

Original Paper

Study on the Disaster Prevention Capacity of Residential Buildings in Enyang Ancient Town

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Received: May 22, 2023

Accepted: Jun 23, 2023

Online Published: July 03, 2023

doi:10.22158/se.v8n3p33

URL: <http://dx.doi.org/10.22158/se.v8n3p33>

Abstract

In the background of protecting the development of historical and traditional cultural buildings, the exploration of disaster prevention technology of ancient town buildings is of great significance. Enyang ancient town has a long history, and its residential buildings have typical Ming dynasty and Qing dynasty architectural features and regional characteristics of northeast Sichuan. Enyang ancient town has experienced many natural disasters such as floods and earthquakes in its history, and the disaster resistance of its residential buildings is worth exploring. Taking the dwellings in Enyang Ancient town as the research object, its architectural space form and architectural structure are analyzed. On this basis, the flood resistance, earthquake resistance and fire resistance of the ancient town's residential buildings were further studied. The research results can provide reference for the analysis of disaster prevention performance and reinforcement protection of similar ancient towns.

Keywords

Enyang ancient town, column and tie construction, flood resistance, earthquake resistance, fire resistance

1. Introduction

Enyang ancient town is located in Enyang District, Bazhong City, Sichuan Province. The whole town is located in the shallow hills of Bashu due to its well-developed water transportation. Once a famous trade town in northeastern Sichuan, it also has a typical “Hu-guang fills Sichuan” background of the immigrant town. A large number of traditional buildings from the Ming and Qing dynasties survive in the town, with distinctive features of the BaShu culture and rich historical and cultural resources, making it a representative traditional water terminal town in the northeastern Sichuan basin with great research value. The ancient town of Enyang is adjacent to the Enyang River and has experienced many large flood

disasters throughout its history, but it is still intact and has never experienced a major fire in its history [2]. In addition, the ancient town is close to Sichuan, Gansu, and other earthquake-prone areas; its straight-line distance with Wenchuan, Lushan, Zhouqu, and other places is less than 500 kilometers, subject to more earthquake disasters, but the residential houses are less affected. In summary, the disaster prevention capacity of ancient towns is closely related to their geographical location, residential structure, and other factors, which are worth further exploration. The related research can provide a reference for disaster prevention and mitigation research of similar ancient buildings and also provide a basis for disaster prevention design of new buildings.

At present, several scholars have conducted studies on the spatial form, architectural features, and cultural tourism of Enyang ancient town. Huang studied the overall form of Enyang ancient town and the formation and evolution of the spatial form of the town, summarizing the characteristics of the overall spatial form of the town and also analyzing the cultural background, spatial layout, and architectural structure of the local traditional architecture. Xie takes the Enyang ancient town as the research object and discusses the development of tourism and the protection of cultural resources in the ancient town from the perspective of cultural tourism development. Liao and Liu summarized the architectural elements, structural shape, and landscape design points of the Qifeng Corridor Bridge in Enyang ancient town, providing experience for the design of the same type of bridge. Although some achievements have been made in scientific research on the Enyang ancient town, there is still a lack of research on its disaster prevention capabilities.

In summary, in the context of the vigorous development of tourism in Enyang Ancient town, it is of practical significance to explore in detail its disaster prevention capability for the architectural conservation and sustainable development of Enyang ancient town. This paper first summarizes the architectural overview of Enyang ancient town, the structural characteristics and structural forms of residential buildings, and then analyzes in detail the disaster prevention characteristics of residential buildings in the ancient town from three aspects: flood resistance, earthquake resistance, and fire prevention. The research results can provide references for the conservation of ancient town buildings and the design of new column and tie construction buildings.

2. Overview of Enyang Ancient town Architecture

2.1 The Current Status of Residential Houses in the Ancient Town

The architecture of Enyang ancient town has strong Ming and Qing architectural features, typical of the northeastern Sichuan residential style. The buildings are laid out in accordance with the mountainous terrain, and the roads are paved with green stone slabs. The original area of the ancient town was more than 1 square kilometer, although repeatedly eroded. There are still 0.5 square kilometers of well-preserved ancient buildings of the Ming and Qing dynasties; the streets are crisscrossed in a “grid” compound street space pattern; the old street and Dragon Street are still intact traditional patterns; there are better preserved 3 main streets, 18 alleys, 598 ancient courtyards, ancient houses, and 82,200 square

meters of construction area. Residential architecture is the most common type of traditional architecture within the ancient town, and its spatial form, architectural structure, and decorative structure can reveal the local historical and cultural characteristics and regional features of the ancient town.

2.2 Spatial Form of Ancient Town Buildings

Enyang ancient town is a gently sloping ancient town, the buildings are mostly arranged along the contour line, the overall shape of the plane shows a grid layout and direction according to the terrain, the streets are in a circular shape, and many lanes grow in dispersion, relying on water transportation to create the basic skeleton of the whole town, so the space of the town shows the characteristics of “loop space”. The topography of the ancient town is tortuous and complex, and the streets follow the direction of the mountain, using stairways and steps to deal with the difference in terrain, forming a high-low, free and lively street interface that is integrated and symbiotic with the surrounding environment. The spatial form of the streets and alleys shows great differences depending on their spatial location and function. The main street and the water terminal passenger and freight streets are flat and open, while the small alleys for residents are compact and narrow, and the height difference between the river side of the ancient town is large, forming a high and low stilt building, as shown in Figure 1.



Figure 1. Spatial Pattern of Streets and Alleys in Ancient Towns

2.3 The Structure and Construction Form of Ancient Town Buildings

Enyang ancient town, as a typical Basho town, the traditional residential houses are mainly wooden structures, generally using bucket-beam structures. Large halls such as Yuwang Palace and Wanshou Palace also use column and tie construction structures, and there are still some stilt buildings located in the riverfront area. As the ancient town is located in the subtropical monsoon climate zone, with humid and rainy summers, its buildings have structural characteristics such as permeability, moisture resistance, and strong functionality. The traditional dwellings in the ancient town use sloping roofs, with the majority of overhanging roofs and a small number of flush gable roofs interspersed. The roofs are lined with small green tiles, the eaves are raised, the ridge is decorated, and the exterior walls are mostly made of vermilion woodwork and white bamboo clay walls.

2.3.1 The Main Load-Bearing Structure

Most of the residential buildings in the ancient town use traditional wooden frame load-bearing structures, and the post and lintel construction and column and tie construction types are the most common. The arrangement of the wood frame through the bucket is shown in Figure 2.



Figure 2. The Column and Tie Construction

2.3.2 The Enclosure Structure

The enclosure structure of Enyang ancient town's residential buildings includes panel walls, bamboo-woven mud walls, brick walls and rammed earth walls, as shown in Figure 3. The bamboo-woven mud walls are the most commonly used, which is made of locally produced bamboo strips to form a skeleton, and then filled with the fermented straw mud mortar. The material of bamboo wall is easy to obtain and the production process is simple.



Figure 3. The Form of Enclosure Structure of Residential Houses in Enyang Ancient Town

2.3.3 Roof Structure

The sloping roof of the ancient town building is dominated by the overhanging gable roof, with a small amount of flush gable roof. Many rafters are placed vertically on the purlins, and materials such as bamboo net and yellow mud are laid between the purlins and rafters to increase the bonding and

compactness between the members, and then small green tiles are laid on top of the rafters. Most of the residential buildings have no arch and few eave decorations, as shown in Figure 4.



Figure 4. Roof Detail Construction

3. Analysis of Disaster Resistance of Residential Buildings in Enyang Ancient Town

3.1 Flood Resilience Analysis

3.1.1 The Influence of Spatial Form of Enyang Ancient Town on Flood Resilience

Enyang ancient town as a whole extends outward in accordance with the mountain trend, showing a gradually decreasing trend from the high ground to the river, as shown in Figure 5. The streets are generally paved with stone slabs, and the road surface slopes slightly on both sides horizontally to form a gentle slope. There are also independent drainage ditches under the streets, so that rainwater falling on the street surface follows the steps and the slope of the terrain to gather at the intersection and form an organized drainage.



Figure 5. Street Form of Enyang Ancient Town

3.1.2 The Influence of Residential Building Construction on Flood Resilience

Most of the residential buildings in Enyang ancient town are made of column and tie construction. The columns are floating on the supports, and the whole building is fixed only by the horizontal friction between the legs of the columns and the supports, which allows the columns to tilt under the impact of flooding without breaking the columns and causing a total collapse. The tenon-mortise joints of the column and tie construction are mostly straight mortise and tenon, and are not fastened, which leaves space for the tilt of the house and is not easy to collapse directly under the impact of flood.

3.1.3 The Influence of Construction Materials on Flood Resilience

Most of the traditional houses in the ancient town are made of wood as a whole structure, and the walls are made of bamboo-woven mud walls, as shown in Figure 6. Bamboo is abundant in the Enyang area, and bamboo is easy to obtain, so bamboo-woven mud walls are more commonly used. The bamboo strips are prepared and set firmly, and then the straw mud mortar is smeared on the bamboo net after wetting it to form the bamboo-woven mud wall. The straw mud mortar is made by fermenting local yellow mud and adding straw and husk, and the straw mud mortar can be firmly adhered to the bamboo weaving grid. When a small flood comes, the toughness of the bamboo woven mud wall can effectively resist the impact of the flood. In the case of larger floods, the mud will be scattered after a long period of immersion, and the floodwater can pass through the bamboo-woven grid, which reduces the impact of the flood on the house frame. After the flood, the wall can be repaired by reapplying the straw mud mortar, which is a simple process.



Figure 6. The Bamboo-Woven Mud Wall

3.1.4 The Influence of Drainage Facilities on Flood Resilience

There are no obvious drains inside the houses and streets of Enyang ancient town, and the drainage facilities are hidden underground. Most of the traditional houses in the ancient town have large roofs and shallow patios, which facilitate the collection of rainwater to the floor drains in the patios, and the rainwater is discharged to the outside of the house through underground drains. The water in the house is collected into the culvert through the sewer inside the house, and the rainwater in the street flows into the culvert through the gap between the stone slabs and finally converges into a general drainage

ditch to discharge rainwater and sewage to the Enyang River next to the ancient town. The traditional drainage facilities in the ancient town drain effectively and do not take up surface space.



Figure 7. Drainage Gaps

3.2 Analysis of Seismic Capacity of Residential Buildings in Enyang Ancient Town

The building structure of traditional dwellings in Enyang ancient town is dominated by the beam-column structure, which is characterized by the skeleton providing lateral movement resistance stiffness. Wooden frame nodes mostly use dovetail joints. Wooden frame nodes mostly use dovetail. Dovetail nodes can increase the overall ductility of the building structure, reducing the stress in the structure during an earthquake and making it less vulnerable to collapse. The column network arrangement of the traditional building plan is set reasonably. The square-column is in series with transverse wood components and forms a beam-column plane system. The beam-column combination forms a rigid node, which ensures the stability of the wood frame. The column bases of the columns on both sides of some buildings come out to the outside, while the column heads are closed to the inside. The eave tiebeam and the end of the colonnaded are connected and fixed by the Diaogua, as shown in Figure 8. The eave tiebeam, brace bow, and Diaogua form a triangular stable structure, strengthening the stability of the building structure.



Figure 8. Triangular Stabilized Structure under the Eaves

Traditional buildings in ancient towns mostly use natural wood with lighter weight and better flexibility than concrete and steel, which allows natural wood to withstand greater deformation and facilitates structural seismic resistance. Another important mechanical property of wood is its smooth grain strength is higher than the cross-grain strength. In the wood structure of the buildings, the columns, which are the main vertical force members, use the smooth-grain strength of wood, while the beam members use the cross-grain strength of wood. This structure makes the load-bearing capacity of the beam members lower than that of the column members, which reflects the idea of “strong columns and weak beams” in the seismic design of the structure.

3.3 Analysis of Fire Prevention Techniques in Enyang Ancient Town Buildings

Traditional buildings in Enyang ancient town use a variety of fire prevention measures to effectively avoid damage to the buildings. The walls of traditional residential buildings are mostly made of bamboo and wood as the basic skeleton. In order to avoid being destroyed by fire, plaster is applied on the walls to form a layer of fire protection. Under the eaves of the buildings, there are vessels for collecting rainwater, which can be used to get water to put out the fire in case of fire. Large public buildings such as Yuwang palace, Sansheng palace and Wanshou palace all use tall gable walls, which can effectively stop the spread of fire.

4. Conclusion

On the basis of clarifying the spatial morphology, the structural structure, the building materials and the drainage facilities of the Enyang ancient town, the flood resistance, earthquake resistance and flood resistance of the residential buildings were analyzed. The conclusions can be drawn as follows:

- (1) The whole Enyang ancient town extends outward in accordance with the mountain trend, showing a gradually lowering trend, which is conducive to drainage. The column and tie construction of the residential buildings can make the columns of the houses have a certain ability to resist flooding. The bamboo woven mud walls used in the residential buildings can effectively reduce the impact of flooding on the overall structure of the buildings.
- (2) The mortise-tenon joints in the column and tie construction of the ancient town increase the overall ductility of the structure and reduce the stress on the whole structure during earthquakes; the light weight of the wooden building materials is conducive to the earthquake resistance of the structure; in addition, the wooden structure of the Enyang ancient town houses shows the characteristics of “strong columns and weak beams”, which is conducive to the improvement of the earthquake resistance of the structure.
- (3) In terms of fire resistance technology, the walls of residential buildings are coated with a layer of plaster to form a fire protection layer; the vessels for collecting rainwater are set under the eaves of the buildings, which can be used to get water to put out the fire when a fire occurs; some buildings use tall fire sealing walls, which can effectively stop the spread of fire.

Acknowledgement

This work was supported by Open Foundation of the Research Center for Human Geography of Tibetan Plateau and Its Eastern Slope (Grant No. RWDL2022-YB003).

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