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Improvement of physical environment of seaweed house

Recently, because of villagers' production and life style have changed, the physical environment such as ventilation, lighting and insulation of traditional seaweed house in Jiaodong peninsula cannot meet their current needs, the work for improvement in building physical environment appears to be particularly urgent. This study is based on the method of pre-investigation, field-test and post-simulation as well as analytical skills by software of "ECOTECT" and "PHOENICS". Through the housing usage analysis, field test analysis and data simulation analysis, the experimental results are summarized as follows: Firstly, open 600mm×600mm high window in each bedroom, secondly, optimize the materials of doors and windows, thirdly, bedroom is transformed into the kitchenand lastly, install ventilators in kitchen and toilet. The results of this work will provide technical guidance for the improvement in traditional seaweed houses' living environment in Jiaodong peninsula.

Keywords: Seaweed house, physical environment, testing and simulation

1. Introduction

Seaweed house is a beautiful traditional architecture that distributes in coastal areas of Jiaodong peninsula, most of them are located in the eastern part, and merely existing 20,000 rooms now. The summer here is wet and humid and the winter here is snowy and cold. Seaweed house is a characteristic local architecture that forms in accordance with this harsh environment completely[1]. At present, villagers' traditional production and life style such as work from dawn to dusk have changed which leads most adolescents to migrate to cities to work and leave the elderly (low-outgoing rate) at home behind. Therefore, the usage time and frequency of traditional seaweed house has increased. These changes are enlarging the shortcomings of its lighting and ventilation capacity because of its inborn thickness structure. These buildings are hardly meeting the elderly needs in daytime life. Moreover, due to traditional building heating methods, its east-bedroom was mixed usage with kitchen in the past 200 years. Today, modern heating methods have replaced conventional ways, and this untidy layout can be transformed. In the summary, improving seaweed house's capacity of lighting, ventilation and insulation are central issues in this study.

Relevant researches have been conducted on seaweed house's ecological materials, characteristic features and traditional protection[1,2], and there are still no observations at present about its physical environment improved. There exists many related studies on improving of traditional architecture in physical environment, which can be summed up in three categories. The first type is 'test + simulation', such as Hafez evaluated and optimized traditional architecture physical environment by BIM-based quantitative simulation technology that simulated the building wind, humidity, thermal and light environment[3]. However, during the improvement of the seaweed house, arbitrary quantification, evaluation and transformation may destroy its traditional forms and structural features. The second type is 'investigate + test'. For instance, Liu Xinxiong put forward the traditional architectural design strategy after detailed investigation, and then combined with the field test to propose renovation proposals[4]. This method avoids the arbitrary measures for improvement, but lack of simulation and post evaluation that hardly shows the effectiveness. The last type is 'survey + simulation'. Tohid first analyzed building's regional adaptability and made renovation suggestions, then made post evaluation[5]. Nonetheless it would be more convincing if it included a comparison test. Research requires further conduct investigation, test and simulation at the same time.

This paper formed a targeted method for improvement of seaweed house's physical environment. It is based on the method of pre-investigation, field-test and post-simulation as well as analytical skills by using software 'ECOTECT' and 'PHOENICS' to simulate physical environment of traditional seaweed house. By this method, seaweed house's physical environment can be improved, and maintaining its traditional structure and style at the same time.

2. Methods and materials

2.1 Research methods

As illustrated in Fig. 1, the research first investigated seaweed house's service condition and regional environment adaptability, then test and evaluated the physical environment

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optimization capability by traditional construction techniques. Finally, on the basis of maintaining the traditional structure and style, this study improved the physical environment by the simulation technique.

The ways of pre-investigation include interviews, field surveys and literature surveys. The research through interviews with local villagers can obtain specific information of their production mode, lifestyle and inhabit time. Furthermore, analysis and get the seaweed house's using time and using interval, which can also provide support for further research. Through field surveys and literature surveys, this study summarized the physical environment optimization capability that seaweed house was traditional from the begining.

The types of field-test include testing seaweed house's wind environment, humidity environment, thermal environment and light environment. The purpose of these tests is to analyze building's regional environment adaptation techniques, moreover to determine the extent of building transformation. Field-test can also offer reliable data for environment simulation.

The physical environment analytical means of post-simulation mainly use software 'ECOTECT' and 'PHOENICS'. Through simulation and analysis, the study put forward renovation proposals on the basis of traditional structure and style.

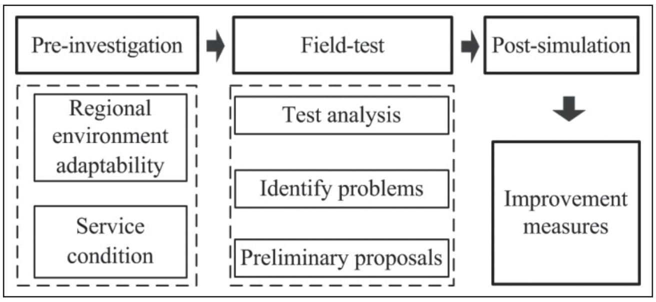

Fig. 1: Technical roadmap

2.2 Data Sources

The current investigation involved sampling and analyzing ten villages, the sites were selected from the Lidao town, Ningjin town and Dongshan town, which had a large number of long history, well-preserved and representative seaweed houses. Through interviews with village chiefs and five villagers that were randomly selected, researcher could obtain the information of migrant work composition, aged population, industrial composition, income structure, inhabit time and environment quality.

Seaweed houses are little different in different areas for historical reasons. The sample for the field test was a seaweed house that located in Jingjiaogang village, Lidao town. In this study, temperature and humidity were continuously measured by thermo-hygrometer for 24 hours in room 2, room 4 and courtyard; illumination was measured

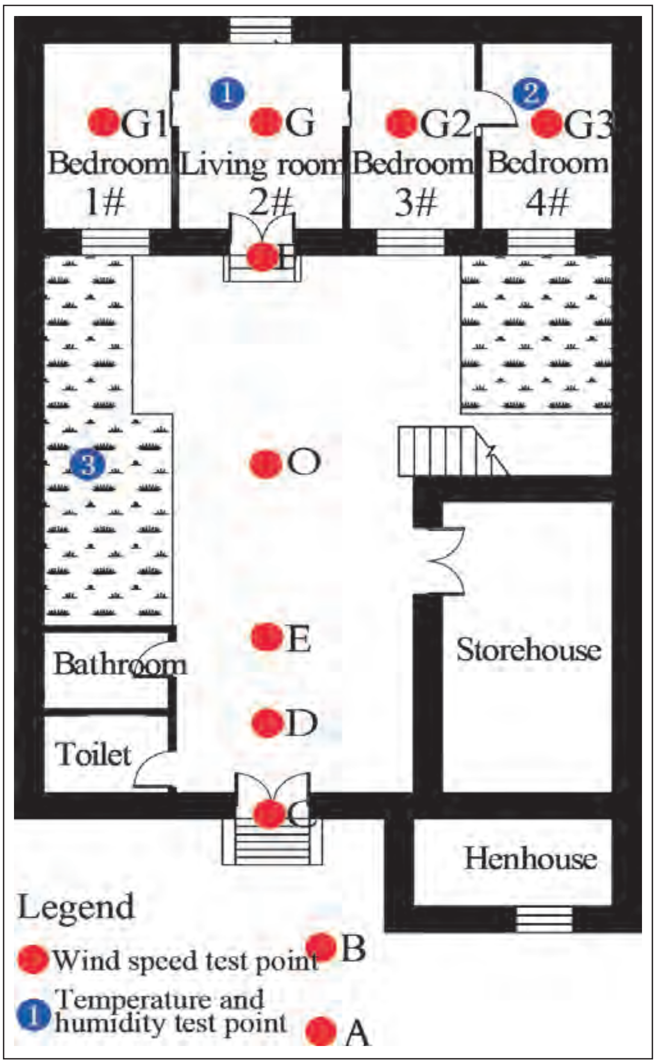

Fig. 2: Test point distribution

by illuminometer for several times in room 1, room 3 and room 4; wind speed was measured by anemometer for six times within two periods in village periphery, main streets, entrance street, courtyard and indoor. Point A and B are located in the entrance street, point O is located in the courtyard, point G, G1, G2, G3 are located in the main room,as shown in Fig. 2.

In this study, through the method of mathematical statistics, chart analysis could determine the preliminary proposals for improvement. And then through simulation and analysis by software ECOTECT and PHOENICS, chart analysis could determine the final means of transformation. It should be completed from three aspects: housing usage analysis, field test analysis and data simulation analysis.

3. Results and discussion

3.1. Usage analysis of seaweed house

By statistical analysis of the interviews of each region, Table 1 shows the local residents'production methods and life style as well as usage of seaweed house. The interviews also concluded 53.2% of villagers are dissatisfied with the current dwellings' lighting and ventilation environment, and 70.2% of villagers prefer to choose a new type of residential house that is with better living condition. Through pre-investigation, it could be concluded that seaweed house is a habitat for daily life of more than traditional residence for bedtime nowadays. Because elderly population increased, seaweed house was required to have better lighting and ventilation environment. Furthermore, it should be more tidy and neat.

3.2. Field test and analysis of seaweed house

Combed through the relevant literature, seaweed house has good regional adaptability against strong sea wind, wet environment, cold climate and intense radiation[1-2,6]. In this study, field test is based on previous studies, and proposes preliminary proposals for improvement through quantitive analysis of its environmental adaptability.

(1) Against strong sea wind environment

Seaweed houses have compact layout, and its gables combine with each other. The angle between building groups and summer leading wind direction is 60° which is beneficial to ventilation. Building groups are also vertical with the winter leading wind and the howling winter winds can be stopped effectively by the lofty roofs. Building structure is shown in Fig 3. The wind speed test result is village periphery > main streets > entrance street > courtyard > indoor when under 6-7 levels of the south wind, as shown in Fig. 4. Seaweed house settlement can reduce strong sea wind effectively, and its layout should not be reformed despite weak indoor ventilation.

(2) Against wet environment

Suitable roof slope is between 50° and 60°, and seaweed roof drainage is efficient in summer, and it hardly accumulates snow in winter. Moreover, it is conducive to absorb moisture. In addition, the thick wall has low permeability and high moisture proof property. In the field test, indoor humidity index fluctuation is prone to be stable and suitable, even though outdoor humidity is ranged from 10% to 100%, as shown in Fig. 5. It could be concluded that seaweed house can be built against local wet environment effectively, and maintenance structure is not suitable for large-scale transformation.

(3) Against cold climate

Benefited from rational layout, small shape, regular form, thick structure and controlled window-wall ratio can effectively reduce house heat loss. In the field test, the outdoor temperature is range from 11° to 33°, but stable at 18° to 23° indoor, as shown in Fig. 6. Seaweed house has good insulation ability, and its general form should not be large-scale transformation.

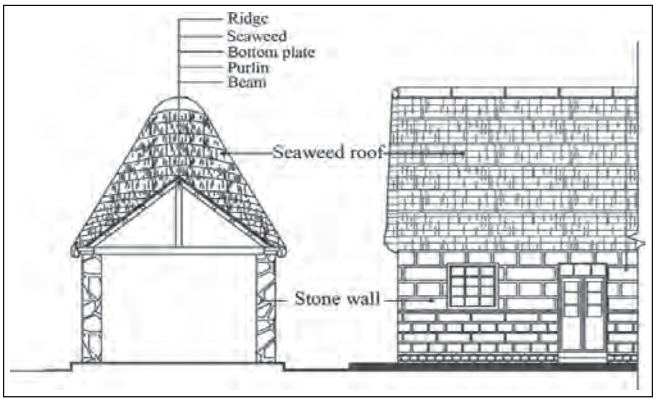

Fig. 3: Elevation and profileof seaweed house

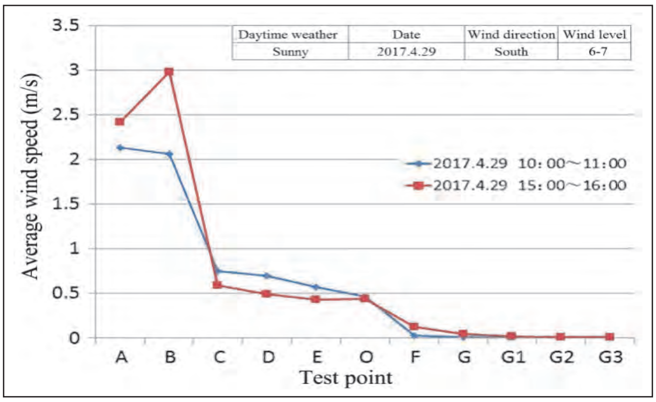

Fig. 4: Wind speed of test point

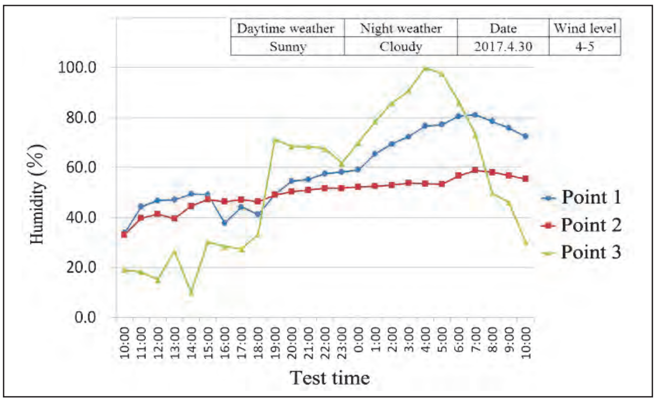

Fig. 5: Humidity of test point

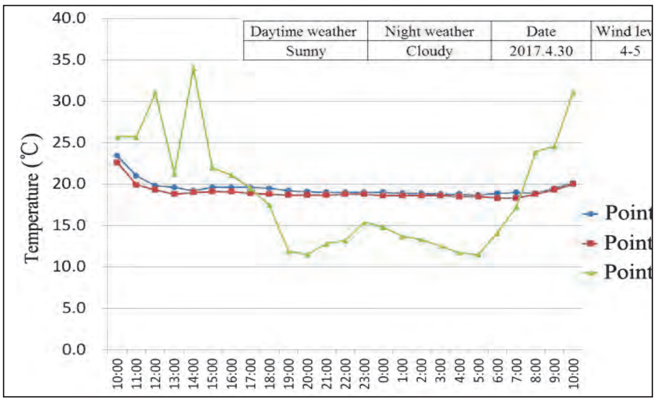

Fig. 6: Temperature of test point

(4) Against intense radiation

Benefited from lofty roof of seaweed house, thick wall and compact layout, summer radiation can be obstructed effectively and leave large shadow behind. As can be seen from Table 2, building has weak indoor illumination in spite of good anti solar radiation ability. Heating slows down in daytime and keeping the indoor environment cool successively is the original design for seaweed house, nevertheless, it hardly meets the lighting demand currently in daytime. Its wall needs to be reformed partly.

By field-test, seaweed house has good regional adaptability, nevertheless, it has weak capacity of lighting and ventilation. The walls should open windows with small size but it can not destroy overall layout, structure and form. Preliminary proposals for improvement are as follows.

(1) Intend to open 600mm×600mm high window in the north part of each bedroom.

(2) In order to reduce heat loss caused by opening windows, the research may optimize the materials of door and windows.

(3) The function mixed with east-bedroom is intended to reform to simple kitchen and aisle.

3.3. Simulation and analysis of seaweed house

Through simulation and analysis the preliminary improvement proposals, the result is as follows:

(1) Simulation and analysis of light environment

Lighting environment simulation is based on outdoor illumination of actual cloudy weather (7500LX). It can be seen from the picture in Fig. 7, the result of illumination simulation is basically consistent with the previous field test. Make new simulation when the wall openes three 600mm×600mm high windows. The result is shown in the picture below.When compared to the formerly building lighting diagram, lighting environment has been remarkably improved. Lighting has been well-distributed in each bedroom. Villagers' internal activity was less affected even though the marginal area still has relatively weak lighting. The improvement basically meets the optimization requirements.

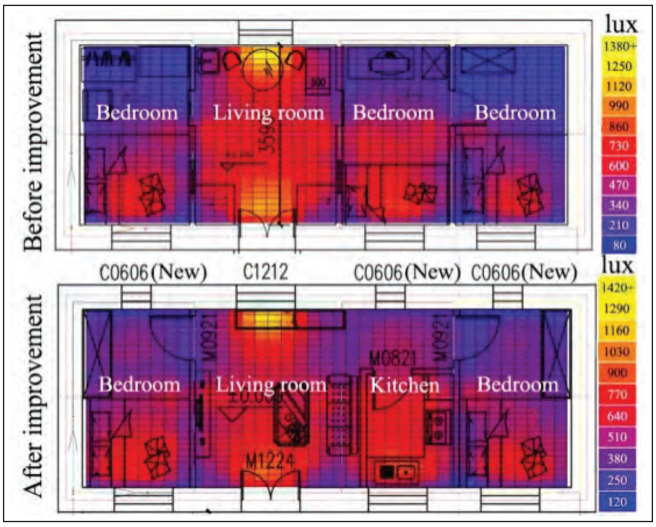

Fig. 7: Light simulation result

(2) Simulation and analysis of thermal environment

In order to reduce heat loss, the materials of doors and windows are replaced by double glass aluminum-plastic frame. Thermal environment simulation indicates that the altered has a higher ability of heat gain (208WH) than before (127WH). Fig. 8 shows the temperature fluctuation of living room and bedroom has been staying within the body's comfortable range, although heat conduction slightly

Table 1. Basic situation of investigation area

Investigation area	Migrant workers proportion	Elderly population proportion	Industrial composition	Income composition	Usage time
Lidao town	29.7%	37.5%	Agricultural sidelines and fisheries	Primary industry 27.8% Secondary industry 64.4% Tertiary industry 7.8%	15-18h (All-day use)
Ningjin town	25.4%	35.1%	Agricultural sidelines, tourism and fisheries	Primary industry 17.2% Secondary industry 59.6% Tertiary industry 23.2%	15-20h (All-day use)
Dongshan town	30.1%	37.4%	Agricultural sidelines and fisheries	Primary industry 33.2% Secondary industry 62.4% Tertiary industry 4.4%	15-18h (All-day use)

Table 2. Illuminance test of seaweed house (unit LX)

	Test time	Northeast corner	Southeast corner	Southwest corner	Northwest corner	Midpoint	Front window	Back window	Side window	Gate
Bedroom 1#	15:00-16:00	33	62.9	53.8	23	486	1905			
Living- room 2#	15:00-16:00	108	126	129	130	365		707		2180
Bedroom 3#	15:00-16:00	60	80	121	62	381	2890		318	
Bedroom 4#	15:00-16:00	40	39.6	36.7	28	206	2530			

increased. Accordingly, the improvement will not only maintain the traditional structure but also meet the needs of residents.

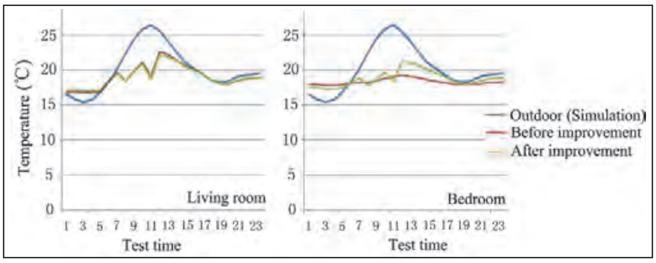

Fig. 8: Temperature simulation result of main room

Extra simulation is needed to base on Big Chill environment that outdoor temperature is between 0 ~ -10°C[7], as the building is located in cold areas. The simulation result shows that the heat loss has been slightly reduced. It could be speculated that building thermal insulation performance still has a slight increase. Seaweed house still needs indoor artificial heating, despite indoor temperature slightly has been increased after transformation.

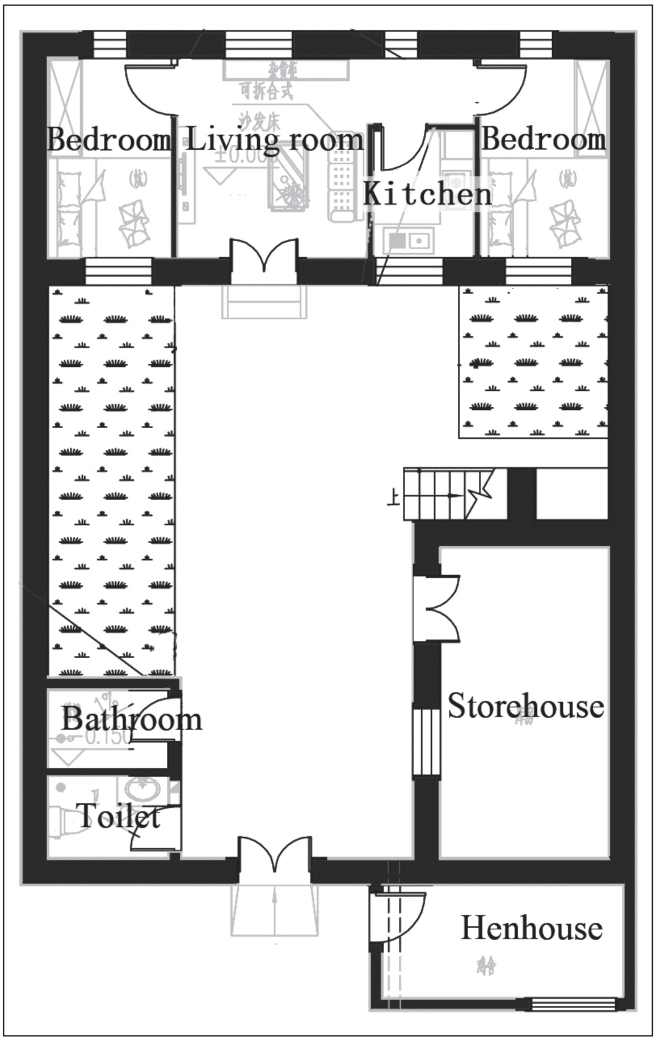

Fig. 9: Reformed layout

Fig. 9 illustrates the reformed indoor layout. In order to keep clean space apart from untidy space, east-bedroom can be reformed to independent kitchen and aisle under the current situation of descendant users. Moreover, living room is bigger than before and more convenient for modern life. Thermal environment simulation is based on 2 users and 15 hours use time. Heat gain of traditional seaweed house is 5.65W/m^2 which is mainly provided by stoves[8]. However,as Table 3 shows, the heat gain after reformed is 4.95W/m^2, which is slightly less than before[9]. Modern kitchen will weaken building heating capacity, but it can be also offset by modern electrical heater.

Table 3. Heat dissipation of different heat source in seaweed house

Heat source	Heat dissipation (kWh)	Total (kWh)	Covered area (m^2)	Heat gain of Building (W/m^2)
Human body	2.10	4.99	42	4.95
Household appliances	1.84			
Lighting lamps	1.05			

(3) Simulation and analysis of wind environment

Indoor draughts may be promoted after improvement. The new indoor wind environment needs to be simulated which is based on the average wind velocities in yard. As can be seen from Fig. 10, wind speed indoor is range from 0.3m/s to 0.4m/s in the case of opening the window. The consequences of altered basically meet the national indoor ventilation standard, although there is no evident promotion. The result can be attributed to the traditional compact layout of seaweed house. In order to improve the wind environment obviously, ventilators could be installed in kitchen and toilet, and moreover ventilation of the courtyard should be improved by planting.

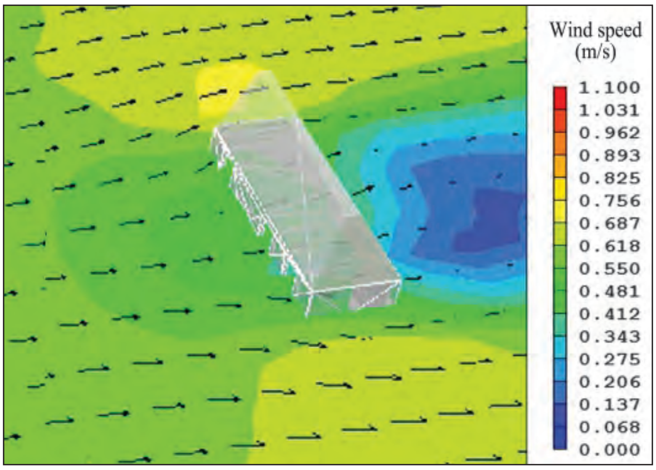

Fig. 10: Wind simulation result

(4) Final proposals of seaweed house improvement

As discussed previously, in order to improve physical environment which is based on traditional style as well as original layout, final proposals for improvement are as follows.

(1) Open 600mm×600mm high window in the north part of each bedroom, where frames colour is advised for warm yellow and grey that is uniformed with the style of exterior wall.

(2) The window could be equipped with a warm colour shutter or curtain which can be actively adjusted for the demands of aeration, lighting and anti solar radiation.

(3) The former east-bedroom could be reformed to simple kitchen and aisle, which would have larger living room as well as tidy and clean space.

(4) Install ventilators in kitchen and toilet for improvement of indoor ventilation. Furthermore, improve courtyard greening at the same time.

4. Conclusions

This study demonstrated that when it improved physical environment of seaweed house which is located in adverse natural conditions as well as unique regional and traditional features, the method should not only be based on regional adaptation technology but also coordinate the relationship between human, architecture and environment. Traditional architecture should meet the needs of modern residents by optimizing the physical environment of building. In conclusions, from the research, it can be stated as follows.

(1) Compared to past mode of production which was based on fisheries, agricultural sidelines and tourism become the dominant nowadays. New mode of production asks for house daytime used and longer use time (15-20h).

(2) Benefit from the unique spatial layout, maintenance structure and architectural form, seaweed house has ability to fight against harsh environment and provide a suitable indoor environment of temperature and humidity.

(3) According to the results of analysis and simulation, the proposals for improvement about light environment, thermal environment and wind environment have a good effect and universality.

The research is currently limited to the seaweed house with the main function of living. However, some of these traditional architectures have been derived new functions for leisure travel owing to its long history, beautiful shape and characteristic features. The change of building function demands more varieties and higher standards of physical environment. It is expected that further study of these types of seaweed house will be carried out.

Acknowledgements

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