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A study on the structural characteristics of wind and rain bridges in the Zijang River Basin, Hunan, China

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Abstract: *As one of the important architectural types in ancient China, the wind-rain bridge, whose architectural structure shows the wisdom and superb construction level of the ancients, has important research value. Hunan wind and rain bridge has a long history .This paper takes the wind and rain bridge in the Zijang river basin of Hunan Province, China, as the object of study. Based on field research, mapping and data review, we investigate the characteristics of the structure of the wind and rain bridge in the Zijang river basin, analyze its scientific structure, and interpret the structural characteristics of the wind and rain bridge in the Zijang river basin.*

Keywords: *Wind and rain bridges, Zijang river basin, Distribution, Tectonic features*

1. Introduction to Wind and Rain Bridge

As Wind and rain bridge is a perfect combination of bridge and architecture, built on the bridge deck or like a tower-like drum tower bridge pavilion both for people far away from the wind and rain, and can supply tea for people to rest and enjoy the river view, this bridge covered with porch house, set bridge, pavilion, corridor three as one of the special bridges is the wind and rain bridge, also known as the porch bridge, pavilion bridge, flower bridge, bridge of blessing, rainbow bridge, centipede bridge, etc. [1] (Figure 1).

Wind and rain bridges have a high practical and artistic value, not only as bridges for transportation, but also as places for people to exchange and gather, each playing multiple important roles: they are places of rest, temples for worship, markets for trade, and platforms for entertainment and welcome. In addition, the wind and rain bridge is a landmark in the traditional settlement, a spiritual home, a link to unite the villagers, a corridor to spread culture, and a carrier of nostalgia.

Wind and rain bridges are more widely distributed in China, and at present, more of them are still preserved in 15 provinces, including Zhejiang, Fujian, Jiangxi, Hunan, Guangxi, and Guizhou[2], [3]. Among them, Hunan wind and rain bridge has a unique personality and temperament, in the layout, selection, materials and decoration and other aspects of high achievement, both in the use of structure, architectural modeling and its own cultural connotations have shown strong diversity and regional, showing the excellent wisdom and exquisite skills of the ancient wind and rain bridge makers in Hunan, reflecting the unique historical heritage of Hunan culture [1], because of its excellent materials and The scientific structure of the wind and rain bridge has survived for centuries.

2. Distribution of wind and rain bridges in the Zijang river basin in Hunan

Zijiang River, a tributary of Yangtze River, also known as Zishui, is an important part of the Dongting Lake water system and one of the four waters of Hunan (four waters: Xiangjiang River, Zijiang River, Yuanjiang River, and Li River, which are the components of the Dongting Lake water system, crisscrossing the whole territory of Hunan and finally flowing into Dongting Lake, and the wind and rain bridges are distributed in the watershed of these four waters). The left tributary of Zijang River is Blushing Water, which originates from Beicheng Mountain in Chengbu Miao Autonomous County, while the right one is Fuyi Water, which originates from Yuechengling in Guangxi Resources County.The two waters converge at the mouth of Shuangjiang in Shaoyang County and are called Zijang River, which flows through Shaoyang, Xinhua, Anhua, Taojiang, Yiyang and other cities and counties, and is injected into Dongting Lake at Ganxi Port in Yiyang City, with a total length of 653 km and a watershed area of

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28,142 km^2 [4].

The number of wind and rain bridges in Hunan is large, and our team has been studying the statistics since 2014, and there are still 239 surviving ones in Hunan [4], which are distributed in all four waters (Figure 1), and the distribution is related to economic geographic factors such as ancient transportation road maps (for example, the ancient tea horse road), average precipitation in various places, population density, and GDP data [5]. The largest number of wind and rain bridges in the Zijang River basin (Figure 2), with 115 existing wind and rain bridges, 29 in Yiyang, 28 in Loudi, and 58 in Shaoyang (Table 1). In terms of topography and geomorphology, wind and rain bridges are mainly concentrated in small tributaries in mountainous and hilly areas, where the threat of flooding is relatively small, relatively easy to build, and easier to maintain and preserve [6].

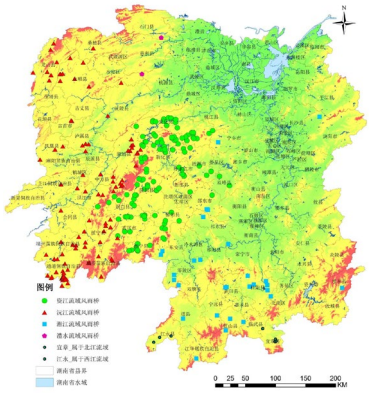

Figure 1: Hunan wind and rain bridge distribution map

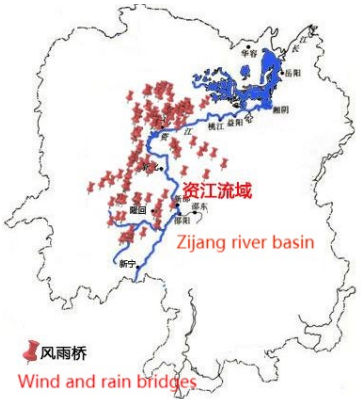

Figure 2:Google Earth-based positioning of the distribution of storm bridges

With the continuous advancement of urbanization, these wind and rain bridges face life and death situation, many wind and rain bridges in disrepair, serious damage, but also can not meet the basic needs of modern transportation and life, construction skills lost, constructive damage is serious, the integrity of the wind and rain bridge and cultural heritage was destroyed. Hunan Anhua County once claimed to have more than 200 wind and rain bridges, but currently only 29 wind and rain bridges remain. At present, the wind and rain bridge is facing a very serious survival and development problems.

Table 1: Distribution of wind and rain bridges in the Zishui watershed.

State	County	Quantity	Belongs to tributaries	Note
Yi yang	An hua	29	Zishui	
Lou di	Xin hua	26	Zishui	
	Leng shui jiang	2	Zishui	
Shao yang	Xin shao	3	Zishui	
	Shao dong	4	Shao Shui	
	Shao yang	6	Fuyi Water、Zishui	
	Xin ning	8	Fuyi Water	
	Long hui	17	Blushing Water、Zishui	
	Wu gang	6	Blushing Water、Polygon Water	
	Dong kou	14	Polygon Water	
subtotal		115		

(Note: Data source team statistics)

3. Structural characteristics

3.1. Beam frame construction

The upper porch practices of Hunan wind and rain bridge is simple and has obvious regional characteristics, thus reflecting complex variations, with raised-beam and pierced-beam practices, as well as inserted-beam frame practices [7] (Table 2).The main frame of the bridge corridor of the inserted-beam frame is four columns, five-frame beam inserted into the middle of the upper part of the two golden

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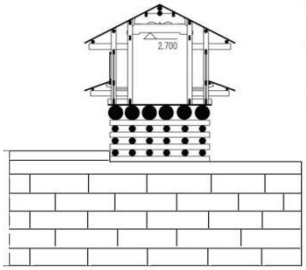
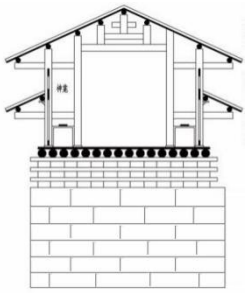
columns. Set up melon pillars on five beams to carry three beams.In the middle of the three beams set up a ridge gourd column, ridge gourd column on the top of the ridge purlins and ridge square , or use a hump on a three-frame beam, bearing ridge purlin and ridge square.The eaves column and the gold column are linked with a single-step beam, the end of the single-step beam is pressed inward under the middle three frame beams, and the eaves purlins and eaves square are picked outward, and the eaves are generally picked out directly with rafters.Most of the wind and rain bridges use columns, beams and columns are mostly made of round, beams are also made of flat, square is very common to do flat work.The bottom of the four columns are connected to the Difu, and the eaves columns are also connected to each other with Difu. The Difu, columns and three-frame beams and double-step beams form a complete frame, and the frames are connected to each other with Difu and purlins.With the use of the Difu, the structural system is complete, and the distorted and tilted practice common to wind and rain bridges elsewhere is rarely seen in the Zijang Valley. This practice of linking the columns with the Difu has good integrity, advanced structural system and better construction practices.

Table 2: Beam frame structure analysis.

Beam frame practice	Illustrations	Pictures	Examples of ancient bridges
Piercing frame			Xiaojia Bridge, Yanjia Bridge, Wolong Bridge, Youyi Bridge, Yinxi Bridge, Yanggong Bridge
Beam inserting frame			Longtan Bridge, Taiping Bridge, Xinqiao Village Bridge, Garden Bridge, Shi Rong Bridge

3.2. Beam frame construction

The central eaves are generally through-length, picked out by the sitting stool at the pick square, the inner bearing sitting stool, the outer bearing pick eaves purlin, pick square through the eaves column, the tail inserted into the gold column, the use of gold column and the upper load balance picked out the central eaves. The middle eaves are used to protect the lowest part of the bridge body, outside to protect the bridge deck beams (dragon wood), inside to protect the bench (Figure 3, Figure 4).In the architectural modeling, the central eaves also play a role in enriching the building facade modeling, and the upper large roof together, the central eaves make the roof of the wind and rain bridge has close to the effect of heavy eaves. The central eaves are also occasionally picked out with a seven-character pick (Figure 5).The so-called seven-character pick, that is, the upper and lower each with a Tiaofang pick out, the next Tiaofang pick out from the sitting stool, its jumping head stand a short column, short column head and on a Tiaofang head each bearing a purlin, from the side of the shape of the Chinese character "seven", so the name seven-character pick.Only one example is seen in Xinhua Sun Village Bridge, where the central eaves are significantly higher and the projection is slightly larger.

3.3. Sitting stool

Sitting stool set between the eaves column and the gold column, generally by supporting the central eaves of the pick square bear, but also pick out the central eaves play a certain role in the pressure of the

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weight (Figure 6).In addition to encountering a shrine, it is also set from the beginning to the end and in every opening for pedestrian rest. Sitting stools and central eaves generally appear in pairs, but while sitting stools are generally set up, central eaves are not necessarily set up (Figure 7).

Figure 3: Anhua Xiaojia Bridge

Figure 4: Anhua Madu Bridge

Figure 5: Xinhua Sun Village Bridge

Figure 6: Xinhua Yongzhen Bridge

Figure 7: Anhua Muzi Bridge

3.4. Rain Barrier

Zijiang River basin wind and rain bridge corridor mostly open and semi-open, if the upper window grille distribution is dense, as well as the upper windows grille to do the rain barrier, it becomes a semi-enclosed bridge corridor.At this time, the main purpose of setting up rain barriers is to protect the upper windows, and even the entire bridge corridor, from the wind and rain (Figure 8 and Figure 9), although the number of such barriers is small and is occasionally seen in the Anhua County area.The rain barrier is mainly set in the lowest part of the bridge corridor, generally flush with the magpie wood and bridge deck girders, effectively protecting the bridge deck wood structure and bridge deck girders (Figure 10, Figure 11).Some of the lower rain barriers are taller, reaching a height of about 1.5 m, and they are set to accommodate the length of the magpie wood when set.Anhua Sixian Bridge lower rain board in the upper and lower water on both sides are set (Anhua Sixian Bridge after renovation, the bridge deck beams into a reinforced concrete, rain board only architectural images on the meaning), this practice is not much (Figure 11), most of the wind and rain bridge in the lower water side of the rain board, may have feng shui on the role of hiding wind and gathering gas.

3.5. Protective Wall

The wall is generally built in the ship-shaped pier, mostly brick wall or stone wall, the length does not exceed the ship-shaped pier, the height and bridge deck beam basic level, and the rain board together, has a certain role in blocking the wind, rain, used to protect the magpie wood and bridge deck beam, but

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the role is limited, so only a little wind and rain bridge masonry.The parapet wall is built at the end of the pier (Figure 12), but also at the head of the pier (Figure 13); built at the head of the pier, and the water splitting tip together into the shape of a ship's cabin. Very few pier head, pier tail are built retaining wall, such as the Shiyi Bridge, Yong xi Bridge.

Figure 8: Anhua Wanshan Bridge

Figure 9: Anhua Shiyi Bridge

Figure 10: Anhua Shiyi Bridge

Figure 11: Anhua Sixian Bridge

Figure 12: Anhua Shiyi Bridge

Figure 13: Anhua Fuxing Bridge

3.6. Partition Wall

Because the bridge corridor is more open, the partition wall is not done much, usually only part of the location, such as the middle of the shrine, more made of wooden partition walls, but also made of woven bamboo clip mud wall, such as the Putang Bridge, Lake Bridge, etc., there are some improperly repaired, converted into brick walls. Putang bridge shrine is a wooden partition wall, both sides of the shrine made of woven bamboo clip mud wall, the inner surface painted, used to inscribe poems, records, etc. (Figure 14).The partition walls of the pavilion in the middle of the lake bridge is typical of the woven bamboo clay wall practice, the wooden wall accounts for a relatively high, woven bamboo clay wall is relatively small (Figure 15).

Figure 14: Long Hui Putang Bridge

Figure 15: Long Hui Lake Bridge

3.7. Roofing

The roof is mostly covered with small green tiles, and the tiles are hung directly on the purlins without

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making roofing panels. When the folk carry out simple maintenance, generally is also to overhaul the roof tile made to prevent leakage. Small green tile is the ordinary butterfly tile, the size is similar, generally 140x160 mm. There are very little wind and rain bridge will be burned on the tile text, such as Xinning Taiping Bridge and Dragon Bridge, Taiping Bridge tile has "Taiping" two characters (Figure 16), Dragon Bridge tile has "Dragon Bridge "three characters (Figure 17), inscriptions, each word an inch square, tile burned text is currently only seen on these two examples.

Figure 16: Xinning Taiping Bridge

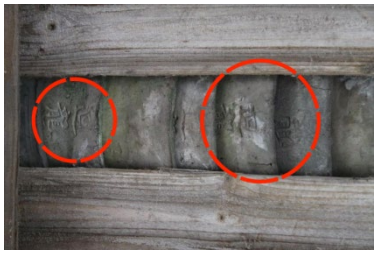

Figure 17: Xinning Huilong Bridge

4. Conclusions

As the material wealth and cultural heritage of the Chinese people, the Wind and Rain Bridge has a unique structure, complex construction methods, and exquisite construction techniques.This paper takes the wind and rain bridge in the Zijang River basin of Hunan Province as the object of study, and through field research, mapping and review of historical data, the following conclusions are drawn：

The structure of wind and rain bridge in Zijiang basin in Hunan is composed of main parts such as beam frame, central eaves, sitting stool, rain barrier, retaining wall, partition wall, roof, etc. The same structure has different practices in different regions, integrating local folk customs in Hunan, with obvious regional characteristics, reflecting the unique local construction level and construction techniques, with good artistic and scientific values.

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