Comparison of Wind Resistance of Street Space between Coastal Traditional Villages and Newly Built Villages -A Case Study of Qinjiang Village and Dinghai Village in Fuzhou

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Abstract. In the context of building a "community of maritime destiny", research on traditional coastal villages in China has been mainly focused on protection and publicity. Nevertheless, the fact that China's traditional coastal villages could keep their integrity even after windstorm attacks of hundreds of years shows excellent wind resistance, which have not yet been fully explored. The newly built villages near the traditional villages, however, have not inherited the good wind resistance. To study the windproof strategies of traditional villages, the differences in the street layout, spatial form and degrees of integration of two traditional villages in Fuzhou, Qinjiang Village and Dinghai Village, with their new extensions are analyzed and compared. As it turned out that, firstly, T-intersections are better than X-intersections in terms of wind resisting. Secondly, the larger block enclosure the better overall wind protection are. Thirdly, the appropriate-sized open space can introduce fresh air. Furthermore, through the simulation of street integration and connection value, it also found that compared with the new villages, street integrations in the center of the old villages are higher, and the integration from the center to the surrounding side streets decreases more slowly, and its connection value is higher, which can create different paths for the wind flow. By comparing the street spatial characteristics between the old and new coastal villages had shed some light in our understanding of the wind adaptation of streets and alleys in traditional coastal villages, with a view to provide technical supports for the protection and renewal of traditional villages, as well as aiding the construction of a marine cultural with Chinese characteristics in the New Era.

Keywords: traditional coastal village, comparison of new and old villages, wind resistance, street space, CFD simulation.

1 Introduction

As a major cultural heritage province, Fujian Province has 552 traditional villages, ranking sixth in China. Due to geographical and climatic factors, Fuzhou City is a key

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defense area for marine meteorological disasters[1]. Despite facing multiple disasters, these villages have managed to remain intact. Currently, research on traditional dwellings mainly focuses on the inheritance and development of spatial features and kernel values, but the impact of the overall street layout of villages and towns on the wind environment is under-discussed. The study adopts the simulation method of CFD digital technology to compare the street and alley layout of old and new villages in Dinghai Village and Qinjiang Village in Fuzhou City. This study contributes to an in-depth understanding of the design wisdom of traditional villages, with a view to providing new ideas for the protection and utilization of traditional villages, as well as for the design of new villages in terms of wind suitability and wind resistance.

2 Literature Review

Wind environment, i.e. meteorological elements such as airflow, air pressure distribution and temperature and humidity conditions inside and outside buildings. As early as in the 1970s, wind environment research were conducted for buildings in the city[1-2], while China's wind environment planning started at the beginning of this century. Among the marine meteorological disasters, in terms of disaster frequency and severity, the wind disaster represented by typhoon is one of the very noteworthy parts. China's southeastern coastal provinces have always been the hardest hit by typhoons, of which Fujian Province is located in the main path of typhoon movement in the northwest Pacific Ocean, with a long coastline and a developed coastal economic zone, which is subjected to more serious marine meteorological disasters every year. Only from 2011 to 2020, the area affected by marine meteorological disasters in aquaculture in Fujian Province is 17. 59×104hm2.[3] Therefore, Fujian Province is representative of many southeastern coastal provinces. The windy weather in the coastal area often brings serious damage to the production and life and buildings, so its building wind environment adaptation has a great impact on the form of residential houses[4].

The history of traditional coastal villages in China can be traced back to the Hongwu period of the Ming Dynasty[5], and the reconstruction and enhancement of sea defenses during the anti-Japanese wars, and the gradual establishment of the military-tuenant sea defense system of "both soldiers and farmers" have resulted in a close relationship between sea defenses and coastal communities[6]. In the economically developed southeastern coastal areas, they often gradually evolved into comprehensive cities[7], while in Fujian and Jiaodong, they were mostly transformed into coastal defense guard settlements. These traditional villages not only remain relatively well-preserved after various types of marine meteorological disasters, but also show better wind-environmental adaptability in contrast to the new villages built next to these traditional villages and planned in the process of urbanization.

Compared with the traditional coastal defense villages in Jiaodong and other places, Fujian's traditional coastal defense villages are special in that there are both coastal defense settlements transformed from military-planned guardhouses and ordinary traditional villages formed spontaneously due to topography and other factors[8]: the former was formed by the gradual civilianization of the Ming military bases, which means that, on the basis of retaining military facilities such as the city walls, the traditional settlement elements such as dwellings, temples were added. The internal transportation system of the settlements is reasonably laid out, which can meet the demand for efficient defense support during wartime as well as the daily life of the military and civilians[9]; the latter are ordinary traditional settlements that underwent village-level defense transformation after being invaded by Japanese invaders, with the most important feature being the construction of walls on the basis of the original villages, and the addition of space for alley warfare on the basis of the original streets and lanes. These two types of traditional sea defense villages are quite different in terms of street structure and spatial pattern, which provide excellent samples for comparing the wind environment adaptation research in the same period.

3 Research Methods

3.1 Case selection

In this paper, Dinghai Village and Qinjiang Village in Fuzhou City, Fujian Province are selected as research cases. Qinjiang Village, which was selected as one of the first batch of Chinese traditional villages in 2012, is located on the north bank of the Minjiang River. In the sixth year of the Yongzheng reign of the Qing Dynasty, soldiers and officers with their families were stationed here. The village now covers an area of 120 hectares, surrounded by factories and close to the estuary of the Min River. The new part of the village is located on the northwest side, closer to the sea.

Dinghai Village is a fishing town in Lianjiang County and a famous historical and cultural village in Fujian Province. During the Hongwu period of the Ming Dynasty, a castle and Xiaocheng water fortress were set up to prevent Japanese invasion, which was one of the five largest water fortresses in the province. By 2000, Dinghai Village had a total area of 3.2 square kilometers, with 1,779 households and 7,720 people.

Both villages are officially recognized as traditional villages and are therefore representative of all coastal villages. Meanwhile, although Qinjiang Village and Dinghai Village belong to coastal defense post settlement and defense strengthening village respectively, they are similar in attributes, and some redundant variables can be excluded in the comparison test. For example, in terms of village structure, both villages have new villages attached to additions to the old village, so the two villages have a similar compositional structure.In terms of geographic environment, the two villages are located in the same prefecture-level city and adjacent to the same sea, so the two villages are similar in terms of the geographic environment of the response to the windstorm. Therefore, the above two villages are selected as the objects of comparative experiments in this paper.

3.2 Data sources

The study extracted epw files of meteorological data for Fuzhou city for 8760 hours of the year from the China Standard Weather Database (CSWD) using ladybug software. The traditional CFD simulation method of obtaining wind environment data cannot achieve hourly level accuracy. And ladybug provides higher precision data by linking to CSWD, and can filter and visualize the meteorological data. Meanwhile, more accurate simulation results were obtained by quickly importing Google Earth images through the CAD to Earth plug-in and generating an accurate base city model from openstreetmap.org. According to the range of calculation area recommended by AIJ of Japan Architectural Association, the horizontal boundary of this simulation is the horizontal range with radius greater than 5H centered on the target building, and the calculation area above is greater than 3H. Since both villages are close to the river and the sea, the value of 0.1 recommended by AIJ for software simulation and analysis is selected for the selection of the ground roughness.[10]. Grid setup is considered for the computational accuracy and stability. The number of external range grids is reduced and the internal is increased to ensure the overall grid size is consistent. The selection of its parameters is mainly based on the type of the surrounding ground, so that the parameters of the same type of area are selected consistently, and the variability is determined by the different areas of wind direction and wind speed.

4 Simulation results

Before carrying out the analysis, the scope of the newly built village in the 1980s was obtained by comparing the maps of the Qing Dynasty with the present satellite maps, which shows that the overall layout within the old village has not changed much compared to the Qing Dynasty, and the additions are mainly in the west and north sides, with a similar overall spatial layout, as shown in Fig. 1.

Fig. 1. Scope of Old and New Village of Qinjiang Village (left) and Scope of Old and New Village of Dinghai Village (right) (Self-drawn by the author)

4.1 Impact of street layout on wind environment

The results of their wind environment simulation are obtained as shown in Fig. 2:

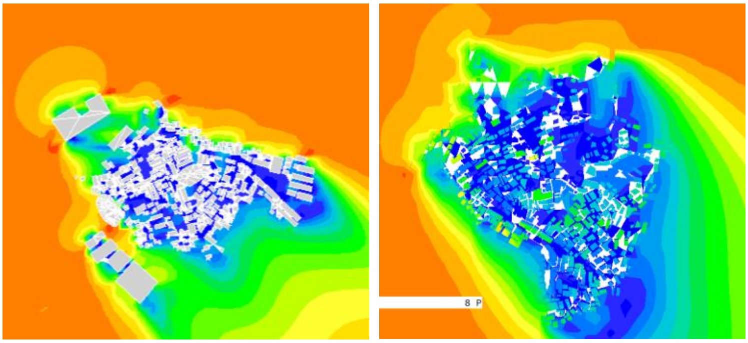

Fig. 2. Wind environment simulation results of Qinjiang Village (left) and Dinghai Village (right) (Self-drawn by the author)

By comparing the street layout and wind resistance of the new and old villages of the two villages, the impact of three different layouts adopted by the new and old villages on wind resistance is proposed:

(1) Difference in wind speed between D-intersections and cross-intersections: By observing the satellite map and combining it with real photographs, it is found that cross-intersections are more prevalent in the new village of Qinjiang village, while D-intersections are prevalent in the old village due to the need for alley warfare in the initial layout. The main street network in the new village of Dinghai Village is a square grid, so most of the intersections are crossroads, while the main roads in the old village are spread out in the form of D-roads. Therefore, three control groups are selected in the new and old villages of Qinjiang and Dinghai villages respectively, and the results of simulated wind speed are compared to explore the influence of their street space on the wind environment, as shown in Figure 3.

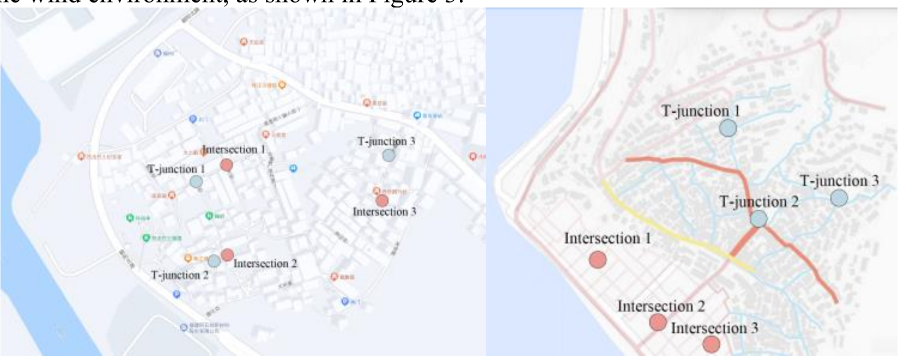

Fig. 3. Control group of Dingzhi and crossroads between Qinjiang Village (left) and Dinghai Village (right) (Self-drawn by the author)

Corresponding the selected control points with the actual simulation results, the differences in wind speeds at the crossroads and dingzhi intersections between the new and old villages of Qinjiang and Dinghai villages were obtained as follows, as shown in Table 1:

Table 1. Comparison of wind speeds at the intersection of Qinjiang Village and Dinghai Village with that at the intersection of Dinghai Village

Qinjiang	Crossroads wind speed	T-junction wind speed
Group 1	0.08-0.16m/s	0.00-0.08m/s
Group 2	0.16-0.24m/s	0.00-0.16m/s
Group 3	0.08-0.16m/s	0.00-0.08m/s
Dinghai	Crossroads wind speed	T-junction wind speed
Group 1	0.23-0.31m/s	0.00-0.08m/s
Group 2	0.16-0.23m/s	0.08-0.16m/s
Group 3	0.23-0.31m/s	0.16-0.23m/s

A comparison of the wind speed data for the new and old Village intersections with the D-intersections reveals that wind speeds are typically greater at the intersections than at the D-intersections. Thoroughfare intersections reduce wind speeds more significantly, helping to minimize the adverse impacts of severe wind conditions on the interior of the street. This is primarily due to the selective wind direction at thong intersections and the single direction of the entrance wind, which helps to disperse high winds and airflow at the intersection.

(2)Collective plazas can effectively increase ventilation and improve the entry of fresh air in the village. As shown in Figure 4, two to three plazas were introduced in Qinjiang and Dinghai villages, and the following table was formed by extracting the wind environment simulation values of the plazas, as shown in Table 2:

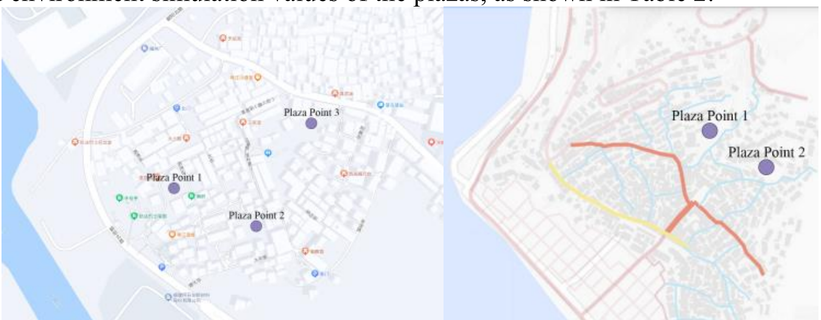

Fig. 4. Selection of distribution plaza measurement points in Qinjiang Village (left) and Dinghai Village (right) (Self-drawn by the author)

Table 2. Wind speed in the center and around the distribution plaza of Qinjiang and Dinghai

Qinjiang village group	Wind speed at the center of the measurement point	Wind speed around the measurement point
Group 1	0.08-0.16m/s	0.00-0.08m/s
Group 2	0.16-0.24m/s	0.08-0.16m/s
Group 3	0.24-0.32m/s	0.08-0.16m/s
Dinghai Village group	Wind speed at the center of the measurement point	Wind speed around the measurement point
Group 1	0.08-0.16m/s	0.00-0.08m/s
Group 2	0.16-0.24m/s	0.08-0.16m/s

According to the data in the above table, the wind speed of the distribution plaza has a more significant increase compared with its surrounding wind speed, which can effectively introduce a certain amount of fresh air in a more closed street environment. At the same time, considering that more residents usually move around here, it can also create a better environment for activities.

(3)The larger the block enclosed by the village, the smaller its wind speed, selected two old village roads enclosed within the block as a measurement point, as shown in Figure 5; through the comparison of different sizes of blocks within the two villages can be seen, due to the street enclosed by more buildings within the block, so that its overall wind speed is slower, the existence of a greater number of winds are difficult to enter the region, which can be effective in strengthening its resistance to the wind, as shown in Table 3.

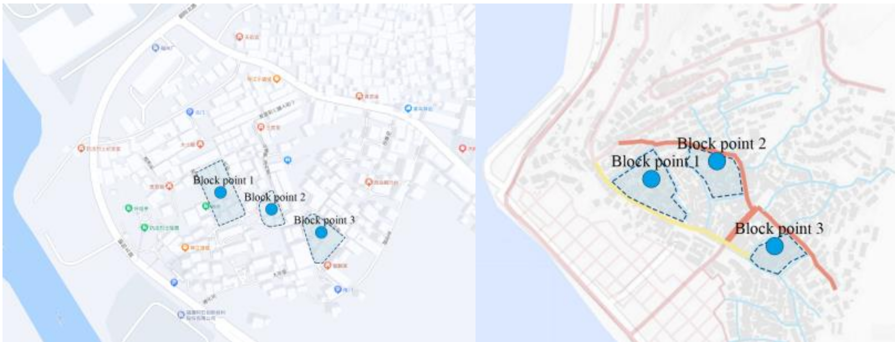

Fig. 5. Selection of measurement points for the blocks of Qinjiang Village (left) and Dinghai Village (right) (Self-drawn by the author)

Table 3. Wind speed of selected blocks in Qinjiang and Dinghai villages

Block Grouping	Wind speed of Qinjiang village block	Wind speed in Dinghai Village block
Group 1	0.08-0.16m/s	0.08-0.16m/s
Group 2	0.16-0.24m/s	0.32-0.40m/s
Group 3	0.08-0.16m/s	0.08-0.16m/s

4.2 Comparison of Street Integration and Connection Values

Simulating the street integration of the two villages with a depth map (Fig. 6), the closer the street color is to red, the higher the integration: it is evident that there is a large difference in the integration between the new and old, with the new village of Qinjiang having a relatively low level of street integration, while the integration of the old village is high. For the old village of Qinjiang Village, the main axis in the center of the village, which is mainly responsible for religious ceremonial activities , and the overall degree of integration is higher. In Dinghai Village, its new village has a lower degree of street integration due to an extremely simple road network based on a grid pattern of squares; while the old village has a higher degree of integration due to wind defense considerations, resulting in more feeder roads and complex roads. However, as both two Villages are connected to the new and the old by a single road, the degree of integration of their connecting roads will be correspondingly higher.

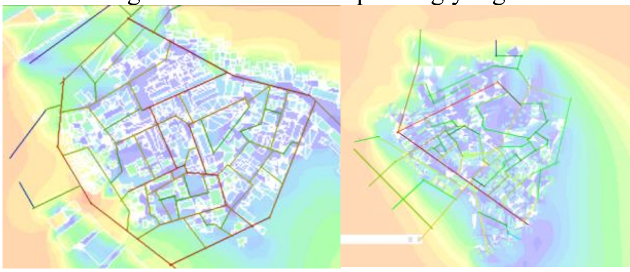

Fig. 6. Comparison of Global Integration between Qinjiang (left) and Dinghai (right) (Self-drawn by the author)

Meanwhile, the degree of integration of internal streets in old villages is better than that in new villages. The old villages of Qinjiang Village and Dinghai Village have good street consistency, tight building layout, high spatial integration of the center street, and slower decrease in integration from the center to the peripheral branch roads; whereas the new villages have a single road structure, and faster decrease in integration from the center to the peripheral branch roads. The wind resistance of the old village is stronger than that of the new village, because of the strong integration of its road network structure, and a variety of branch roads are connected to the main road, providing a variety of options for evacuation paths for the wind.

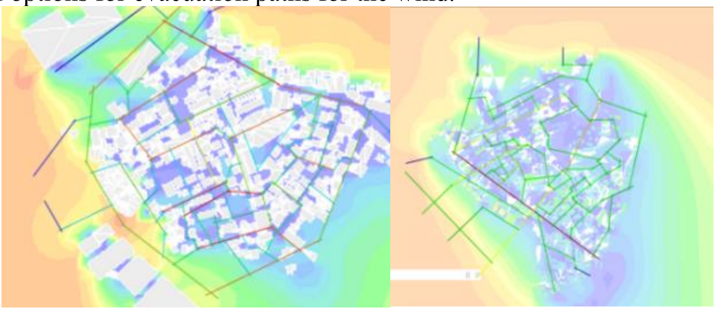

Fig. 7. Comparison of connection values between Qinyang (left) and Dinghai (right) (Self-drawn by the author)

Accessibility between streets can be assessed by and comparing connectivity values, as shown in Fig. 7. The redder the color of the axis, the higher the connectivity value, the more alternative paths are available and the higher the accessibility and permeability.

Comparing the old and new villages of Qinjiang and Dinghai, it can be found that the connectivity value of the main axes inside the new village is higher, which satisfies the need for penetration; the external additional part has a lower connectivity value due to its proximity to the traffic arteries, which are mainly used by residents. The ancient village has a high overall connectivity value due to the complex road network.

Based on the above analysis, the wind resistance of the village can be strengthened by appropriately increasing the building density of the village and providing more dinky intersections between streets and lanes. In the construction of new coastal villages, the combination of additional thong intersections, enlarged block areas and open squares can be used to improve wind resistance. For the regional differences of different villages, it can be reflected in the composition of the street elements and the windproof elements of the arrangement of the density of species.

5 Conclusion

This paper compares the wind environment of the old and new villages of Qinjiang Village and Dinghai Village in Fuzhou City by computer simulation. Furthermore, it combines the spatial syntax to study the relationship between the spatial morphology of the villages and the wind environment as a whole. The research conclusions are as follows:

①. With other conditions controlled, T intersections seem to reduce the wind speed to a greater extent compared to X intersections, which can effectively reduce the negative impacts of excessive wind speed in the street in hush wind environments;

②. Traditional villages utilize residents' activity squares interspersed between streets and lanes to ensure smooth ventilation inside the village. Placing the squares appropriately can speed up the air flow and improve the ventilation efficiency;

③. The complexity of road network, the building density and the degree of enclosure around the streets also have great impacts on the village wind environment. Complex roads enclose larger blocks with a greater building density can reduce the air flow into the block, which could reduce the negative impact of wind environment on residents' daily lives;

④. The fish bone structure of the traditional villages with main roads connected to a variety of village roads can effectively spread the wind flows more effectively, compared to the grid road structure of new villages.

The traditional coastal villages have condensed the wisdom of the ancients, which require not only protection, but also in-depth research on their adaptive climate design in the local environment. This study of the relationship between street space and wind environment in traditional villages has put forward the above conclusions with a view to provide references and lessons for better environmental adaptative planning and design.

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