Study on microclimate Environment of Jiaodong Seaweed house -- Taking Dongpudao Village as an Example

(Study on microclimate Environment of Jiaodong seaweed house)

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【Abstract】 Taking the seaweed house settlement in Jiaodong as the research object, this paper study the microclimate of seaweed house through experimental data, wind environment and thermal environment simulation. The analysis of seaweed house under the coastal climate conditions have three aspects: macroscopic settlement form, middle view block form and microscopic courtyard.

【Keywords】 seaweed house, settlement, ecology, microclimate

In the long history of farming in China, the unique geographical, climatic characteristics, historical , cultural of various places have created many traditional settlements, such as the settlement of cave dwellings in Shanxi, the settlement of Tulou in Fujian, and the settlement of bamboo buildings in Yunnan. Although these traditional settlements have different forms, they all contain ecological wisdom that is ingeniously adapted to the regional climate. The settlement of Jiaodong seaweed houses(Figure 1) is one of them. The existing traditional seaweed house settlements are mainly distributed in the coastal areas of Weihai, Yantai and Qingdao. The complex and diverse climatic conditions of the region (wet and rainy, high salinity, windy, strong radiation) and the geographical features of the integration of mountains and seas have an impact on the settlement pattern of seaweed houses. At the same time, the settlements of seaweed houses also form from macroscopic settlements. The settlement form, block form and micro-court form respond to the local geographical climate. After long-term development, the seaweed house settlement not only forms a simple and beautiful settlement environment, but also has ecological characteristics, realizing the unification of ecology and modality, and is a precious ecologically sustainable architectural cultural heritage in the northern coastal of China.

Figure 1 :*seaweed houses*

1. Macro ecological strategy

At the settlement level, temperature, ventilation and drainage are the main factors affecting the settlement pattern of seaweed houses. The seaweed house settlement creates comfortable temperature and ventilation conditions through the location of facing the sea with the hills for a background, the compact layout, reasonable orientation and the sand surface with big specific heat capacity increase the thermal stability of the settlement, at the same time, The good permeability of sand land and open ditch can effectively reduce the impact of the torrential rain disaster that is prone to occur in the coastal area. The macro-settlement ecological strategy of seaweed houses includes,

1.1 Settlement site of facing the sea with the hills for a background

The seaweed house settlement is generally located on the adret in the coastal zone. This traditional location of facing the sea with the hills for a background can make full use of the climatic characteristics of the land and sea junctions in the coastal area of Jiaodong to create a comfortable and livable settlement.

Utilization of coastal climate: Seaweed house settlements are generally distributed within a certain distance from the coastline but not more than 10km. This kind of sites can take full use of the climatic characteristics of the summer and winter temperatures in the coastal zone, and avoid the humid climate in the coastal area. Living close to the sea is also facilitates fishermen to go out to sea and effectively improve the comfort of living (Figure 2). Relevant meteorological data show that the distribution area of seaweed houses is obviously affected by ocean climate. The temperature in summer is 4°C~6°C lower than that in inland areas in the same latitude, and the temperature in winter is 3°C~5°C higher than that in inland areas in the same latitude.

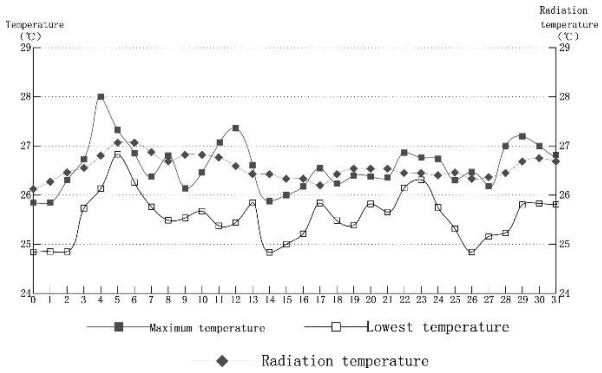

Figure 2 : Indoor daily highest (lowest) temperature measured in August

Use of altitude difference: Most of the mountains in Jiaodong are wide and gentle. The settlement of seaweed houses is generally located in the area with suitable slope and open terrain on the south side of the mountain. The flat land below the mountain is reserved for cultivated land. The building gradually rises with the hillside in order to obtain good sunshine, while the good ventilation of the sunny slope helps to accelerate the diffusion of humid air. In the winter, the mountain can also block the cold wind for the settlement.

1.2 The settlement form on the mountain

Affected by mountains and coastlines, the construction base of seaweed houses is relatively small, so the settlement is compact (Figure 3). Take Dongchuudao Village for example, the settlement covers an area of 2,160 ㎡, its total construction area is 90,65 ㎡ and building density is 42%. This compact space shape can maximizes the impact of the external environment and creates a comfortable thermal environment inside the settlement. In summer, the high-density settlement form allows buildings to block each other, greatly reduce the area and time of exposure the sun and increase indoor thermal comfort (Figure 3). In winter, the cold wind passes over the roof of the seaweed house and the Internal space forms a continuous wind shadow, which can effectively reduce the wind speed inside the settlement (Figure 4) and reduce heat loss.

Figure 3：*Seaweed house courtyard form*

1.3 Sandy and soil mixed ground

The ground of the of seaweed house settlement is the sand formed by the weathered mountain stone, which has good thermal stability and drainage performance. First of all, the specific heat capacity of the sand is large and a large amount of solar radiation is absorbed during the daytime, so that the temperature inside the settlement is lower near the ground. At night, the sand has good air permeability, fully releasing the heat accumulated during the day and maintaining the temperature stability at night. Secondly, the porosity of sand is high, a large amount of rainwater can quickly infiltrate into the sand during the rainy season. The remaining rainwater

flows into the open channel and is discharged into the sea, so that the settlement avoids the impact of rain and flood disasters (Figure 4). In addition, the sand is not easy to produce muddy water after the rain, so it has little impact on the outdoor activities of the fishermen after the rain.

Figure 4： *After the rainstorm*

2. Block Ecological Strategy

The streets are not only the transportation spaces of the seaweed house settlement, but also important places for outdoor activities of local fishermen. Therefore, the microclimate environment of street space directly affects the quality of outdoor activities of fishermen. The microclimate environment in the street space is mainly affected by two ecological factors, wind and solar radiation. The seaweed house settlement can provide fishermen with a cool space through the appropriate street height-width ratio .The streets can also guides the summer ventilation and blocks the winter cold wind with reasonable street orientation; The 'long street short lane mode'can effectively stabilize the wind and thermal environment of the street space. The ecological strategy of the seaweed house street space includes,

2.1 Shade-cooled street aspect ratio

The air permeability in the coastal areas is high. The ultraviolet rays can effectively pass through the atmosphere to reach the ground. In addition, the reflection of ultraviolet rays by seawater and the stimulation of human skin by saline-alkali air can easily cause ultraviolet burns on the skin. In the summer, reasonable street height ratio of seaweed houses helps to create more shaded areas street space, effectively alleviating the effects of ultraviolet rays, and avoiding the radiation warming effect caused by direct sunlight. It is important for seaweed house settlements to improve the comfort of summer street space.

In the seaweed house settlement area (latitude 37° north), the influence of solar radiation on the thermal environment of the north-south roadway is greater than that of the east-west street. Therefore, the seaweed house settlement is usually have east-west street and north-south narrow alley. Take the street space of Dongchudao Village as an example, the height-width ratio of the street of east-west streets effectively reduce the solar radiation entering the street. At night, the sky space

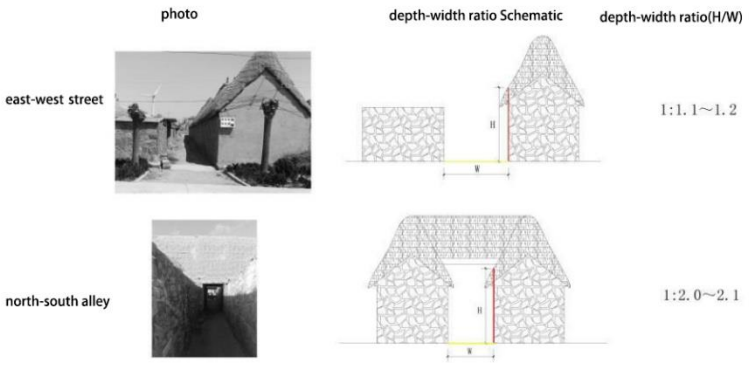

Figure 4： *street (alley)shade*

factor of the seaweed house street space is large, and the heat dissipation through long-wave radiation with less hindered. The heat accumulated during the day can spread rapidly so that the street space in summer is very cool. For the north-south narrow alley, although it is exposed to direct sunlight at noon, its small width prevent solar radiation from entering the alley so the solar radiation has little impact on the outdoor activities of fishermen. Local fishermen often use the method of riding the roof to enhance the shading effect (Figure 6). In addition, because the sunshade effect of the seaweed house settlement space is good, the air temperature in the street space is lower during the daytime, and the high temperature air above the roof cannot enter the street space, so the street space can be keep cool.At night, the solar radiation

disappears, the temperature of the air above the roof drops sharply, the temperature is lower than the temperature of the street space, and the cold air enters the street space and forms a convective wind, which makes the micro-climate in the street space cool and pleasant.

2.2 The influence of street orientation on the wind

The seaweed house settlement street is about 15° eastward from the south of the settlement, which can effectively guide the summer ventilation and block the winter cold wind. In summer, the local wind direction (southeast wind) and the street direction (east-west street) are at an angle of 60°. The wind environment simulation software PHOENICS was used to simulate the wind environment of the seaweed house street space. It can be seen from the simulation result 1 (Figure 5) that when the street interface and the airflow direction are at an angle of 60°, the effective span becomes smaller, which can effectively guide the airflow . so that the wind speed in most areas of the street space is between 1.2 and 1.8 m／s, which is very comfortable in summer. In addition, when the basic airflow in the summer is weak, the unique' sea breeze and land breeze' is blown into the settlement with the wind direction is parallel with the street direction. So that the wind has less resistance during the flow, and the street space can still obtain a comfortable wind speed. In winter, the local wind direction (northwest or northwest) is between 95° and 110° from the main street, and the wind direction is basically

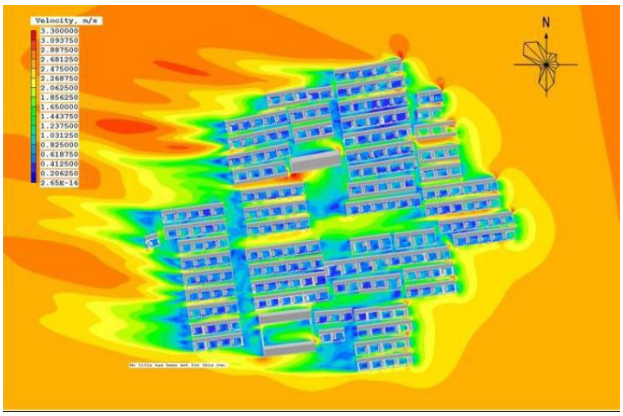

Figure 5：*Summer wind simulation*

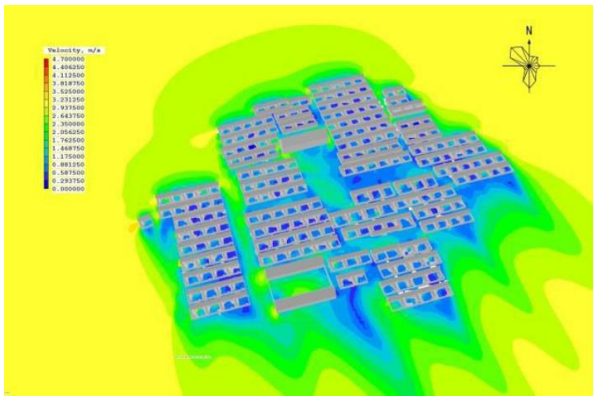

Figure 6：*Winter wind simulation*

perpendicular to the street. From the wind simulation result 2 (Figure 6), the wind speed in the street space is significantly smaller than the wind speed outside the settlement. In most areas, the wind speed is between 0.3 and 0.9 m／s, and the human body barely feels the wind speed. It can be seen that the street space can effectively block the cold wind, greatly reduce the wind speed in the street space, and minimize the heat loss caused by the cold air movement.

2.3 Climate stable street pattern

The reasonable orientation and aspect ratio of the seaweed house settlement street effectively improves the thermal comfort of the street space, while the' long -street-short-alley' mode can further stabilize the thermal environment in the street space. Limited by topographical factors such as mountains and coastlines, seaweed house settlements are generally arranged in rows (Figure 3), forming a street pattern of' east-west long streets and north-south short alley' (Figure 7). This kind of street mode can bring more shadows in the summer while storing more heat in the winter. In addition, the number of north-south alley in the seaweed house settlement is small, which can reduce the channels for the northerly winds entering the settlement in winter. The existing north-south alley are also tortuous. After the cold wind enters the alley, the flow is blocked and the wind speed is greatly reduced.

3. Courtyard ecological strategy

Courtyard is the most commonly used place for fishermen. Its temperature, humidity and wind speed directly affect the comfort of living. Seaweed houses are highly ecological and coastal in terms of courtyard layout, building scale, building materials and their construction practices. The ecological strategy of the courtyard of seaweed houses includes:

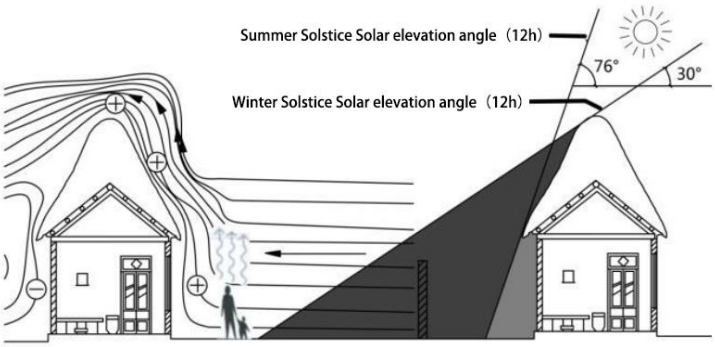

Figure 7： *Seaweed house profile*

3.1 Reasonable courtyard space

(1) The combination of courtyards: affected by the coastal climate and the defense military, 3 to 5 seaweed houses are general in a row, and the two share the middle wall (locally known as “JieShan”). This type of courtyard link can save land and save building materials and reduce heating energy consumption. It also reflects the good neighbourhood between fishermen.

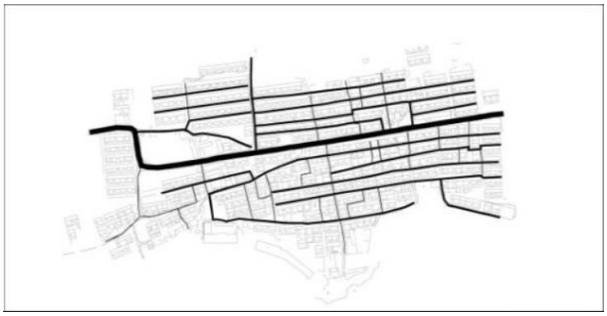

Figure 8：*street and alley*

(2) Reasonable courtyard size: The courtyard of the seaweed house is 5~7m long from and 4~5m wide. In summer, the deciduous trees planted in the courtyard are lush and cover almost the entire courtyard and making the temperature in the courtyard lower than the temperature outside the courtyard. The difference between the internal and external air pressure promotes the air flow, which brings the cool air and promotes the evaporation of water, which can effectively dehumidify and dissipate heat. In the winter, the small courtyard space and the heavy structure make the inner space of the courtyard less affected by the external cold wind, forming a stable and comfortable microclimate.

(3) Reasonable main room scale: The plane of the main room of the seaweed house is rectangular, and the width of main room (9~12m) is beneficial to increase the radiation heat in winter, and the depth of main room (3.6~4.0m). At the same time, the square shape has the smallest coefficient (about 0.6), which can effectively improve the indoor thermal environment.

3.2 Towering roof

The roof of the seaweed house has a large slope, usually between 50° and 60°, which adaptability to local climate well. In view of the climatic characteristics of high winds, high precipitation and sufficient sunshine, the slope roof can make full use of wind resources and solar energy.

3.2.1 Leading the winter cold wind to high altitude

In winter, the wind speed and humidity in the coastal zone are large, and the humid cold wind makes people feel abnormally cold. The roofs of seaweed houses are connected to each other to form a continuous wind-shielding interface, which can effectively lead the winter cold wind to the high altitude, greatly reduce the wind speed inside the settlement, and slow down the heat exchange process through the vertical circulation flow. In the simulation of the winter wind environment in the seaweed house settlement (Figure 9), the wind speed at the courtyard space of the seaweed house settlement and the pedestrian height (1.5m) of the street space is 0.5~0.9m/s, which wind speed in winter. In addition, the saddle-shaped curve

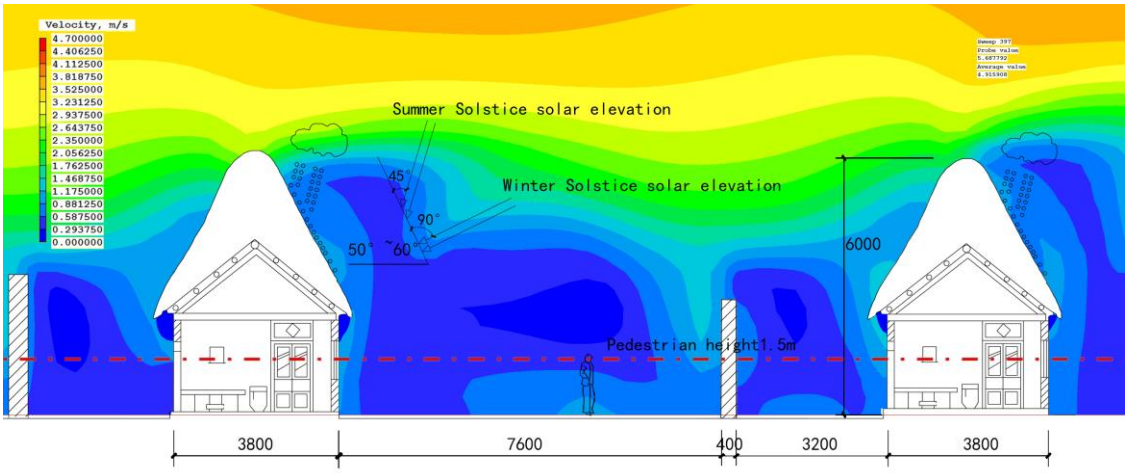

Figure 9：*Profile wind simulation*

of the ridge of the seaweed house can smoothly guide the airflow, avoiding the “corner wind” effect, causing the wind speed at the ridge to be too large, and blowing the seaweed on the ridge.

3.2.2 Make full use of sun radiation in winter

The roof of the seaweed house helps to absorb winter solar energy and prevent summer exposure, improving the thermal comfort of the indoor environment. As shown in Figure 10, the roof of seaweed house is basically perpendicular to the sun's rays on the winter solstice. The effective area on the sunny side of the roof is the largest. The thick material absorbs the solar radiant heat during the day and effectively blocks heat loss the indoors On the summer solstice, the roof and the the sun's rays at a angle 45°, which reduces the roof's radiation area by 30%, helping to create a cool interior environment .

3.2.3 Accelerate drainage and reduce accumulated snow

In order to minimize the impact of heavy rain and snow in the coastal zone, the slope of the seaweed house has a slope of 50°~60°(Figure10), which can quickly eliminate summer rain and reduce accumulated snow. According to the mechanical calculation, under the same friction coefficient (with a friction coefficient of 0.1), the 60° slope roof is 1.7 times better than the 30° slope roof, and can reduce the snow by 50%. The good drainage performance of the seaweed house roof prevents the seaweed from being damp and greatly prolongs the service.

depth-width ratio	Slope	Windward wind pressure	Leeward wind pressure	Description
≤1:7.5	≤15.0	-0.6	-0.5	The slope is very small, the windward surface reaches the maximum, and the roof is very threatening.
1:6.3	17.5	-0.5		The windward and leeward negative pressure values are the same, and the roof is subjected to a thrust of 0.
1:5.5	20	-0.4		The negative pressure on the leeward side of various slope roofs is -0.5
1:5.0	21.8	-0.3		Fujian coastal residential roof slope
1:4.0	26.6	-0.1		The windward negative pressure is very small
1:3.5	30	0		Windward without wind load
1:3.0	33.7	0.1		The wind pressure on the windward side is small and positive
1:1.0	45	0.4		Positive pressure on the windward side increases with increasing slope
≥1:1.2	≥60	0.8		Slope ≥ 60°, positive pressure on the windward side is equivalent to vertical wall positive pressure

Figure 10： *Roof wind pressure*

3.2.4 Wind disaster reduction

Because the seaweed is light and easily blown by strong winds, the windproof performance of the seaweed roof is very important. The towering roof of the seaweed house can effectively alleviate the impact of strong winds. Table 1 shows the wind load coefficient of the roof under various slopes calculated according to the current 'Load code for the design of building structures'. It can be seen that the flatter the roof, the greater the negative pressure on the windward side, and the greater the negative pressure coefficient of the windward side of the roof. The slope of the seaweed house roof is generally between 50° and 60°, and the windward side of the roof is in the positive pressure zone (Figure 10). Therefore, the seaweed is not easy to be blown by strong winds, and the positive wind pressure on the windward side of the roof can press the seaweed more compact. In addition, the seaweed slowly absorbs the moisture in the air, and the roof becomes compact from fluffy, and the whole body is strengthened, and it is not easy to fall off. Even if the part is blown off, the seaweed is light, and it will not hurt local fishermen.

3.3 Ecological materials and construction

The fluffy seaweed roof and the thick rock wall are typical features of the seaweed house, which is due to the particularity of the building materials and the complexity of the construction process. The main materials of the roof are seaweed and wheat straw, and both materials are taken locally. The straw is smooth and breathable, and the seaweed is firm and resistant to corrosion. The thickness of the seaweed is gradually thickened from the eaves to the ridge, and the thickest part is 1~2m (Figure 11). This special structure maximizes the ecology of the material. The characteristics make the roof have good thermal insulation effect. The gap between the seaweeds also gives the roof a 'breathing function', which provides a cool and breathable condition for the interior space. In addition, the seaweed used for roof

contain halogen and glue, so its service life can be as long as 100 years.The seaweed also has the characteristics of insect proof, antisepsis and non-burning. The granite blocks of the wall are all from the mountain around the settlement, the stone masonry is round and be builded in a random way. In order to achieve thermal insulation, the thickness of wall of the building is more than 400mm, and some of the walls are covered with a layer of plaster to prevent moisture. At the same time, the tiny permeability of granite (0.2%~4%) can effectively prevent outdoor moisture and rain from entering the room.

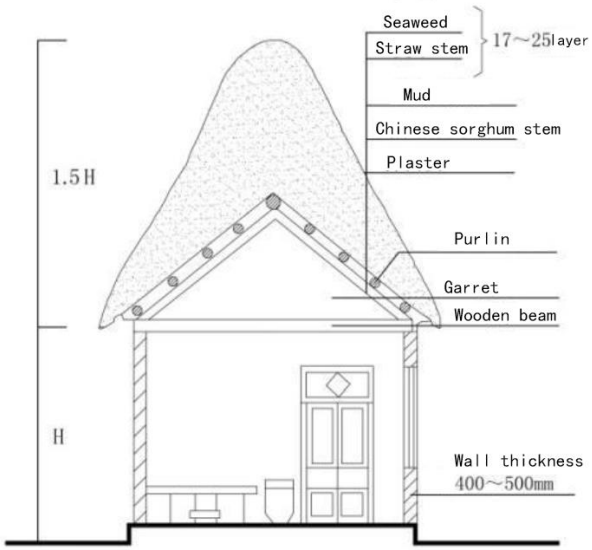

Figure 11： Construction practice

Conclusion:

The seaweed house is an important part of traditional Chinese dwellings which was been created in a specific environment for generations. As a symbolic residential symbol in the Jiaodong area, seaweed houses are gradually disappearing as the fishermen's lifestyle changes. We have the responsibility to protect the remains of the seaweed house and the ancient technology. At the same time, it is necessary to understand the aesthetic value from the construction process of seaweed house, explore the value of traditional ecological residential building technology and materials. We should study the application of traditional building materials in modern architecture, then promote development of traditional architecture.

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