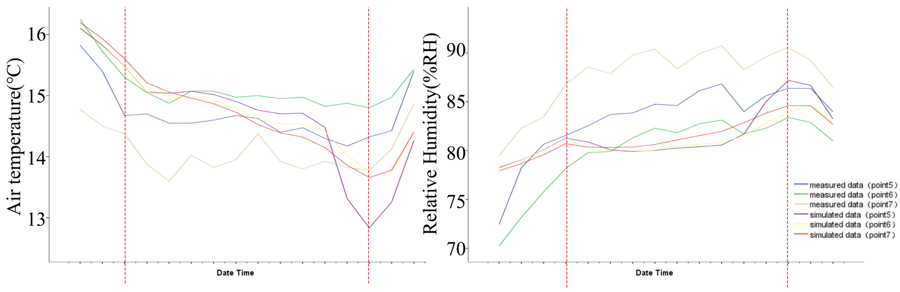


Figure 5. Simulation and measured contrast of Air Temperature and Relative Humidity(1.4m).

After comparison, the simulation is consistent with the actual measurement. More than 90% of simulated and measured values in air temperature are within 1.5 °C, more than 80% of simulated and measured data values in relative humidity differ by 8%. It determines the ENVI-met simulation results can roughly reflect the spatial distribution characteristics and changes of the near-surface thermal environment.

At the same time, according to the data chart, it is determined that NanPing village on the night of 18th, 20:00 is the starting point of the air temperature tends to be stable, and also the critical point of the relative humidity of 80%. Starting from 20:00, the air temperature of several measuring points is lower than 15 °C, and the relative humidity is higher than 80%. At 6:00 on 19th, it is the lowest point of night air temperature and the highest point of relative humidity.

The conclusions show that the subsequent experimental data analysis should focus on the temperature and humidity threshold (20:00,18th) and the temperature and humidity limit (6:00,19th).ENVI-met outputs microclimate simulation data at 20:00 and 6:00.(Fig. 6)

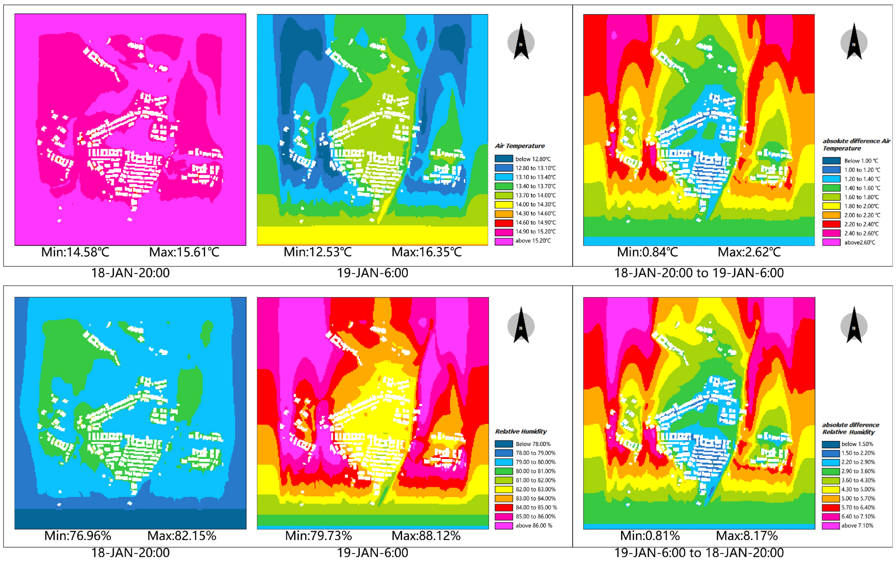


Figure 6. Air temperature and relative humidity simulation result by ENVI-met.

To summarize the improvement of the wet and cold climate in NanPing in winter, it should focus on two points:

(1)Stretch the duration of the comfortable temperature and humidity (comfortable standard time ratio);

(2)Expand the comfortable area of the temperature and humidity(comfortable standard area ratio).

4.3. COMFORTABLE STANDARD TIME RATIO

The hourly microclimate data of 36 girds can be obtained by using the same method in Table.1. It is mainly the comfortable standard of the time-to-standard ratio of 36girds' points. Using SPSS to calculate the Pearson correlation of urban roughness and temperature-to-humidity comfortable standard time ratio. (Fig.8).

(1)There is no obvious coupling relationship between the air temperature comfortable standard time ratio and the urban roughness.

(2)the Pearson between the relative humidity comfortable standard time ratio and urban roughness is more than 0.3 and less than 0.5, which is a low correlation linear correlation. It is determined that the design of the urban roughness can be used to improve the length of the relative humidity comfort interval.

4.4. COMFORTABLE STANDARD AREA RATIO

4.4.1. comfortable area ratio (20:00 ,18th)

The weather conditions of the site at the critical point of night humidity (20:00,18th) were selected. The relative humidity at this time was relatively stable, and the relative humidity range of 77.97 to 83.15% could effectively show a comfortable relative humidity range of 30 to 80%. Data section(20:00,18th) Get the field area within the comfortable relative humidity range of 30 to 80% through photoshop.Using ImageJ to calculate the interval area data can obtain the relative humidity area ratio of each grid at 20:00(Fig.7).In the same way, the air temperature comfortable standard area ratio of each grid at 20:00 was obtained.

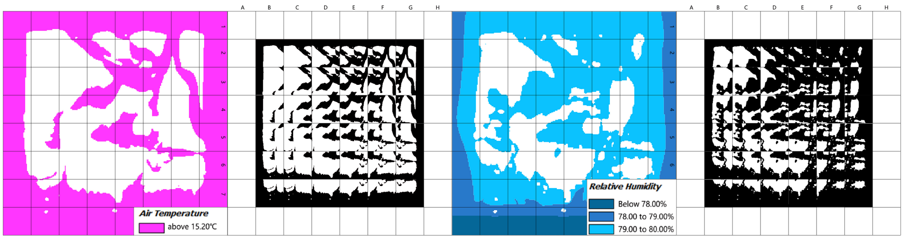


Figure 7. Air temperature and relative humidity comfortable area(1.4m).

Using SPSS to calculate the Pearson between standard area ratio and urban roughness. Except the relationship between building dispersion ratio and air temperature comfortable standard ratio, there is a coupling relationship between other urban roughness and the standard area. It is determined that the design of urban roughness can be used to improve the comfort zone area of temperature and humidity. (Fig.8).

4.4.2. comfortable area ratio (6:00 ,19th)

At 6:00 on January 19th, the minimum humidity of NanPing village on the morning of 6:00 was 80.73%, and the air temperature was low from a comfortable standard. Most areas of the site at 6:00 were unsuitable for temperature and humidity, which does not apply to data research through comfort compliance rates. ENVI-met shows the average PMV was around -1.5(6:00,19th). Under the current climatic conditions, the research on urban roughness can't improve the Relative humidity comfortable area ratio.

4.5. RELATIONSHIP BETWEEN URBAN ROUGHNESS AND MICROCLIMATE IN 36 SIMULATION GRIDS

Pearson correlation values obtain the relationship between urban roughness and winter temperature and humidity by eleven relations, in which blue is negatively correlated, and red is positively correlated (Fig.8). Extending the duration of comfortable humidity can be achieved by increasing building density, FAR, building dispersion ratio, and reducing green rate. Increasing the area of comfortable temperature and humidity can be achieved by reducing building density, FAR, building dispersion ratio, and increasing green rate.

Pearson	Air temperature Comfortable Standard Time Ratio	Relative humidity Comfortable Standard Time Ratio	Air temperature Comfortable Standard Area Ratio	Relative humidity Comfortable Standard Area Ratio
Building density (C)	-0.029	0.453 (>0.3)	-0.309 (<-0.3)	-0.342 (<-0.3)
FAR (R)	-0.03	0.441 (>0.3)	-0.329 (<-0.3)	-0.386 (<-0.3)
Building dispersion ratio (T)	0.129	0.403 (>0.3)	-0.278	-0.325 (<-0.3)
Green rate (D)	-0.037	-0.464 (<-0.3)	0.313 (>0.3)	0.303 (>0.3)

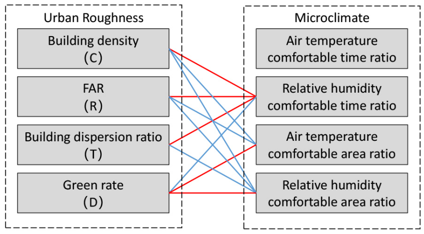


Figure 8. Pearson between urban roughness and microclimate.

There is an opposite relationship between extended comfort time and increased comfort area. The data under 36 grids were coupled to the urban roughness to obtain four scatter trend plots (Fig.9). For building density, the suitable range is 0.05˜0.2; for FAR, the suitable range is 0.1˜0.3; for building dispersion ratio, the suitable range is 6˜8; for the green rate, the appropriate range is 0.6˜0.8.

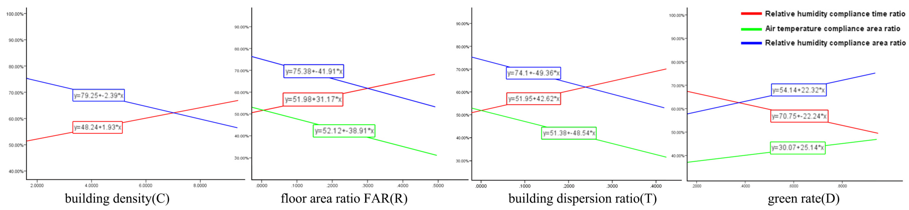


Figure 9. Trend graph of urban roughness and temperature and humidity compliance.

4.6. DESIGN STRATEGIES

For the final range of suitable urban roughness, here are three design strategies for sustainable development of NanPing village:

4.6.1. Suggestions for the renovation of village buildings

Most of the villagers have the idea of renovating their own houses by added height based on the original houses. This change will mainly affect the FAR. It can calculate the FAR data within the 150*150m gird of the building. If the total building FAR after added is guaranteed to be within the appropriate value range(0.1˜0.3), the building height should be allowed added.

4.6.2. Suggestions for new construction of villagers

It is crucial that consider the building density and building dispersion in the surrounding area if the villagers want to build a new house in the surrounding homestead. When the building density can be guaranteed within the appropriate value range(0.05˜0.2), then building a new building can be allowed.

4.6.3. Suggestions for rural planning and urban design

In the plan of rural expansion area, optimizing the environment and improving the quality, the village committee should comprehensively consider the adaptation intervals of the four urban roughness to ensure the basic comfort of the villagers and the sustainable development goals of the village.

5. Discussion and Conclusion

Green design should be promoted not only in cities but also in rural. The concept of sustainable green is mainly reflected in the three aspects of providing a comfortable environment, reducing the burning of bonfires, and reducing the use of heating equipment. Studying the relationship between the winter wet and cold microclimate and urban roughness in NanPing village can effectively solve the contradiction between comfort and energy.

There are two main methods to improve the nighttime wet and cold Microclimate. One is to extend the comfortable temperature and humidity duration, and the quantitative time ratio can be used for quantitative evaluation. The second is to expand the comfortable area of temperature and humidity, and the quantitative area ratio can be used for quantitative evaluation.It is determined that the design of the urban roughness can be used to improve the length of the relative humidity comfort interval and the comfort zone of temperature and humidity.

In summary, the study of the relationship between urban roughness and microclimate can help designers and decision-makers to establish a green concept in rural sustainable planning. The use of some rules of architecture and environment can ensure the best comfort for residents, while also meeting the sustainable development of buildings and cities.

6. Funding

The research was supported by

National Key R&D Program of China (no. 2017YFC0702309)

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