Reuse strategies and green building performance simulation of Jincheng Cocoon Station

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Abstract. Jincheng Cocoon Station, as the earliest and largest township cocoon station in the main area of Zhejiang silk production, has special historical value. Its structural form is a brick-wood hybrid system with brick exterior walls, wooden interior columns, and wooden roof trusses. Its organizational form corresponds to the regional climatic characteristics. The original spatial structure was specifically designed to serve its production functions, such as cocoon drying and stacking. After the end of the operation, an appropriate spatial transformation was needed to achieve the transformation of reuse. This study deduced a reuse plan from the historical value, cultural value, and pratical value of Jincheng Cocoon Station. Then the spatial variables are extracted. After forming a preliminary plan, the green building performance simulation was conducted on the program variables through Design Builder software to measure the rationality of the reuse countermeasures. This article aims to explore the dual protection of heritage value and green building performance in the process of achieving reuse through performance simulation.

1 Introduction

1.1 Architectural features of Jincheng Cocoon Station

Jincheng cocoon station is located in Huzhou City, Nanxun District, Qianjin Town, covers an area of about 5,000 square meters, with a total construction area of about 7,000 square meters, is the earliest time to build the station in the main producing areas of Zhejiang silkworm, the largest township cocoon station. See **Figure 1**.

1.1.1 Spatial characteristics

The main function of the cocoon station is to store silkworm cocoons. Fresh silkworms are kept on the first floor, while semi-dried and dried silkworms are stacked on the second floor. The drying room uses a "double-sided stove type" and has a spacious aisle of about 7 meters wide in the middle. According to research by Zhongguan cocoon station1, each row of drying and transportation channels is approximately 2 meters, and the space required for drying and transportation workers is around 0.55 meters. The opening state of the drying room door is approximately 1 meter, and the total side is about 3.55 meters.

The cocoon storage room has two floors and entrances on both the upper and lower floors, located on the north side near the drying room. There are delivery ports on the bamboo and wooden floor for placing semi-dried and dried cocoons on the second floor into the first floor. Semi-dried cocoons are transported to the drying room, and dried cocoons are transported out to the silk factory. The drying room and the hall building are connected to two north-south cocoon storage rooms, which serve as the starting and ending points of the flow line in the cocoon storage room. The main traffic space is located in a rectangular space formed by the intersection of five volumes in the east-west direction.

1.1.2 Structural characteristics

The roof frame of the cocoon station is made up of timber and steel, where the timber beams transfer the loads to the brick columns below. The roof frame of the Passage Hall consists of a combination of round timber, square timber, and rebar that forms a load-bearing herringbone structure. This structure is then connected to the traditional floor-to-ceiling round timber columns. This roof structure helps to reduce the construction and maintenance costs of the cocooning station, making the space bright and usable without the need for frequent repairs[2].

1.1.3 Facade characteristics

The Jincheng Cocoon Station boasts a unique architectural design with a prominent feature being the sloping tiled roof. The roof is fitted with skylights that interlock to form a distinct fifth elevation when viewed from above. From the entrance, the sloping roofs of neighboring buildings create a silhouette reminiscent of cascading mountain ranges. The façade elements that stand out the most are the windows with moisture-proof structures in the cocoon storage area, and the repeating

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rhythmic wall surface that is formed by the windows, brick pillars, and the wall surface between them.

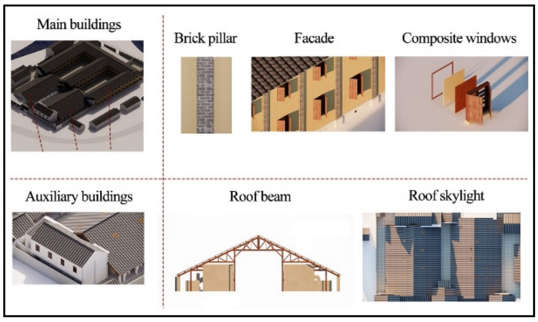

Fig. 1. Architectural features.

1.2 Research objective

The cocoon station lacks outstanding characteristics when compared to similar historical buildings in the area. Static protection measures may lead to a lack of operating funds and abandonment. A more practical approach is to transform and reuse the space for new functions while preserving its heritage value. By simulating the impact of spatial changes on energy consumption, dual protection of heritage value and green building performance can be weighed for reuse plans.

2 Methodology

This study utilized the Design Builder software for energy simulation3 and employed orthogonal test methods to analyze the impact of spatial variables. The researchers first identified the spatial variables and then created separate models for the original building and each variable. The simulation was set up to measure the energy consumed in maintaining a comfortable temperature within the space. This data was then used to estimate the energy consumption generated by the space4**. T**he area of change is shown in **Fig. 2**.

2.1 Spatial variable extraction

2.1.1 Adding atriums

The former Cocoon Station building has a long and narrow space which is ideal for the production process. However, the space is too single and clear for the exhibition function. To address this, an atrium can be added by incorporating the inner patio between the north and south oriented cocoon storage into the interior. This will provide a richer choice of paths for the flow of exhibitions within it, making it a spatial variable in this case.

2.1.2 Adding stairwells

The Cocoon Station has functional needs that require additional stairwells for fire evacuation. However, due to the building's structural form and size of openings, the stairwells cannot be added through dividing the original space. Instead, external blocks must be inserted into the original form, making the insertion of the block a spatial variable in this case.

2.1.3 Double-heights space

The building has two floors that are separated by bamboo and wood floor slabs, and there is only a staircase on the north side to access them. To design the exhibition space, it is necessary to partially open up the floor to reorganize the internal space. Therefore, in this case, the opening up of the floor slabs is defined as a spatial variable.

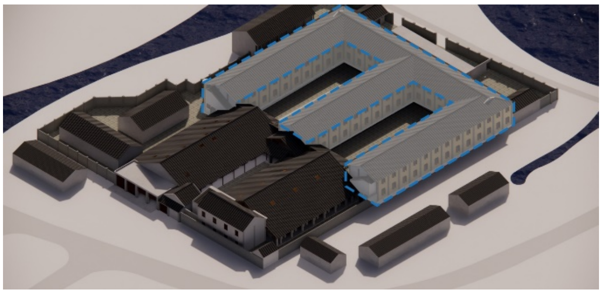

Fig. 2. Areas of change.

2.2 Orthogonal experimental method

The orthogonal experimental method is used to study multiple factors and levels[5-7]. This approach uses partial tests instead of full tests in order to reduce the number of tests required. In this particular study, 3 programmatic factors were identified as the focus of the research: the addition of an atrium (A), the addition of stairwells (B), and the connection of two floors (C). Three levels were considered for each factor, labeled as 1, 2, and 3 respectively. These levels correspond to no adoption, one-sided adoption, and two-sided adoption in that order, based on the symmetrical layout of the original building. Blank columns were added to estimate random errors[8].

3 Results and discussion

3.1 Stochastic analysis and optimal plan

The simulation results indicate that the building's energy consumption mainly occurs during summer cooling. By calculating the extreme deviation based on the test results, we can analyze the impact of changing the value of different factor levels on the test results[9]. The larger the polar deviation, the greater the influence of the factor. As shown in **Table 1**, excluding the blank columns, we find that the magnitude of the extreme deviation follows the order R1>R2>R3. This indicates that the order of magnitude of the impact on the building energy consumption of the spatial variables of each reuse scenario is A>B>C. Among them, adding atriums (A) and stairwells (B) increases the building's energy consumption, whereas opening the floor slabs to connect the two floors (C) reduces energy consumption.

Lower energy consumption indicates better green building performance. The optimal solution was found by combining relatively smaller k with certain design features. Based on the results in **Table 1**, the best solution is (A1, B1, C3), which includes an additional atrium on both sides, an extra stairwell on both sides, and a two-story connection on one side.

Table 1. Orthogonal test and polar analysis of variance results.

No.	Factors				Site energy (kWh)
	Atriums (A)	Stairwells (B)	Double-height Space (C)	Blank (D)	
1	1	1	1	1	700875
2	1	2	2	2	700485
3	1	3	3	3	703051
4	2	1	2	3	833793
5	2	2	3	1	833976
6	2	3	1	2	870084
7	3	1	3	2	980531
8	3	2	1	3	1018338
9	3	3	2	1	1016565
K_1	2104412	2515201	2589298	2551418	–
K_2	2537855	2552801	2550845	2551102	–
K_3	3015435	2589702	2517559	2555183	–
k_1	701470	838400	863099	850472	–
k_2	845951	850933	850281	850367	–
k_3	1005145	863233	839186	851727	–
R	303674	24833	23912	1360	–

3.2 Significance analysis

The orthogonal test used in this study was a 3-factor, 3-level orthogonal test consisting of 9 trials and a degree of freedom of 2. There was no interaction between the factors and the blank column was used as the error column[10]. Based on the ANOVA results in **Table 2**, it was observed that the addition of an atrium (A) had a more significant effect, followed by the effects of adding a stairwell (B) and two-story connectivity (C). Therefore, when designing Jincheng Cocoon Station, it is recommended to prioritize the improvement of the green building performance of the additional atrium part, followed by the performance of the additional stairwell. Additionally, the space of the two-story connectivity can be increased appropriately to reduce summer cooling and achieve the effect of building energy savings.

Table 2. ANOVA table.

Source of variation	Sum of squares	Degrees of freedom	Mean squares	F-value
A	138435506380	2	69217753190	40280
B	925092895	2	462546447	269
C	859213838	2	429606919	250
D	3436798	2	1718399	1

4 Conclusion

This paper provides a analysis of the factors involved in the reuse of heritage buildings, specifically based on the Jincheng Cocoon Station scenario. The three factors analyzed were adding an atrium, adding a stairwell, and connecting two floors. Simulation calculations were carried out using Design Builder building energy simulation software, and the results were analyzed to determine the primary and secondary order of influence of each factor on the annual cooling load of the building. The analysis revealed that adding an atrium was the most significant factor in affecting energy consumption, followed by adding a stairwell, and then connecting two floors. An optimal level scheme was obtained for the three factors, which would minimize the annual energy consumption of the building. Significance analysis was also conducted to determine the degree of significance of each factor in the energy-efficient design of the building. This method provides a comprehensive way to measure program requirements and green building performance for heritage reuse design. The combination of the significance level of the influencing factors and the reuse needs of the heritage are considered. After splitting the program into spatial variables that can be assessed for performance, the optimization and adjustment of the program is carried out.

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