Study on Ecological Adaptive Reform Strategy of Traditional Dwellings in Jiarong Tibetan Ethnic Group——Taking Jiaju Tibetan Village as an Example

Study on Ecological Adaptive Reform Strategy of Traditional Dwellings in Jiarong Tibetan Ethnic Group——Taking Jiaju Tibetan Village as an Example

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Abstract: Jiaju Tibetan Village is a representative area of Jiarong Tibetans. This paper will take it as the research object, and find out some existing shortcomings by investigating its current situation, and analyse its ecological adaptability from three aspects: spatial layout, building structure and components, and building materials. On the basis of research and analysis and drawing on the existing literature research results, the paper discusses the ecological adaptive transformation strategies of traditional residences in Jiaju Tibetan Village from three aspects: architectural layout, envelope structure and renewable energy utilization. From the perspective of ecological energy conservation, it proposes a specific transformation strategy for the traditional dwelling of Jiarong Tibetans.

1. Introduction

The traditional residences of Jiarong Tibetans have distinct regional characteristics and are of great research value. With the development of the times, the quality and safety performance of traditional residential buildings have also improved, but energy-saving measures are still at a low level. In this paper, the representative Jiaju Tibetan villages of Jiarong Tibetans will be selected as the research object, and the current situation and ecological adaptability of their residential houses will be discussed. On this basis, some ecological energy-saving transformation strategies are proposed.

2. The current situation of traditional residences in Jiaju Tibetan Village

2.1 Geographical environment and Climate analysis

Jiaju Tibetan Village is located in the Danba County which is located in the eastern part of Ganzi Tibetan Autonomous Prefecture. The terrain is high in the west and low in the east, with an average altitude of 1800 meters. The five rivers meet in the Danba County, cutting the mountains, and the three-dimensional landforms are remarkable. The Jiaju Tibetan Village is mainly distributed on the northwest side of Danba County, on the west bank of the Dajinchuan River. More than 200 Tibetan-style houses in the village are located in the gathering place of the Qionglai Mountains and the

Bayankala Mountains.

Danba County is a high archetype monsoon climate in Qinghai-Tibet, but due to the special geographical factors of its alpine valley landscape, it forms a high archetype monsoon climate that differs from the Qinghai-Tibet Plateau. The annual average temperature is 14.2 °C. The coldest month (January) has an average temperature of 4.4 °C. The hottest month (August) has an average temperature of 22.4 °C. The frost-free period is 316d and the annual average temperature is not fluctuating. In addition, the four seasons are not obvious and the temperature difference is larger. Another impact is that the winter is very dry and the summer is very humid which means the dry and wet seasons are distinct. The rainfall is concentrated and the total annual precipitation is about 500~1000mm. More importantly, it is located in a region with abundant solar energy resources. The light is sufficient and sunshine time is about 2106.9~2318.5h/a.

2.2 Architectural features

As a representative of Jiarong Tibetan Village, Jiaju Tibetan Village has more architectural and regional features. It is a unique Tibetan-style building, based on the principle of local materials, built in the hillside slope under the high mountains, with local stone and stone technology as the material foundation of the building. Jiaju Tibetan Village is generally 4-5 storeys, and the building is retired from floor to floor, leaving a flat roof of sufficient area to dry the grain. The four corners of the roof feature the Tibetan-style religious structure "Mani Heap".

2.3 The disadvantages of existing residences

1） The insulation structure is poorly insulated

Due to the limitation of local materials and the irrationality of traditional stone masonry technology, there is the problem of poor thermal insulation of the envelope structure.

2） Door and window ventilation are poor

In the past, in order to prevent thieves and wild animals, cold climate and building structure technology did not allow people to open large-area windows.

3） Poor indoor lighting

In order to improve the insulation of the building, the traditional Tibetan dwellings have fewer windows. And the wall thickness is 800mm, which results in lack of illumination in the room and basically no natural lighting.

4） Problems caused by “toilet picking”

“Picking the toilet” is a characteristic space of Jiaju Tibetan Village, which is located usually on the second floor of the building. A wood structure is used to hang out a space outside the main body as a toilet. The corresponding layer has a collection pool for collecting excrement. The excrement can fall directly into the collection pool. In the traditional sense, “toilet picking” is not only a special facade decoration but also a convenient way to make fertilizer, which is very ecological and environmentally friendly. However, with the development of the times, the poor sanitary environment brought by “toilet picking” and the psychological barriers of tourists from other places determine that its form and structure need to be improved and upgraded.

3. Study on ecological adaptive reform strategy of Jiaju Tibetan Village

3.1 Study on ecological adaptability

The ecological adaptability of Jiaju Tibetan Village will be analyzed from three aspects: spatial layout, building structure and components, and building materials.

3.1.1 The study on ecological adaptability of spatial layout. The gates of Jiaju Tibetan Village are mainly oriented to the south, while the windows are mainly on the east and south sides. Its orientation choice mainly considers natural factors and cultural factors.

In terms of natural factors, Danba lies to the north of the Tropic of Cancer, and the direction of

sunshine all year around is towards the south, so the front of the houses is mainly towards the south. From the perspective of the overall distribution of the houses, the buildings are scattered. Even the group layout does not be lined up along north-south, but east-west direction, which allows each house to receive sufficient sunlight. Moreover, the seasonal westerly jet zone is of low height and high wind speed when the dry season comes. In order to effectively block the westerly wind, most of the residential windows are set in the East and south side. Although such measures can effectively prevent wind and reduce the loss of indoor temperature, it brought about some problems like unsmooth indoor air and high levels of carbon dioxide.

In terms of cultural factors, jiarong Tibetan's unique religious belief has a profound influence on its architecture. Jiaju people mainly believe in Bonismo and Tibetan Buddhism, worship Sacred Mountain, Sacred Water, Sacred Lake and Sacred Stone. The Mordo Mountain and the Dadu River in Danba are located on the east side of the Jiaju Tibetan Village. And it is necessary to consider facing the Shenshan and Shenshui when holding religious activities. Therefore, the long side of a single dwelling house is basically facing the east side, forming the trend of Fengshui Mountain.

The layout of the residential buildings mainly has two modes. One is the "L" type, the other is the enclosed type, and the enclosed type is added and expanded on the basis of the "L" type. The enclosed type is also a more common layout pattern in the Jiaju Tibetan Village. Both of them are the layout methods most suitable for the site environment and user behavior habits, which have been summarized by the local people through long-term experiments. They are summarized as follows:

1) The functions of each layer are distinct

The negative layer of the dwelling house is the livestock circle. The first reason of its location is health environment is poor, it needs to be separated from the main activity space of the person, and it is also convenient for independent management and grazing. The second reason is the entire site is high in the west and low in the east, the main entrance of the building is flush with the west high ground, and the negative floor is flush with the low level of the east. This single side lighting pattern can not only meet the lower lighting requirements of the livestock pen, but also reduce the digging and filling of earth. The first floor of the residential area is the main activity space, and the most functional room is the Guozhuang. Guozhuang is a characteristic space inherited from ancient times. It is roughly square in shape, with a large area facing south. It is a family activity place where families sit around the fireplace for meetings, chatting, eating and heating. Now the function of the pot is gradually weakened, but such a characteristic space is still preserved in the dwellings. The second floor of the residence is the prayer hall and bedroom, as well as the sun dam partly formed by the roof of the first floor. The hall opens the window to the east side and has a good view of the Sacred Mountain and the Sacred Water. The third floor is a large area of dam, with only a small grain storage room.

2) Adaptation of the regionalized characteristic space to the environment

The characteristic spaces such as Guozhuang, toilets and sunbathing are not only show the feature of local culture, but also have certain ecological adaptability. For example, the large south-facing outer wall of Guozhuang can absorb solar radiation in the daytime, and the fire pool in the middle of the room can also generate heat when used, which can improve the indoor temperature and become a shelter for the family in cold winter. Another example is that Danba is suitable for agricultural production, but the local terrain is steep. There is no large area of land and garden for drying the grain. In addition, the precipitation is concentrated in the summer, so the building is in the form of a flat roof, and the roof is used as a sun dam to make full use of the light.

3.1.2 The Study on ecological adaptability of building structures. The Jiaju Tibetan Village building is a typical stone frame system in the ancient Chinese architecture system. Its structural form is mainly mixed with the block wall and the wooden beam column. The outer protective structure of the building is mainly the outer wall of large stone masonry. The small stone piece is used for caulking, and the mud formed by mixing raw soil and water is used for jointing, leveling and bonding. The outdoor stone masonry wall bears the weight of the building itself, while the wooden beams, columns and rafts form a vertical and horizontal equidistant grid structure to support the interior of the building.

Specifically, the thickness of the bottom stone masonry wall is generally 600~800mm, and the inner side of the wall is perpendicular to the ground. The second to the outer wall is divided into 8° from the bottom to the top, and the wall is thinned to 400~600mm. In addition to ensuring the thermal stability of the maintenance structure, the thick wall also has a heavy facade effect. The uniform and regular beam-column layout combined with the heavy external masonry walls gives the building itself a certain degree of shock resistance.

3.1.3 The study on ecological adaptability of building materials. The building materials required for the construction of the Jiaju Tibetan Village are difficult to transport from the outside because of the complex terrain. Therefore, it has to be taken locally, so stone, wood and loess, which have a large amount of natural reserves in the local area, have become the main materials for traditional houses. These materials are low-energy-consumption building materials on the one hand, and suit the concept of sustainable development on the other hand.

1） Stone

The main stone in Danba is shale, which has a hard texture, high density, weather resistance and long storage time. It is the main wall material that lasts for hundreds of years. While ensuring the stability of the building, the stone can bring a distinctive texture to the local architecture.

2） Wood

The Danba region is rich in forest resources, so access to wood is very convenient and is a renewable resource. It has light weight, high strength, good heat insulation, high plasticity and strong decoration.

3） Loess

Loess is widely used in Tibetan areas because of its low cost and heat insulation properties. It is mainly used to smooth the inner wall and roof.

4） Straw

As a product of local production methods based on farming, straw is easy to obtain, and it has excellent thermal insulation properties as building materials, which can effectively reduce building energy consumption. However, at present, straw is only doped in the loess to increase its adhesion.

3.2 The ecological adaptive reform strategies

The ecological adaptive *reform* strategies of traditional residences in Jiaju Tibetan Village will be discussed from three aspects: building layout, envelope structure and renewable energy utilization.

3.2.1 Building layout transformation strategy. The existing architectural layout is the result of local residents' conclusions. It is largely adapted to local living habits and has certain ecological rationality. In recent years, with the development of local tourism, the traditional layout model has failed to meet the current needs. The disorderly self-construction of villagers also destroyed the original style and ecology to a certain extent. Through investigations, it is found that the existing residential body shape coefficient is mostly above 0.4, which is not conducive to building energy conservation. Therefore, there is a way to decline the body shape coefficient is that reduce the unevenness of the outer wall and the surface area in contact with the outside world instead of adding new functional blocks at will.

3.2.2 Reconstruction strategy of envelope structure. Due to the immature local construction techniques, poor economic conditions, and years of disrepair, most of the residential building envelopes have not met the human body's requirements for thermal comfort. In Danba County where Jiaju Tibetan Village is located, the temperature difference between day and night is large, and the temperature in winter nights can be as low as minus 10 °C. Therefore, it is especially important to improve the thermal performance of the envelope structure.

1）Wall reform strategy and thermal analysis

The outer walls of the traditional dwellings in Jiaju Tibetan Village are mainly stone walls made of local shale. The thickness is usually 600-800mm. The inner walls are laid with loess flat and have certain heat preservation. Some interior walls are directly made of 100-150mm thick wooden. The thermal physical properties of each material of the building wall were obtained by consulting the *Civil Building Thermal Design Code GB50176-93*. According to the calculation formula of the flat wall heat transfer, it can be concluded that the thermal resistance and thermal inertia of the structural layers of the existing residential wall are shown in Table 1. The greater the thermal resistance, the more the enclosure structure can prevent heat transfer between indoor and outdoor, and the better the thermal stability of the maintenance structure.

Table 1. Thermal resistance and thermal inertia of various parts of the wall

Index	Stone wall	Wooden wall	Loess	Straw
Thickness	600mm	100mm	40mm	40mm
Thermal resistance R[(m²·k)/W]	0.23	0.71	0.07	0.85
Thermal inertia indicator D	5.98	2.53	0.53	0.71

It can be seen from the calculation results that the thermal resistance of the 600mm thick stone wall is much lower than the 100mm thick wooden wall, and the gap generated during the stone wall masonry process is also the main way of heat loss. Stone wall is a symbolic element of local dwellings. Its facade texture is very beautiful and distinctive. Therefore, it is not possible to directly install an external thermal insulation system to increase the thermal insulation of the external wall, but it can be realized by adding an internal thermal insulation system. The main purpose of laying the loess on the inner wall of the existing stone wall is to level the wall instead of keeping warm. Taking into account the local economic level and ecological concept, the insulation of the stone wall can be increased by increasing the insulation of the straw and the thickness of the loess. The specific approach is:

- The stone wall base is cleaned and sprinkled with water
- Laying 20mm thick loess mixed with a small amount of straw as a bonding layer
- Set 40mm or 60mm thick plaited straw board as insulation layer on the bonding layer
- Use 15mm thick loess screed
- Apply 5mm Anti-cracking composite mesh
- Apply 5mm thick loess as the finish layer

The stone wall and the original stone wall of the internal insulation system are increased by the calculation of thermal resistance and thermal inertia. As shown in Table 2, it can be clearly seen that the stone wall insulation performance after the transformation is much better than before. For the cracks generated during the stone wall masonry, the outer wall surface can be made of loess or some more modern materials such as cement mortar joints, or combined with the decorative paint of the outer wall itself. It can transform the gap of the stone wall into the air layer and further improve the insulation performance of the wall without breaking the original features of the traditional dwellings.

Table 2. Comparison of thermal insulation performance between original wall and the renovated wall

Index	The original stone wall	40mm plaited straw board as insulation layer of stone wall	60mm plaited straw board as insulation layer of stone wall
Average thermal resistance R [(m²·k)/W]	0.44	1.30	1.73
Heat transfer coefficient K[W/(m²·k)]	2.30	0.77	0.58
Thermal inertia indicator D	6.38	7.22	7.57

2） Roof renovation strategy and thermal analysis

The traditional practice of the roof of the traditional residence of Jiaju Tibetan Village is to lay 150-200mm thick loess on the hay and shoot it. In the course of use, if it is found to be leaky, it will be renovated and a layer of yellow mud will be placed on it for the maintenance work. The above-mentioned practices have led to serious safety hazards on the thick soil of the roof. Therefore, in

recent years, people have abandoned this traditional method and directly made a 30mm thick cement board on the roof to prevent water, but the insulation performance has not improved. Therefore, when the transformation is carried out, the loess should be eradicated to reduce weight and a straw board or the like may be added as a heat insulation layer, as shown in Fig. 1. By comparing and analysing the reconstructed roof and the original roof, the heat transfer coefficient of the original building roof is 0.62 W/(m²·k), and the heat transfer coefficient of the roof after the transformation is 0.42 W/(m²·k) which meets the energy-saving design standard of residential buildings in cold regions. And it is not difficult to find that the thermal insulation performance of the roof after the transformation has been greatly improved.

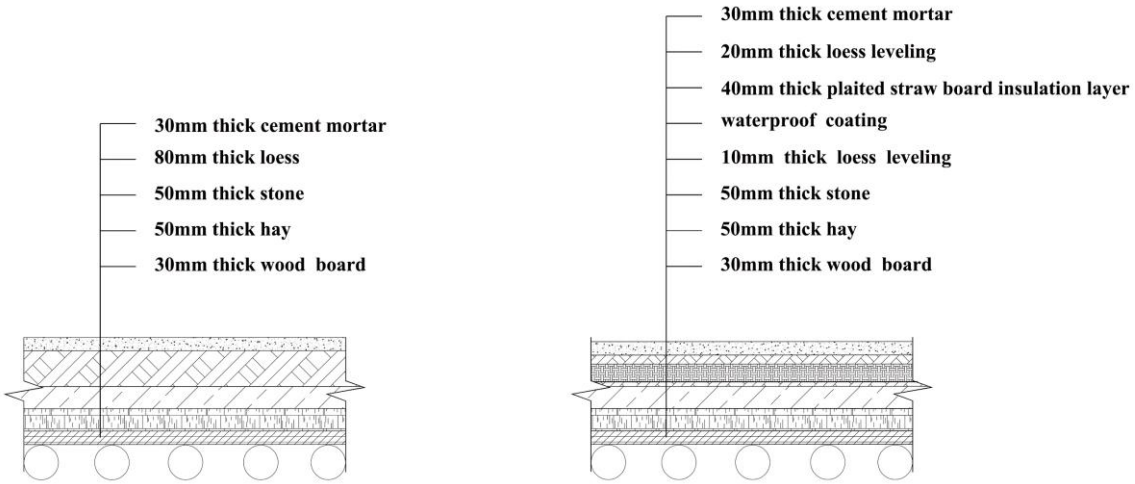

Figure 1. Comparison of roof construction before transformation（left） and roof construction after transformation（right）

3） Door and window renovation strategy

The opening windows of the traditional dwellings in Jiaju Tibetan Village are generally little and small. On the one hand, it can prevent thieves and beasts in the past, on the other hand, it can reduce the heat exchange between the room and the outdoor. After investigation, most of the residential buildings have a window-to-wall ratio of 0.08 in the south and east. Although it helps the room to keep warm, it also causes problems such as lack of room air and lighting. For newly built dwellings, the window area can be appropriately increased to improve the indoor environmental quality. For existing dwellings, stone walls cannot be opened arbitrarily. Therefore, the area of doors and windows on the stone wall cannot be changed. It can only improve its airtightness to prevent cold air from invading and improve its own thermal insulation performance and reduce the energy consumption of temperature difference.The airtightness can be increased by adding a sealing strip at the joint between the door and the wall of the existing dwelling house or filling the gap with putty and fibrous material. It is also possible to add a second layer of glass to the single-layer window and a transparent plastic film on the inside of the window frame to reduce the heat transfer coefficient of the window. For the door and window openings on the wooden wall, the insulation performance can be increased by the above method, and the area of the window can be appropriately enlarged or a partial glass member can be used to increase the natural lighting of the room.

3.2.3 Utilization of solar renewable energy utilization. Solar energy refers to the solar radiant energy, which is a new type of energy that is safe, efficient and inexhaustible. The Danba area has sufficient light throughout the year, but the local residents still use the solar energy in the basic stages of drying the grain, solar water, and solar panels, which have no significant impact on the light and heat environment of the building. In the subsequent renovation process, the interior layout and architectural form of the building can be appropriately adjusted. The roof can be surrounded by a glass structure to

form a "sun room" in the form of a simple space to enhance the heat storage capacity of the roof and store more solar radiation energy during the day.

Biomass energy refers to various types of organisms produced by photosynthesis using the atmosphere, water, land, etc. It is actually a converted form of solar energy which is stored in the interior of biomass and a renewable resource that can be used forever. In the local residential buildings, there is generally a collection of excreta. In the collection of excreta, simple fertilizers and biogas are made from biological manure and straw. However, there are certain safety risks and health problems in this kind of practice. In the subsequent transformation process, some simple straw gasifiers can be set to more effectively manufacture flammable gas. Biogas digesters can also be used to convert manure and straw into higher quality energy sources without damaging the building's gas environment.

4. Conclusion

After a long period of evolution, the traditional residences of Jiarong Tibetans finally formed the existing model. The thick stone walls, the sturdy form and the beautiful decoration are not only the embodiment of the national culture, but also the adaptation of the building to the local ecological environment. This paper analyzes the current situation of the Jiaju Tibetan dwellings in Jiarong. When discovering the problems, it also extracts some ecological adaptive design techniques, and on this basis, puts forward some new transformations based on the concept of ecological energy conservation. The strategy hopes to provide reference for the transformation and design of the traditional houses of Jiarong Tibetans.

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