Energy Saving Design in Historical Settlements Planning of Northern Guangxi

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Abstract. Based on the analysis of thermal environmental data of Jiangtou Village, a traditional settlement in northern Guangxi, this paper proposes that energy saving for planning is an important guide for building group design. In view of heat insulation and heat protection requirements in the summer, natural factors such as mountain, water body and terrain, as well as artificial factors such as roadway, yard and patio are analyzed respectively, which are important planning elements of energy saving. It summarizes the design methods of building group planning and energy saving, and provides ideas and theoretical basis for village reconstruction and architectural creation in northern Guangxi.

1. Introduction
Energy conservation of buildings is an important measure for human settlement environment and sustainable development. In today’s view, the historical building groups created by ancients through construction practice from generation to generation still have a remarkably livable environment that warm in winter and cool in summer, which has to cause us to think deeply. To interpret the thought and characteristics of planning energy saving generated by settlements in such a primitive state, it could provide reference and inspiration for our scientific construction of modern living environment undoubtedly. It is the most direct and effective way to reduce building energy consumption that going back to the earliest stages of architectural design, and exploring the relationship between the layout of historical settlements and the natural resources and environment.

Jiangtou Village in Lingchuan County of Guilin City, a well-preserved large-scale historical settlement in northern Guangxi, is one of the 6th batch of national key cultural relic protection units approved in 2006. Influenced by topography, climate and historical environmental changes, the settlement is very representative, because that it presents an overall and continuous structure, While also maintains the typical architectural style of the traditional settlement in northern Guangxi. Therefore, from the perspective of history and geography, the paper attempts to take Jiangtou Village as the object, and summarizes the energy-saving design principles and livable strategies of building group planning combined with the basic data for auxiliary analysis.

2. Historical Evolution and General Layout of Jiangtou Settlement
Jiangtou settlement is located in Jiuwu Town, Lingchuan County, Guilin City. At present, there are more than 180 well-preserved historical buildings, mainly those of the Ming and Qing Dynasties,
which account for more than half of the total (figure 1). The settlement is surrounded by mountains on the east, west and north sides. There is a large area of flat and open land for construction at the foot of the west mountain, WU Zhijie, which belongs to the continuous and low hilly landform. The eastern mountain has two mountains named Bijia and Yuyin because of its external shape like a pen and a seal, that far away from the settlement. The central part near the east mountain, there are some flat land, parallel to the water flow and also the east and west mountain ranges, which are conducive to farming and irrigation. It forms the settlement pattern of “hall in front and back against the mountains” from east to west, that very consistent with the livable site selection principles of circle around the sunny side and back to the dark side, back mountains and facing water, and harmony between man and nature since ancient times in China.

Figure 1. Geographical Location of Jiangtou. Figure 2. “Mountain-Valley Wind” of Jiangtou.

As a matter of fact, since the Yuan Dynasty (1206-1368), residential activities of Jiangtou settlement had existed, but due to lack of experience in flood control, they chose to build a few houses on the western highland far away from the river bank, forming the dotted and scattered form initially. Until the Hongwu (1368-1398) and the Hongzhi Periods (1488-1505) of Ming Dynasty, The bright implication of the two mountains symbolized “Pen” and “Seal”, was affirmed by the descendants of Zhou Dunyi, a Neo-Confucianist in the Northern Song Dynasty of China, who emigrated from Hunan Province twice. The settlement buildings were all oriented towards the eastern mountain, and spread out freely following the direction of the river. Its terrain was still at a certain distance and altitude from the river, and lay out the tortuous lanes that meet the need of strong defence. Although it was too small for the number of the space units, and the scale of the width and depth, the number of residential population and houses increased significantly. Because the owners of the houses were related to each other, it further developed and formed the adjacent and cluster pattern on the basis of sitting west to east.

In the early Qing Dynasty, with the prosperity of Zhou’s family and their status as the owner, the space of “mother’s house” located in Jiangtou Village had expanded eastward step by step, which made the settlement space present a significant grade differentiation. A considerable number of buildings and courtyards approached the low-lying areas of the river. At the same time, the building height was generally raised based on the original structure and orientation of the houses. The courtyard space extended to the bank of Dongjiang River with increasing depth gradually, forming a continuous space series of the settlement groups with the terrain decreased from west to east slowly, which is not different from the existing ancient buildings in Jiangtou settlement.

3. Overview of Thermal Environment of Jiangtou Settlement

Guilin, where Jiangtou Village is located, the north of Guangxi, belongs to subtropical humid and hot climate zone, and the climate zone is divided into the southern end of hot summer and cold winter areas. The average annual rainfall of Guilin is 1900-2000mm, with April to July as the highest, accounting for 40%. The hottest months are June to September, and the heat lasts longer, reaching its peak in July. The coldest ones are January and February, and the average temperature is 8-9°C. The climate is not so cold, and it is rare to see the freezing weather below zero. According to the feedback
from residents in Jiangtou settlement, there is no condition the temperature consistently below zero for more than half a month in winter. In the past, people used to take many measures to ensure the thermal comfort of the indoor space in winter, such as adopting certain insulation materials and wall structures of sufficient thickness, matching the sunshine of the courtyard, closing the main doors and Windows of the room, and even a fire to keep warm and so on. Therefore, the author chooses the data related to insulation in summer as the focus index of energy saving analysis of Jiangtou settlement. Based on the measured temperature data of the chosen key settlement units in July, the hottest month, the author could analyse the problems of building heat insulation, shading and ventilation, and summarize the energy saving strategies and methods of planning layout in the original state.

Table 1. Average Temperature of A,B&C at the End of July (the Hottest Month/13:00).

| Units | Yard 1 | Indoor 1 | Yard 2 | Indoor 2 | Yard 3 | Indoor 3 |
|-------|--------|----------|--------|----------|--------|----------|
| A     | 38.5℃  | 36.5℃    | 39.2℃  | 36.0℃    | 32.5℃  | 32.3℃    |
| B     | 35.0℃  | 35.1℃    | 35.5℃  | 34.5℃    | 34.0℃  | 33.6℃    |
| C     | 38.0℃  | 36.1℃    | 38.3℃  | 35.8℃    | 37.0℃  | 35.2℃    |

The author selects A, B and C settlement group units located in the east, middle and west sections of the ancient settlement as representatives for temperature measurement and comparison (table 1). It is found that the temperature indoor and outdoor changes with a certain regularity. For example, the temperatures in the main courtyard of Unit A were 38.5℃, 39.2℃ and 32.5℃ at about 13 o’clock, respectively. The temperature in the third entrance courtyard decreased significantly with a difference of 6.7℃, while the central temperature indoor was basically stable at about 34℃, 5.2℃ lower than that in the second entrance courtyard with the highest temperature. Obviously, with the change of the structure level of the settlement group units and the spatial forms of the courtyard, the temperature has a significant difference. Undoubtedly, it provides a “low-technology” guiding method for the energy saving design of modern building group planning. Therefore, it is necessary to return to the design source and explore the elements of historical settlement planning layout and courtyard space organization. It can be summarized as two types of natural factors and artificial ones. The former includes the topographic site selection, morphological composition, climate adaptability etc., while the latter includes the use of materials, methods, subjective wills and so on. The following would discuss the two major aspects of energy conservation planning.

4. Natural Factors of Energy Saving in Jiangtou Settlement Planning

Natural elements such as mountain, water and topography affects the built environment of all the settlement directly, and also affects the physical environment and microclimate where the settlement inside, that constitutes the objective factors for the energy saving of Jiangtou settlement planning.

4.1. Mountains and Wind Environment Orientation

Jiangtou settlement is surrounded by mountains on three sides, forming a natural valley gentle slope. There is a “gap” between the two peaks of Bijia and Yuyin Mountain on the northeast side. It is just the entrance to the dominant northeast wind of Guilin and keep the settlement above it in the summer, combined with the south outlet of the settlement. In the daytime, affected by the heating of solar radiation, the peak appears high temperature and low pressure firstly, while the valley floor where the settlement is located forms higher pressure due to the lower temperature. As a result, the airflow moves along the gradient through the mountain to the top, called “valley wind”. On the contrary, at night, the peak temperature drops faster, and the high pressure comes first, pushing the airflow in the opposite direction, called “mountain wind”. In such a cycle, the surrounding mountains cause the air flow in the lower part of the valley to form the microclimate environment of “mountain-valley wind” with alternations of day and night (figure 2). It can further accelerate the natural ventilation of each
settlement unit, take away parts of the indoor heat, and play a certain positive role in improving the indoor thermal environment in the summer.

On the other hand, in winter, the higher mountains on the western and northern, WU Zhijie and Huang Jiapo, have a shielding effect on the dominant northwest wind, that can prevent the cold air from reaching the settlements, so that the indoor temperature is not too low. And then, time to warm by charcoal fire in the winter may be shortened, and reduce energy consumption directly. The thermal environment of the settlement could always be maintained in a relatively comfortable energy-saving state.

4.2. Waters and the Adjustments of Temperature and Humidity

At the same time, as the surrounding environment of the settlement belongs to the common geological features, a “dust pan ground” formed by three sides mountains and a gully formed by two peaks, that makes the groundwater flow be concentrated highly to enrich the water system of Jiangtou at the end of the dust pan ground. From west to east, there are the Lotus Pond and several interlaced rivers, Wulong, Dongjiang and Longjing, which flow in a gentle slope, parallel to the overall trend of the settlement in the form of high in the west and low in the east. With the changes of the topography elevation of the land and water and the difference of the surface covering materials, the temperature and humidity have changed.

In the daytime, under the influence of solar radiation and surface long-wave radiation, the land surface with low heat capacity will heat up rapidly and obviously, and the air may expand and rise under heat and form low pressure, which push the air flow from the water surface area with high pressure and low temperature to the land, called “river wind”. It can relieve the high temperature in the daytime of summer, especially in the afternoon, and play a certain role in humidity regulation. On the contrary, in the night, the land area will cool down faster than the water surface one, “land wind” and its thermal circulation appears, opposite to that in the daytime, accelerating the air circulation between the land and the water surface.

Generally, due to the temperature difference between the land and river during the day is greater than that at night, that is to say, “river wind” is stronger than “land wind”. The airflow of the water surface area located in the northeast is moved to the settlement group located in the southwest by the dominant northeast wind in summer, which makes the external space of the buildings in a natural and comfort ventilation circulation system, humidity increases and temperature decreases, and the improvement of the settlement micro environment would be realized.

4.3 Adaptation of Terrain and Site Environment

Buildings of Jiangtou settlement was good at adapting to local conditions. According to the gentle terrain slope of the west high and the east low, the contour line of the blocks descended slope in turn, and building units grouped arrangement at different slopes (figure 3). On the whole, the buildings located west and faced east. The height and volume of each settlement unit was very unified, and there was no courtyard with extreme differences. In this way, when the dominant northeast wind in summer blows to the west exit of the settlement, the buildings in the front row would not be obscured by the back one, which ensures the good ventilation of the main rooms in each unit and saved the power consumption needed for cooling to some extent.

In this way, the design method of building groups facing the sun and releasing the slope slowly along the terrain creates a “compact” settlement pattern with reduction of building height step by step. It not only cut the loss of earthwork quantity needed by ancient people to build settlements at that time, but also saved the cost of manpower and financial resources and protected the soil and ecological environment. In addition, the slope was consistent with the flow direction of groundwater and surrounding water systems, which was very favorable for natural drainage and flood control of the settlements, and also an important reason for developing and preserving the settlement up to now.
5. Artificial Factors of Energy Saving in Jiangtou Settlement Planning

The three types of space, alleys, patios and courtyards, were the main structures of the settlement. It was not only the material carrier of the builders’ will and thoughts at that time, but also the reproduction practices of constructing human settlement environment combined with landscape natural environment, which constitutes the subjective factors of energy saving in Jiangtou settlement planning.

5.1 Roadway Space and Skeleton Composition

The main and branch alleys unfurled along the terrain and formed the main skeletons of the settlement. The mains were radial from west to east, with which a large number of branches were perpendicular to, mostly in the north-south direction. A corresponding deflection occurred where the terrain changed, also catered to the direction of the Wulong River in the east to some extent, and promoted the internal structures of the settlement to form a crisscross and integrated road pattern.

The main alleys has a trumpet-shaped entrance, wide in the east and narrow in the west, apparently catering to the dominant wind direction in northern Guangxi (figure 4). The possibility of wind coming in from the roadway increases, speeding up air flow and forming the “effect of cold lane” to release more heat. And a relatively comfortable environment around the courtyard is ensured, it can further promote the balance of thermal comfort in the interior space. On the other hand, the main and secondary allays are not wide, and the external walls around them are made of heavy bricks with high thermal mass. The ratio of height and width is usually between 3.5-4. It is very favorable for the shading of the roadway that high walls and narrow lanes. It not only make full use of the high thermal mass wall with thermal insulation performance and thermal stability, but also avoids the adverse factors of excessive solar radiation absorbed by the wall causing overheating at night. It further provides a foundation for the comfort of the settlements interior space.

5.2 Courtyard Space and Order of Rows and Columns

Based on the previous space interpretation of Jiangtou settlement, there were a number of unitary spatial sequences that expand with the courtyard as the center, which constituted the basic units of the settlement pattern, each of them was in clear order with each other and arranged in high density to maximize the land use efficiency. It could be identified of the owner of the courtyard space from the width, depth and number of the column unit. In fact, this kind of sequence reflected the relative relationship between the owners of the settlement unit, and the historical development of the family settlement. it also payed attention to the influence of natural terrain and topography.

In addition, when the slope was large or the terrain turned over and it was not suitable to form “rows and columns”, more “open space” appeared at intervals to grow fruit trees and vegetables, that
played a certain regulating role in the air circulation inside the settlement. Together with the tall trees around the settlement, it formed a series of “green clusters”, which made full use of sunlight and absorb a certain amount of radiant heat, becoming a natural and continuous microclimate system.

5.3 Patio Space and Unit Composition
Each sequence space contains a number of courtyard units composed of patios and buildings around. The space of buildings consisted of porches and rooms. The main rooms always a single floor, with the height above 4.2m. It was divided into two kinds of spaces, halls and bedrooms. The hall was located on the central axis, and the door usually was designed as a detachable one in six or opposite parts, which was a transition space between indoor and outdoor. It can not only avoid the sun and rain, but make the outdoor air flow enter to the maximum. The bedrooms were divided into two parts and spread out symmetrically, forming the common three-room plan system called “one bright and two dark” in Hunan and Jiangxi’s housing systems. In order to better create hot pressure ventilation, take away indoor radiant heat, and maintain constant temperature as far as possible, hollow decoration were equipped on the part above 1.3m of doors and the beam to that of the roof junction. Through the measurement of group A, B and C, the temperature difference between indoor and outdoor of the buildings was above 2℃ (measuring point height of 1.2m).

In order to better avoid the drawback of strong sunshine in the east-west orientation defined by place and custom, the front facade facing the east of the front entrance of each unit column was not equipped with any window holes, but with a large area of solid brick wall. There was only a small recessed “door bucket” ( the width generally 2-3m ) set at the north end of the wall. The direct sunlight to the east was cut off, and the space concession was designed to as an entry door for each unit, in the form of a “porch” for shading. The south side of the end wall was the same depth as the "door bucket" or a porter and a utility room. Windows were all facing the inside of the patio, which also plays a good heat buffer effect.

The depth of the patio varied from 1.7-4m, often 1/4 of the depth of the main room, with the length-width ratio between 2-3. The surrounding buildings were set with large eaves, which can control the direct duration of sunlight entering the courtyard effectively and prevent excessive radiant heat from entering the courtyard or transmitting to the interior through the surrounding walls. In the longitudinal sequence, the narrow patio and the building were interlocked and connected (figure 5). As the temperature was slightly lower, the wind pulling effect caused by the increase of the bottom pressure would form a series of air flows, which could take away the excess heat energy around to realize air exchange and ventilation cooling. That is the numerical result for the courtyard’s temperature measured at Part 3 dropping as the number of yards increase.

6. Conclusions and Implications
To sum up, in the summer of the south, it is very difficult to carry out heat insulation and heat protection only by relying on the thermal insulation performance of building materials, so we must have the idea of planning energy conservation. The livable environment of Jiangtou historical settlement proves that some traditional experiences and methods are effective. While catering to the natural environment limited by mountain, water and terrain,we should pay more attention to the layout of roadway space, the organization of courtyard space and the construction of patio space and other planning design factors. In this way, the effective shading and natural ventilation of the whole settlement could be solved largely, so as to reduce the solar radiation heat of the building surface, and meet the special climate adaptability requirements of the northern Guangxi. It reflects the methods and characteristics of traditional settlement different from modern buildings in dealing with climate problems, what just is the lack and overlook of modern architectural design and its energy saving methods.

Therefore, from the perspective of history and planning, it is necessary to think and adjust the energy saving ideas and methods of residential building groups. On the one hand, It needs to be adapted to local conditions, make the best use of the natural landform, cut down the construction cost
at the same time, and carry out the planning of building group design. On the other hand, it is essential
to control and minimize the energy consumption, and make efficient use of energy while fully
Implement adequate measures to save energy in building space layout. And finally, the construction
goal of economical and environment-friendly would be realized.

Acknowledgments
Thanks for the financial support of Guangxi Key Laboratory of Building New Energy and Energy
Conservation. This research is supported by Study on form of the ancient town and building energy
conservation design of planning in Guangxi (Guangxi Young Teachers Basic Ability Enhancement
Project. No. KY2015LX111). Thanks to Xie Tingting, Chen Jiaming, Shi Jiaqi, Tao Cuihua and Jiang
Yingzhi, my students, for the basic measurement and drawing of the research.

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