Integrated Design Research on Function aNanyangnd Performance Improvement of Stone and Wood Residential Buildings in South Henan Province Based on Green Building Performance Analysis—A Case Study of Shek Wo Heng Village in Nanyang City

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Abstract. Under the influence of the modern tourism development trend, an analysis is conducted on the acoustic, lighting, and thermal structural performance factors of stone and wood residences in southern Henan Province, based on the sustainable design principles of green buildings. Based on the data results, the integrated design strategy aims to enhance the function of stone and wood residential buildings and improve the performance of external enclosure structures in southern Henan through ecological green technology and energy-saving low-carbon methods. Through design interventions, the functionality of the original residence and the performance of the external enclosure structure will be enhanced. Subsequently, an integrated design approach will be employed to develop a comprehensive design strategy. Through analysis and verification, the lighting, energy efficiency, wind environment, indoor thermal conditions, and other indicators of residential buildings in the village have been enhanced. The integrated design strategy is practical and innovative in guiding the renovation of stone and wood residential settlements. It enhances the life experience and comfort of both villagers and tourists. It can be used as a reference to promote the high-quality development of rural tourism in southern Henan.

Keywords: Green building performance ;Southern Henan ;Stone and wood dwellings ;Integrated design.

1 Introduction

In recent years, rural tourism in China has entered the fast lane of development. The integration of agriculture and tourism is the prevailing trend in agricultural and rural development [1]. According to the data [2], among the factors influencing rural tourism, the "comfortable natural environment" and "distinctive folk culture" are the two main considerations for Chinese rural tourism users. The percentages were 65.5% and 56.7%, respectively. In the process of rapid development of rural tourism, the traditional stone

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houses in the mountain villages of southern Henan have become famous for their unique ancient style. On the one hand, the geographical environment is relatively isolated, and the economic foundation is weak. The original style of the traditional stone houses in southern Henan is highly appealing, offering clear advantages for the advancement of rural tourism. On the other hand, the contradiction between the function, spatial layout, facilities, and modern rural tourism is becoming increasingly prominent as the main body of the settlement. Obviously, to minimize the damage to the village ecological environment is the decisive condition for the development of tourism industry of stone and wood dwellings in southern Henan.

With the global spread of the concept of sustainable development, the protection of the ecological environment and the establishment of ecological civilization have become fundamental principles guiding tourism activities in various countries [3]. Therefore, in light of the impact of modern tourism development trends, it is highly significant to optimize the function and performance of stone and wood dwellings in southern Henan by relying on the sustainable design theory of green buildings.

Currently, the academic community in our country has conducted extensive and in-depth research on the renovation of various types of traditional houses, such as stone and wood houses. The existing research results mainly focus on two aspects [4], one aspect is functional renewal, which emphasizes the functional replacement of residential spaces, reorganization of space, and improvements in kitchen and bathroom functions. The other aspect is performance improvement, which focuses on investigating and analyzing technology and equipment levels. However, research on how to coordinate energy-saving renovation designs with traditional styles is rarely addressed. At the same time, research on the microclimatic environment and its improvement at the settlement level is also lacking [5] [6]. To sum up, although the existing research results are rich, they are more focused on functional improvement or thermal performance enhancement, and the integration of the two is insufficient [7]. Based on the above analysis, the article takes the integrated design strategy of integrated thinking as the breakthrough point. Through analysis and verification, the interaction between functional renewal and performance improvement demand of stone and wood dwellings is comprehensively considered, so as to solve the current situation of functional performance research separation in stone and wood dwellings renewal. Strive to realize the complementary advantages of the two.

Shek Wo Keng Village was listed in the fifth batch of Chinese traditional villages in 2019 and was awarded the title of "China's Beautiful Leisure Village" by the Ministry of Agriculture and Rural Areas of the People's Republic of China. In 2020, it was designated as the "National Key Village of Rural Tourism" by the Ministry of Culture and Tourism of the People's Republic of China. Based on this premise, this paper uses Shek Wo Keng Village as a case study, drawing on the sustainable design principles of green buildings [8]. It considers all elements of the settlement as interconnected, with a specific focus on enhancing functionality. Considering the acoustic, light, heat, and outer envelope factors related to human comfort in the settlement, this paper explores the integrated design strategy for improving the function and outer envelope performance of Shek Wo Keng villager houses.

2 Present Situation and Analysis of Villagers' Residence in Shek Wo Keng

2.1 Basic situation of villagers living in Shek Wo Hang

Shek Wo Keng Village, also known as Stone Village, is a part of Iron Buddha Temple Village, located in Yunyang Town, Nanzhao County, Nanyang City, Henan Province [9]. The village was formed in Qing Dynasty, with a total area of more than 379 acres, and the existing housing of 42, more than 100.

The residential houses in Shek Wo Hang Village are mainly Sanhe Yuan, with a small number of Erhe Yuan. The houses have different functions, including a hall, wing, kitchen, and livestock pen, arranged in an orderly manner (Figure 1). The structure of the dwellings consists of a beam-bearing system made of stone and wood. The walls of the dwellings are relatively thick, made of rubble of various sizes, and generally about 30 cm thick.

2.2 The Predicament of Tourism Development in Shek Wo Hang Village

As the geographical environment is relatively isolated and the economic foundation is weak, Shek Wo Keng and other rural tourism service facilities in Shek Wo Keng Village mainly consist of simple functional replacements of rural residential buildings. The residential houses in the village are single-story, which cannot meet the needs of tourists. Meanwhile, there are aging residential houses, indoor water leakage, poor outdoor ground drainage, and a disorderly courtyard layout. It affects the experience of residents and tourists, so it needs to be renovated to align with the functional integration of the rural tourism industry.

2.3 Principles for renovation and renewal of Shek Wo Hang Village

In order to meet the needs of eco-tourism development in Shek Wo Keng Village, the reconstruction and renovation of Shek Wo Keng Villagers' Residence should not only make full use of various existing resources and energy, reduce resource waste, but also pay attention to the integration of buildings and external environment space. While reducing building energy consumption, it provides a comfortable and safe environment for the original residents and tourists. It is generally believed that the practice of sustainable design theory for green buildings should follow two principles [10]: one is to save resources and enhance energy efficiency in building resources; the other is to optimize the building environment and create green and healthy building spaces. Based on the sustainable design theory of green building, the physical properties of sound, light, and thermal structure, which are related to human body comfort and building safety, are analyzed. Based on the data results, a systematically integrated design strategy is proposed to enhance the function and performance of the settlement at the settlement level. This approach is of significant importance in guiding the development of the rural ecotourism industry.

Fig. 1. Present Situation and Research Area of Shek Wo Heng Village Source：Self-drawn

2.4 Research methods

Based on the analysis of remote sensing images combined with field investigation and the analysis of physical environmental performance, the paper summarizes the functional requirements of traditional stone and wood dwellings in southern Henan and the requirements for improving building properties. And the corresponding integrated design strategy research. The main analysis software is the Green Building Software Svell. This series of software covers the simulation analysis of "inside and outside buildings, wind and light thermal sound" [11], which can realize multi-calculation in one model, which is efficient and convenient; support the national standard Evaluation Standards for Green Buildings (GB/T50378-2014) and the requirements of national local standards, closely follow the relevant national standards for green buildings. On the premise of respecting the original environment and buildings of the village, the renewal materials of residential buildings (adjusted according to the scheme and supplementary materials) are mainly selected as steel. LOW-E glass and outdoor permeable brick. First, these materials are relatively common, economical and practical, light weight and short construction period. Secondly, these new materials can make up, these new materials can make up for the limitations of stone and wood materials technology, and have stronger adaptability in modern living environment.

3 Performance Analysis of Green Buildings in Shek Wo Heng Villagers' Houses [12]

Through remote sensing image analysis and field investigation, the area depicted in Figure 1 has been chosen as the research area, with residential buildings 1 and 2 selected as the typical research subjects. Utilize the Green Building Software Svell to analyze the different properties of residential buildings (Figure 2). The reasons are as follows: Firstly, residential 1 is a typical three-section compound, while residential 2 is a two-section compound, ensuring objective analysis results. Secondly, the two dwellings are adjacent to each other in the village, and the environments are similar, which helps minimize errors.

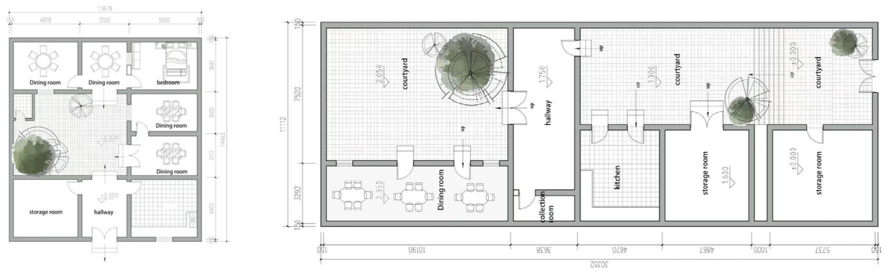


Fig. 2. Residential 1(left)， Residential 2(right)Plane graph Source: Self-drawn

3.1 Daylighting analysis

The daylighting analysis software Dali is utilized to analyze the daylighting, uncomfortable glare, and dynamic daylighting of two residential buildings. The results are as follows:

(1)In terms of building lighting, the stairwell and dining room of Residential 1 do not meet the requirement that the lighting level should not be lower than level V, and the bedroom does not meet the requirement that the lighting level should not be lower than level IV. Additionally, the bathroom is overly bright. None of the seven rooms in Residential 2 meet the criteria for non-reinforced bars (Figure 3).

(2)In terms of glare, two functional rooms in the residential house, the bedroom, and the living room, were analyzed. The main rooms of both Residential 1 and Residential 2 meet the standard requirements. The bedroom in Residential 1, as well as the bedroom and living room in Residential 2, do not meet the lighting uniformity requirements (Tables 1 and 2).

(3)In terms of dynamic lighting, the indoor space of the building was analyzed for dynamic lighting throughout the year. The results indicated that the total area of lighting in Residential 1 was 94.82 m2, with a compliance ratio of 48%. The total lighting area of Residential 2 is 188.36 m², with a compliance ratio of 7%. Both of them did not reach the 60% required by the standard.

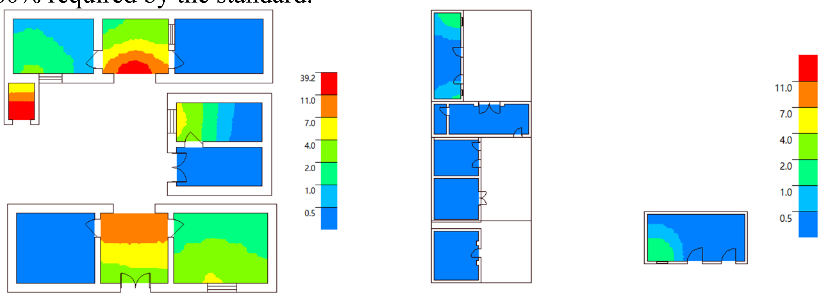


Fig. 3. Residential 1 (left), Residential 2 (right) Lighting effect analysis Source: Self-drawn

Table 1. Lighting uniformity of residential 1 Source: Self-made

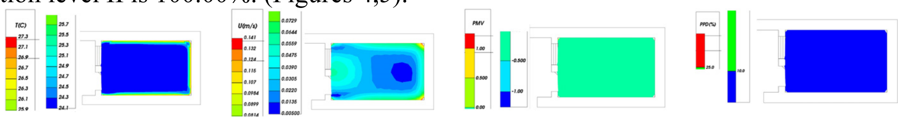
Story	Room number	Room type	Daylighting levels	Daylighting type	maximum values	Average value	Lighting uniformity	conclude
1	1005	Living room	IV	Lateral side	0.06	0.05	1.23	Fulfill
	1006	Bed room	IV	Lateral side	5.78	0.68	8.48	Unfulfilled

Table 2. Lighting uniformity of residential 2 Source: Self-made

Story	Room number	Room type	Daylighting levels	Daylighting type	maximum values	average value	Lighting uniformity	conclude
1	1001	Living room	IV	Lateral side	4.80	0.52	9.26	Unfulfilled
	1005	living room	IV	Lateral side	0.00	0.00	-1.#J	Unfulfilled

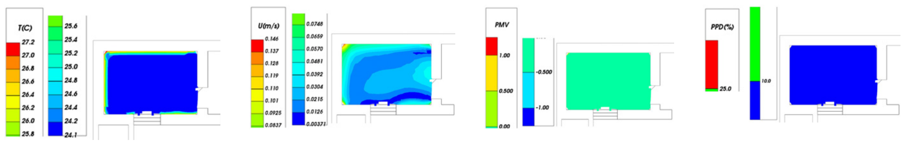
3.2 Thermal Comfort Analysis

Based on this standard, the software calculates the PMV and PPD compliance area of each main functional room and determines the overall PMV-PPD evaluation result of the building by applying a weighted average of the main functional room areas, in accordance with the Green Building Evaluation Technical Rules. The results indicate that the ratio of the area of indicators evaluating hot and humid environments, PMV and PPD, in the main functional rooms of Residential 1 and 2, to achieve an overall evaluation level II is 100.00%. (Figures 4,5).



Temperature field distribution at pedestrian height | **Velocity cloud at pedestrian height** | **PMV distribution at pedestrian height** | **PPD distribution at pedestrian height**

Fig. 4. PMV-PPD analysis of the master bedroom of Residential 1 Source: Self-drawn



Temperature field distribution at pedestrian height | **Velocity cloud at pedestrian height** | **PMV distribution at pedestrian height** | **PPD distribution at pedestrian height**

Fig. 5. PMV-PPD Analysis of Residential 1 Dining Room (Lower) Source: Self-drawn

3.3 Building acoustic environment analysis

The sound insulation performance of the enclosure structures of the two residential buildings is being analyzed. The results indicate that the airborne sound insulation performance of the external walls, partition walls, floor slabs, doors, and windows of the main functional rooms in Residential 1 and Residential 2 meets the minimum requirements of the current national standard Code for Sound Insulation Design of Civil

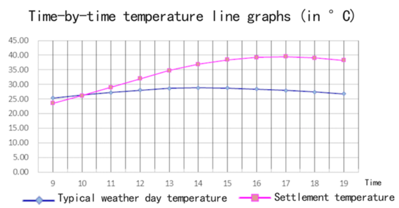
Buildings GB 50118. The airborne sound insulation performance between the components and adjacent rooms of Residential 1 and Residential 2 meets the high requirements specified in the current national standard Code for Sound Insulation Design of Civil Buildings, GB 50118 (Table 3).

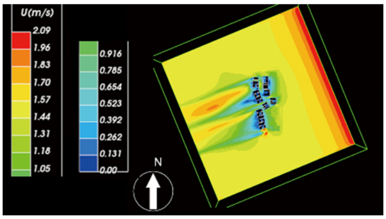
Table 3. Evaluation results of sound insulation performance of enclosure structures of residential houses1,2 Source: self-made

checklist	Basis of evaluation	conclude
Airborne sound insulation	Control items: 5.1.4 The sound insulation performance of the external walls, partition walls, floor slabs, doors and windows of the main functional rooms should be able to meet the requirements of the low limit in the current national standard *Code for Sound Insulation Design of Civil Buildings* GB 50118.	**Fulfill**
	Rating scale: 5.2.7 The airborne sound insulation performance between components and neighboring rooms reaches the average value of low and high standard limits in the current national standard *Code for Sound Insulation Design of Civil Buildings* GB 50118, and scores 3 points; reaches the high standard limit, and scores 5 points.	**Meet high demands**
Impact sound insulation	Control items: 5.1.4 The sound insulation performance of the external walls, partition walls, floor slabs, doors and windows of the main functional rooms should be able to meet the requirements of the low limit in the current national standard *Code for Sound Insulation Design of Civil Buildings* GB 50118.	**Fulfill**
	Rating scale: 5.2.7 The impact sound insulation performance of the floor plate reaches the average value of the low standard limit and high standard limit in the current national standard *Code for Sound Insulation Design of Civil Buildings* GB 50118, and scores 3 points; reaches the high standard limit and scores 5 points.	**Meet high demands**

3.4 Analysis of heat island intensity and wind environment in settlements

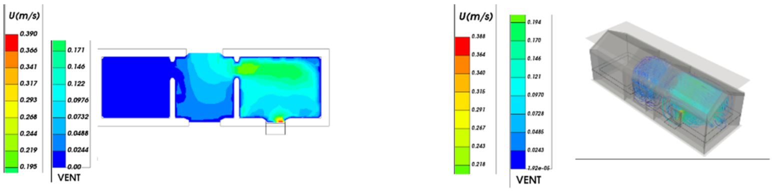
According to Article 3.3.1 of JGJ 286-2013, Thermal Environment Design Standards for Urban Residential Areas, when evaluative design is carried out, the average summer heat island intensity of the residential area should not exceed 1.5°C. According to JGJ 286-2013, "Thermal Environment Design Standards for Urban Residential Areas," the CTTC set total parameter model was used to calculate the study area. The result is that the average heat island intensity of the study area is 6.64°C, which does not meet the standard.





Analysis of heat island intensity **Outdoor wind environment**

Fig. 6. Analysis of heat island intensity (left) and outdoor wind environment (right) in the constituency Source: Self-drawn



Indoor velocity field distribution **Indoor wind speed vector**

Fig. 7. Analysis of indoor ventilation in residential 1 Source: Self-drawn

In terms of the wind environment, according to the Green Building Evaluation Standard GB/T50378-2019, the outdoor summer and winter season wind environment was analyzed using the building ventilation calculation software Vent2022. The results indicate that during winter, the wind speed, wind speed amplification factor, and wind pressure on the windward and leeward sides of the building in the outdoor wind environment all meet the standard requirements. There is no area with a wind speed greater than 5m/s in the pedestrian zone. Additionally, there is no area with a wind speed greater than 2m/s and a wind speed amplification factor greater than or equal to 2 in the outdoor rest area and children's recreation area. Moreover, there is no building where the difference in wind pressure between the windward side of the building and the leeward side of the building's surface is greater than 5Pa (Figure 6). In the three indicators of windless area, vortex area, and wind pressure difference between the indoor and outdoor surfaces of the exterior windows in the transition season and summer, there is no vortex area in the human activity area, but there is a windless area. The wind pressure difference between the indoor and outdoor surfaces of the open exterior windows does not meet the requirement that more than 50% of the indoor and outdoor surfaces of the openable exterior windows have a wind pressure difference of more than 0.5 Pa (Figure 6). Through computational fluid dynamics (CFD) analysis, the results indicate that the indoor airflow organization is reasonable and complies with the green standard requirements (Figure 7).

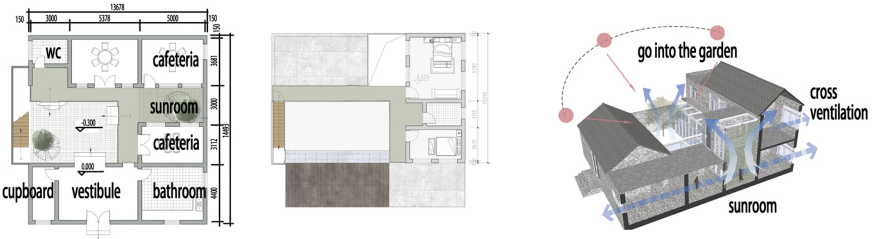
4 Study on the Integrated Strategy of Improving the Function of Villagers' Residence and the Performance of Outer Envelope in Shek Wo Keng

The analysis reveals that the building performance of Shek Wo Keng Village has certain deficiencies in terms of heat island intensity analysis, indoor thermal comfort, lighting performance, and indoor and outdoor wind environments. In the era of experiential tourism economy, enhancing technology through a series of ecological green technologies and energy-saving building methods is crucial. This improvement aims to elevate the living experience and comfort of both villagers and tourists, playing a significant practical role.

4.1 Integration Strategies for Improving the Functionality and Performance of the Exterior Envelope of Residential Houses

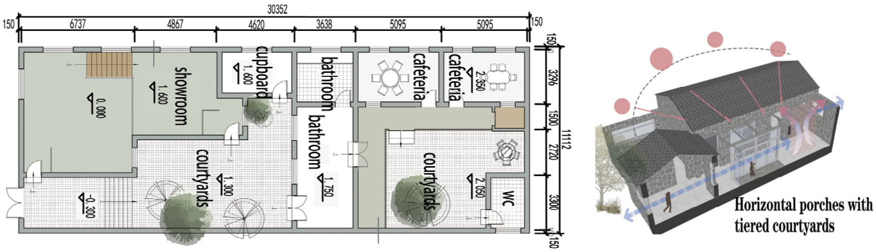
In summary, the main synergistic optimization strategies proposed in the article are as follows: First, in conjunction with rural tourism, the exploration model of "business +" is proposed to rationalize the design and reconstruction of the original rural houses and public buildings; Second, the village's vernacular landscape and outdoor public space and the surrounding environment are planned and integrated into the characteristic scene; Third, energy-saving renovation of the exterior envelope of village dwellings. The details are as follows:

(1) In terms of the reconstruction and expansion of the original residential houses, the main strategy for Residential 1 is to replace the functions based on the original plan and to incorporate a sunroom and a courtyard. The sunroom and courtyard are used to facilitate indoor and outdoor heat exchange. In addition to the measures described above, Residential 2 incorporates a character-defining display space (Figures 8,9).



Altered planes   Altered planes   Residential + Commercial Model

Fig. 8. Residence 1 after the transformation of external environment Source: Self-drawn



Altered planes   business model

Fig. 9. Residence 2 after renovation Source: Self-drawn

(2) In terms of external environmental planning, the general layout was re-planned initially. Various materials and techniques were employed to address issues such as high heat-island intensity in the settlements, outdoor wind environment not meeting standards, poor road surface drainage, and the absence of distinctive spaces. For example, water-permeable tiles were installed, water-cycling technology was introduced, native vegetation was enriched, and characteristic spaces were put in (figure. 10).

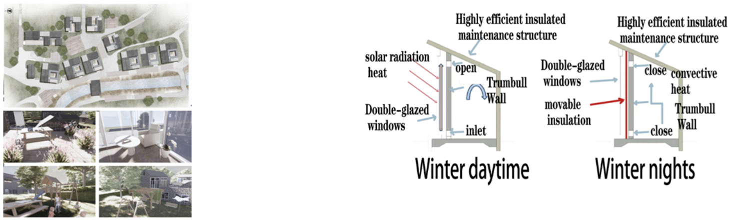


Fig. 10. Energy-saving reconstruction of external environment and external protection structure of residential buildings Source: self-painting

(3) In terms of energy-saving renovation of the external enclosure structure, several strategies can be implemented. Firstly, widening and heightening the door and window openings and using a lightweight steel structure for the addition part can minimize damage to the original building. Secondly, passive energy-saving measures for the door and window openings, such as using low-e energy-saving glass and increasing sunshade construction, can be effective. Furthermore, technical improvements to the external enclosure structure, such as planting green roofs and enhancing internal heat preservation of the external walls (figures. 10,11).

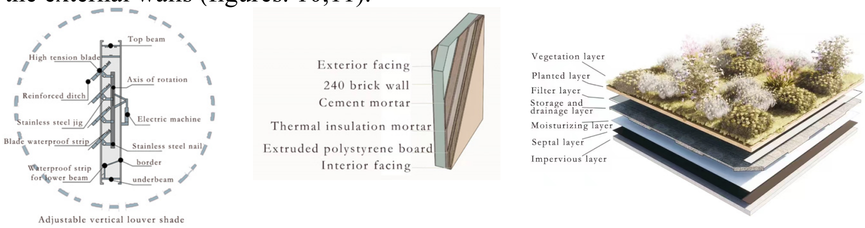


Fig. 11. Passive energy saving measures for residential houses Source: Self-drawn

4.2 Post-retrofit analysis

After the renovation of Residences 1 and 2, the green building performance analyses of both residences were still conducted using the same method as before. The data show that after the renovation, the indoor lighting performance of both Residential 1 and 2 has improved and now meets the standard requirements (Table 4); in terms of the general plan renovation, the average windward surface area ratio, shading coverage rate of the activity site, infiltration evaporation indicators, and roof greening rate have been improved (Table 5). Concerning indoor thermal comfort, all rooms in Houses 1 and 2 meet the standards (Table 6); in terms of carbon emissions, the annual carbon emissions of Houses 1 and 2 have decreased from the original 14.517 tCO2 and 28.121 tCO2 to 0.042 tCO2 and 14.028 tCO2, respectively (figures. 12,13).

Table 4. Comparison of data before and after retrofitting of indoor lighting in Habitat 1 (left) and Habitat 2 (right).

Room(Unit type)	totality	Required quantity	Percentage meeting requirements (%)	Rooms/apartment types that are not suitable for non-strong bars	Rooms/apartment types that are suitable for non-strong bars
Apartment type (unit)	3	0	0	1-A 1-C	1-B
Rooms (unit)	9	6	66.67	1003 1004	1010
Lighting area (m2)	94.82	60.04	63.31		
room(area)	totality	Required quantity	Percentage meeting requirements (%)	Rooms types that are not suitable for non-strong bars	Rooms/apartment types that are suitable for non-strong bars
Apartment type (unit)	11	11	100		
Lighting area (m2)	144.42	144.42	100		

Room (Unit type)	totality	Required quantity	Percentage meeting requirements (%)	Rooms/apartment types that are not suitable for non-strong bars	Rooms/apartment types that are suitable for non-strong bars
Rooms (unit)	7	0	0.00	1002 1005 1006 1007 1001 1003 1004	
Lighting area (m2)	188.36	0.00	0.00		
room(area)	totality	Required quantity	Percentage meeting requirements (%)	Rooms types that are not suitable for non-strong bars	Rooms/apartment types that are suitable for non-strong bars
Apartment type (unit)	7	7	100.00		
Lighting area (m2)	169.44	169.44	100.00		

Table 5. Comparison of data before and after general plan modification Source: self-made

category	Check item	conclusion	remark
Mandatory provision	Average windward area ratio	dissatisfy	Mandatory provisions must be met
	Shading coverage of activity venue	dissatisfy	
Prescriptive design	Bottom ventilation ratio	satisfy	If any of them is not satisfied, evaluative design is carried out
	Leaf area index of greening shading body	satisfy	
	Pervaporation index	dissatisfy	
	Greening rate of roof	dissatisfy	
conclusion		dissatisfy	
category	Check item	conclusion	remark
Mandatory provision	Average windward area ratio	satisfy	Mandatory provisions must be met
	Shading coverage of activity venue	satisfy	
Prescriptive design	Bottom ventilation ratio	satisfy	If any of them is not satisfied, evaluative design is carried out
	Leaf area index of greening shading body	satisfy	
	Pervaporation index	satisfy	
	Greening rate of roof	satisfy	
conclusion		satisfy	

Table 6. Thermal comfort of each functional room after the renovation of residential house 1 Source: self-made

Floor number	House type	Room number	Room name	PMV-PPD standard Area (m2)	area	PMV-PPD standard area ratio (%)	score
1	1001 1002 1003 1005 1006 1007		storeroom	7.0	7.0	100%	8
			room	24.9	24.9	100%	8
			kitchen	19.3	19.3	100%	8
			Dining room	13.2	13.2	100%	8
			Dining room	17.2	17.2	100%	8
			Dining room	15.9	15.9	100%	8
Building PMV-PPD standard area ratio (%)				100%			

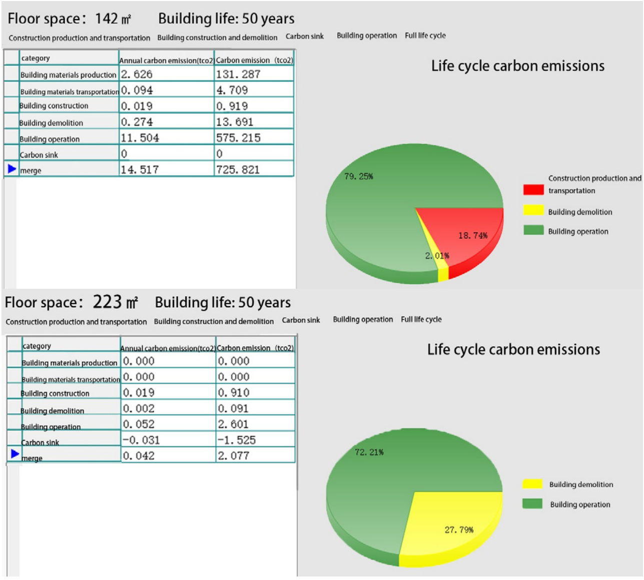


Fig. 12. Carbon emission analysis before and after the renovation of residential house 1 Source: Self-drawn

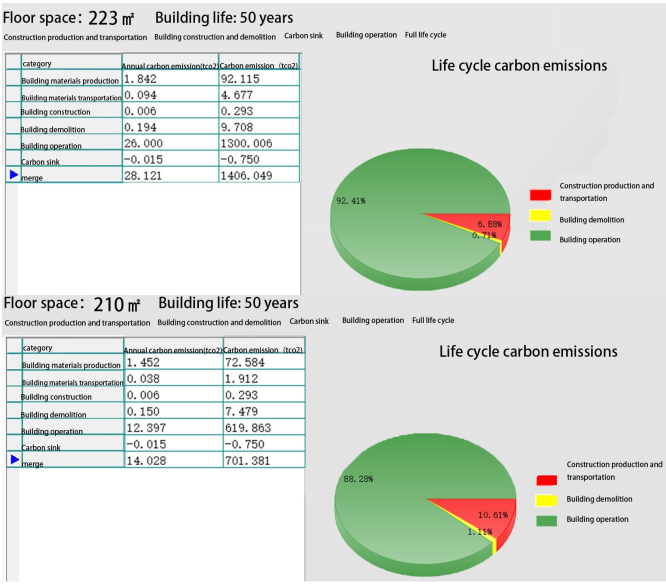


Fig. 13. Carbon emission analysis before and after the renovation of residential house 2 Source: Self-drawn

5 Conclusion and outlook

In the process of the rapid development of rural tourism, many issues such as the blending of rural culture and the loss of local characteristics are becoming increasingly prominent [13]. This paper is centered on the concept of sustainable green building. It involves simulating sound, light, and heat performance factors as indicators of Shek Wo Keng village. The analysis results serve as a guide for improving the design from the cluster level to the entire village. The aim is to integrate village functions and the performance of the external enclosure structure to enhance integration strategies. Following analysis and verification, the study focuses on enhancing the design by integrating the performance of the external enclosure structure to improve both indoor and outdoor spaces of the Yu'nan stone and wood dwellings. The living conditions of the stone and wood dwellings in Yu'nan have been improved, enhancing the living experience and comfort of the villagers and tourists. However, due to the limitation of the research scope and the author's theoretical knowledge and time, this paper belongs to the periodical research achievement, which also leads to the integration design update strategy proposed in this paper to be more individual. The design strategy is a little fragmented and systematic, so it is difficult to be universally applied. In view of these problems, the next step of my team will expand the scope of investigation, to investigate different types of stone and wood residential settlements in southern Henan, and further refine, correct, enrich and perfect the design strategy proposed in this paper. Nonetheless, this study is still of reference significance to the sustainable development of stone and wood rural residential buildings in South Henan [14]. The integrated design of stone and wood residential buildings for function and performance upgrading still has a broad prospect due to its holistic approach and efficient enhancement of function and performance.

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