Wooden Cantilever Covered Bridges in Anhua, China

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Wooden cantilever covered bridges are known for their marvelous shapes and manufacturing technique. Many wooden cantilever covered bridges were constructed during Ming and Qing Dynasties in Anhua province, China, due to the "Tea-Horse Trade" policy. The excellent performance of wooden materials and exquisite building techniques have kept these wooden bridges well-preserved and worthy of investigation. This paper conducted a comprehensive review of wooden cantilever covered bridges in Anhua, especially for the eight bridges listed as historical and cultural heritage protected at the provincial or the national level. The discussions covered the historical background of the bridges, their locations and dimensions, and the details of their structures including the cantilever systems, corridors, and roofs. Moreover, the cultural background was introduced to better understand the meaning of the decorations carved on the bridges and the logic of location selections.

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INTRODUCTION

China's ancient wooden bridges show a small corner of the splendid Chinese culture and history. In Anhua county, Hunan province, some ancient wooden covered bridges were constructed with the local pines in Ming and Qing Dynasty thanks to the "Tea-Horse Trade" policy. Attracted by the high quality of dark tea planted in Anhua, it was categorized by the government as the official tea in 1595 A.D. and the relative policy named as "Tea-Horse trade" had been implemented, to serve the demands of tea from the officials and the civilians in the Northwest of China, as well as to exchange horses in return to maintain the capacity of trade (Chen 2010). Until then, local residents did not travel frequently, given the poor road conditions in this mountainous county. In order to meet the business objectives, wooden cantilever covered bridges were constructed by the natives and the nearby natural resources were utilized, especially the wood and stone. Wood, naturally planted everywhere in this mountainous county, is naturally a great raw material for bridge constructions given its characteristics of being light, strong, and highly energetically dissipative (He *et al.* 2016; Xie *et al.* 2017). The application of wood in that time also laid the ground to create imaginative building techniques. After the constructions were completed, the business could be smoothly set up and the Anhua dark tea firstly being transported to the Northwest of China through the "Ancient Tea-Horse Road" and to exchange the horses in return.

Until now, only 29 wooden cantilever bridges have been preserved and categorized as heritage, to show the necessity and urgency for preservation. The geographical location of these bridges is presented in Fig. 1.

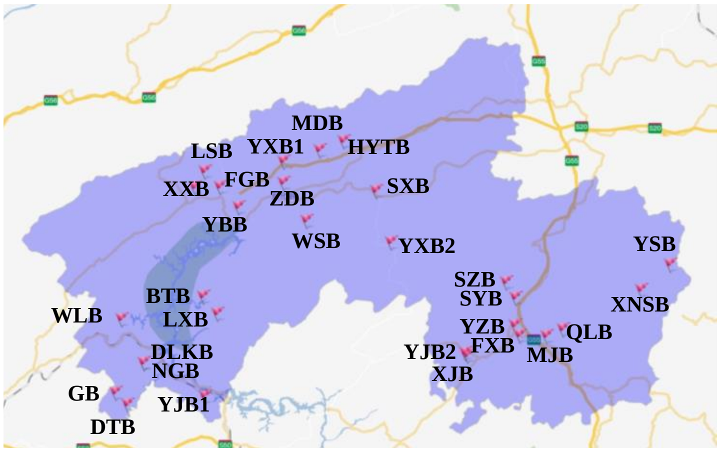


Fig. 1. Geographical location of 29 wooden cantilever covered bridges in Anhua. BTB: Baotai bridge, DTB: Datang bridge, DLKB: Dalinkou bridge, FGB: Fugu bridge, FXB: Fuxing bridge, GB: Gao bridge, HYTB: Hongyantang bridge, LSB: Leshan bridge, LXB: Liexi bridge, MDB: Madu bridge, MJB: Mujia bridge, NGB: Nanguan bridge, QLB: Qilong bridge, SXB: Sixian bridge, SYB: Shiyi bridge, SZB: Shizhong bridge, WLB: Wolong bridge, WSB: Wanshan bridge, XJB: Xiaojia bridge, XNSB: Xianniushi bridge, XXB: Xiaoxi bridge, YBB: Yaoba bridge, YJB1: Yangjia bridge, YJB2: Yanjia bridge, YSB: Yongsheng bridge, YXB1: Yixi bridge, YXB2: Yongxi bridge, YZB: Yanzi bridge, ZDB: Zhendong bridge

Typically, a covered bridge incorporates four components: stone piers, wooden beams, wooden corridors and a traditional Chinese roof, in accordance with the construction process. Firstly, stones from the nearby mountains are chosen for rhombus stone piers. Then, wooden cantilever beams are arranged on top of those piers and being worked as the major structural components. On wooden cantilever beams, a wooden corridor is designed for passersby to rest and to shelter from rain and storms. On top of the bridge, a typical Chinese traditional roof is always placed, where the configuration of roof generally reflects the hierarchy.

In this paper, eight wooden covered bridges categorized as heritage are thoroughly discussed. Coverage of the discussion ranges from the historical background to the locations and dimensions, as well as the details of the structures including the cantilever systems, the corridors and the roofs. In addition, the cultural background reflected on the bridges was also introduced.

STRUCTURAL DIMENSIONS

In this section, the eight most representative wooden cantilever covered bridges are introduced as follows.

Fugu Bridge

Fugu Bridge, shown in Fig. 2, was firstly built in 1907 and the latest maintenance ended in 2020. It also has been listed as a historical and cultural heritage protected at the national level. It is composed of three spans with respect to the lengths of 9.8 m, 7.4 m and 12.85 m, as well as with the widths of 3.87 (2.33+0.77×2) m, two stone piers and two stone abutments. The bridge deck and upper corridor are carried by six simply supported beams in every span, where they are all over the top of a cantilever system composed of six crossed layers of wooden beams. On the bridge deck, the corridor with the height of 4.00 m was designed to let pedestrians and horses pass through. A highly artistic flush gable roof with grey tiles was designed to drain the rain in order to protect the wooden bridge from damage and decay.

Fig. 2. Photograph of Fugu Bridge

Fuxing Bridge

Fuxing Bridge shown in Fig. 3 is also known as Luoma Bridge. It was firstly fabricated in 1887 during the Qing Dynasty and has been listed as a historical and cultural heritage protected at the provincial level. Having experienced the long-time service and wet climate, it was repaired three times in 1930, 1997, and 2015, respectively. It comprises of three spans with the lengths of 15.1 m, 12.2 m, and 14.5 m, respectively, and a deck with the width of 3.65 m. For each span, the bridge deck and upper corridor are carried by six simply supported beams, where they are over the cantilever system, a system being composed of five crossed layers of wooden beams. Two stone piers and two stone abutments are used altogether to support the cantilever systems and the whole upper structures. The corridor with a flush gable roof and grey tiles is with the height of 3.85 m and is separated into three parts in its lateral direction, with the width of 0.7 m, 2.25 m and 0.7 m respectively.

Fig. 3. Photograph of Fuxing Bridge

Madu Bridge

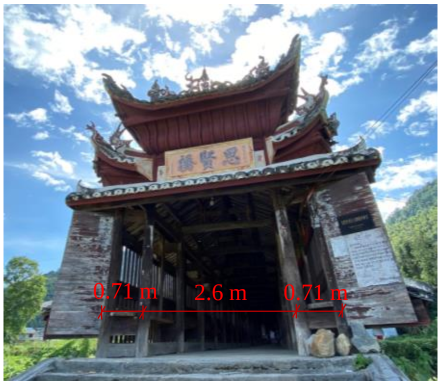
Madu Bridge, shown in Fig. 4, comprises of three spans with respect to the lengths of 16.3 m, 14.5 m, and 16.7 m, and a deck with the width of 4.02 (2.6+0.71×2) m. The bridge was debuted in 1917 and has been listed as a historical and cultural heritage protected at the national level. For each span, five simply supported beams are arranged over the cantilever system to support the bridge deck and upper corridor, where each cantilever system is composed of five crossed layers of wooden beams. Two stone piers and two stone abutments are used altogether to support the cantilever systems and whole upper construction. The corridor with a flush gable roof and grey tiles is with 4.15 m height.

Fig. 4. Photograph of Madu Bridge

Sixian Bridge

Sixian Bridge, shown in Fig. 5, was built in 1917. It comprises of three spans, with respect to the lengths of 16.3 m, 14.5 m, and 16.7 m, and a deck with the width of 4.02 m. For each span, the bridge deck and upper corridor are carried by five simply supported beams over the cantilever system being composed of five crossed layers of wooden beams. Two stone piers, together with two stone abutments, are used to support the cantilever systems and the whole upper construction. The corridor, with the height of 4.15 m, comprises three parts with the widths of 0.71 m, 2.6 m, and 0.71 m in its lateral direction. A flush gable roof with grey tiles represents the notable characteristics of the bridge.

(a) front view



(b) side view

Fig. 5. Photographs of Sixian Bridge

Shiyi Bridge

The Shiyi Bridge, shown in Fig. 6, was put into use in 1887 during Qing Dynasty and refurbished in 2017, and has been listed as a historical and cultural heritage protected at the provincial level. It comprises of four spans, with the length of 14.7 m, 12.7 m, 16.3 m and 13.9 m, and a deck with the width of 3.93 m. For each span, the bridge deck and upper corridor are carried by two layers of simply supported beams over the cantilever system, and six wooden beams are arranged in each layer. The cantilever system is composed of six crossed layers of wooden beams, supported by three stone piers and two stone abutments. A flush gable roof with grey tiles is fabricated on the corridor frame with its top distance of 3.7 m to the bridge deck.

Fig. 6. Photograph of Shiyi Bridge

Yanzi Bridge

The Yanzi Bridge has been listed as a historical and cultural heritage protected at the national level. It was firstly built under the governance of Qianlong Emperor of the Qing Dynasty, and rebuilt in 1822, the year under the governance of Daoguang Emperor of the Qing Dynasty. In 2019, the refurbishment took place due to aging and wet climate. As shown in Fig. 7, it comprises of three spans, with the lengths of 9.6 m, 10.7 m, and 10.9 m, and a deck with the width of 3.77 m. For each span, the bridge deck and upper corridor are carried by six simply supported beams over the cantilever system composed of six crossed layers of wooden beams. The cantilever systems are arranged on two stone piers and two stone abutments, where the relative loads are transferred to the foundation. The corridor is with the height of 3.65 m and a flush gable roof with grey tiles is fabricated on top of the bridge.

Fig. 7. Photograph of Yanzi Bridge

Yixi Bridge

Yixi Bridge, shown in Fig. 8, was built in 1898, the duration under the governance of Guangxu Emperor of the Qing Dynasty, and it has been listed as a historical and cultural heritage protected at the provincial level. It comprises of four spans with the lengths of 18.2 m, 15.3 m, 17.65 m and 17.85 m, and a deck with the width of 3.8 (2.5+0.65×2) m. For each span, the bridge deck and upper corridor are carried by seven simply supported beams over the cantilever system, a system composed of five crossed layers of wooden beams. The cantilever systems are arranged on three stone piers and two stone abutments, from which the relative loads are transferred to the foundation. The corridor is 3.94 m height is fabricated under a flush gable roof with grey tiles.

Fig. 8. Photograph of Yixi Bridge

Yongxi Bridge

Yongxi Bridge, shown in Fig. 9, was built in 1878, the year under the governance of Guangxu emperor of the Qing Dynasty and it has been listed as a historical and cultural heritage protected at the national level. The Yongxi Bridge comprises of four spans, with the lengths of 17.26 m, 18.60 m, 17.80 m, and 15.65 m, and a deck with the width of 3.75 (2.35+0.7×2) m. For each span, the bridge deck and upper corridor are supported by seven simply supported beams over the cantilever system composed of six crossed layers of wooden beams. The cantilever systems are arranged on three stone piers and two stone abutments, from which the relative loads are transferred to the foundation. A flush gable roof with grey tiles is fabricated on top of the corridor with the height of 3.94 m.

Fig. 9. Photograph of Yongxi Bridge

DETAILS OF MAIN STRUCTURES

Stone Pier

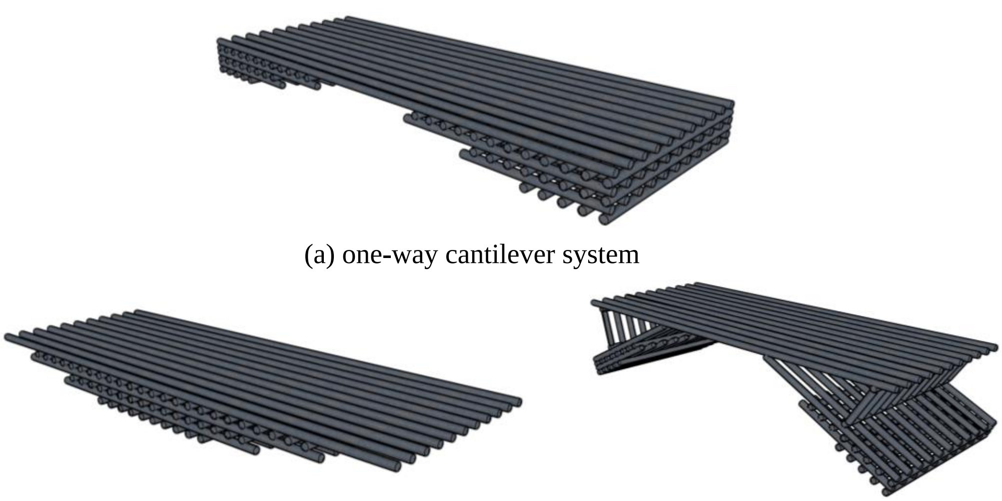
To protect the bridges from floods, rhombus stone piers were constructed in the river (Fig. 10). In spite of using the stone piers as the support, all the bridges were constructed without any steel connections. The red pine planted in the nearby mountains was also utilized to build the main structures of the bridges.

(a) front of bridge piers **(b)** back of bridge piers

Fig. 10. Rhombus stone piers

Cantilever System

The earliest applications of cantilever systems were found in the Northwest of China, where these bridges are equipped without the corridor (Xiang *et al.* 2009). Typically, when faced with the narrow river, the bridge with a single span was constructed in priority, along with the one-way cantilever system used for supporting the upper structures. On the contrary, if the river was broad enough, it would be challenging to construct the multi-span simply supported bridges with piers. Instead, the two-way cantilever system was usually selected for the support. Furthermore, in order to increase the maximum length of a single span, the cantilever system with diagonal braces was also successfully developed (Mao 1985). Three types of the cantilever systems are presented in Fig. 11.



(a) one-way cantilever system

(b) two-way cantilever system (c) increased cantilever system

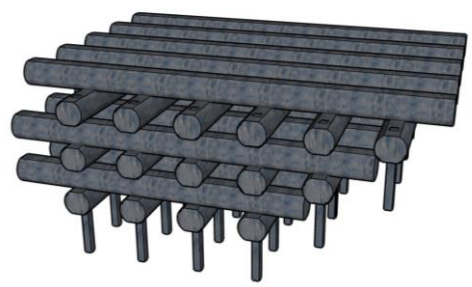
Fig. 11. Three types of cantilever systems

All the eight bridges discussed in this paper utilize the former two types of the cantilever systems. Typically, one-way cantilever beams are matched with the abutment, while the two-way counterparts are matched with the piers of the bridges. The typical cantilever systems used in the wooden cantilever covered bridges within Anhua are illustrated in Fig. 12.

(a) Cantilever system on abutment

(b) Cantilever system on pier

(c) Detail of cantilever system



(d) Wood beam arrangement

Fig. 12. Typical cantilever systems used in Anhua wooden cantilever covered bridges

Bridge Corridor and Roof

Bridge corridor, mainly used to protect the passersby from rain and storm, is also a symbol of the politics and culture, as well as a good reflection of the old feudal hierarchy (Wang 2019). Therefore, it is remarkable from the view of art and culture even if it is without being used as a part of the main structures (Liu 2017).

A corridor of a covered bridge consists of beams, columns, and joints. As shown in Fig. 13, wooden frame, one of the typical structures in ancient China, is widely utilized in Anhua bridges. For a covered bridge, a corridor contains many bays, which are divided by a series of columns in the longitudinal direction. In the lateral direction, the corridor is divided into three parts, where the middle part is for pedestrians and horses passing by and two benches are designed both on the left and right. In the covered bridges, no steel connection is used, while the mortise tenon joint connection is added to ensure the structural stability. Loads generated by wind, rain, and snow are transferred from purlin beams to the columns of the corridor, then go through the cantilever system, piers and finally reach the foundation. A typical bridge corridor used in Anhua bridges is illustrated in Fig. 14.

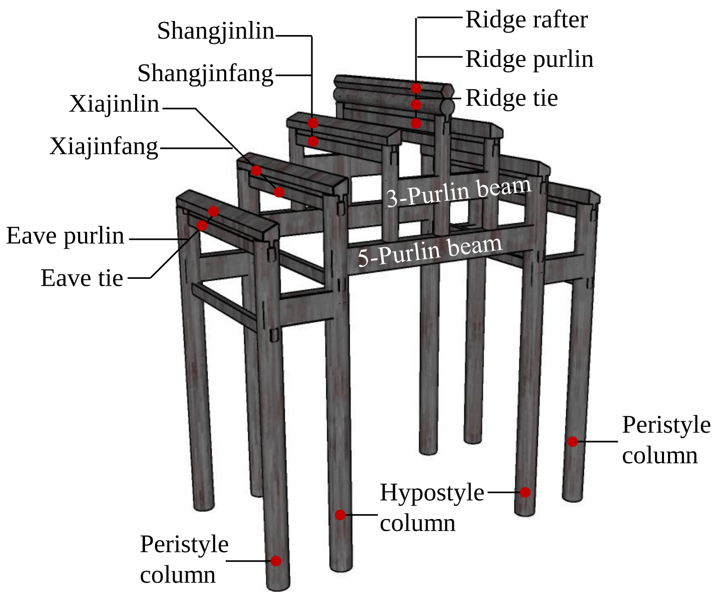
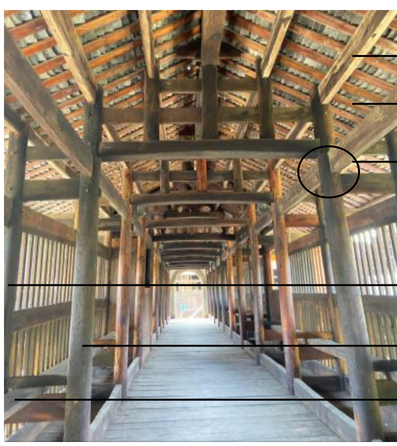


Fig. 13. Wood frame of ancient Chinese structure

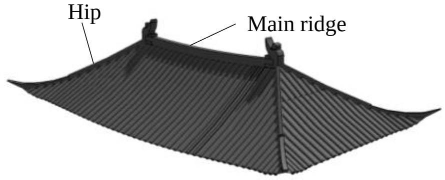


(a) Bridge corridor

(b) Detail of joint

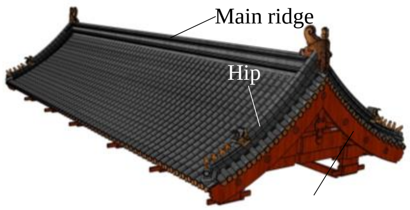
Fig. 14. Typical bridge corridor in Anhua covered bridges

On top of the corridor, the tile roof sheltered the pedestrians, protected the wood from rain and other weather conditions, and it was also for the decoration of the bridge, which was constructed usually at the end of the construction period. As presented in Fig. 15, four types of roofs were generally used in China's ancient wood architectures, Hip roof, Gable and hip roof, Overhanging gable roof, and Flush gable roof (Liang 2006; Guo 2015). In the ancient times, the roof style also reflected the feudal hierarchy, where the class representation ranking from high to low is Hip roof, Gable and hip roof, Overhanging gable roof, and Flush gable roof. The flush gable roof style was used for the Anhua covered bridges, in the meanwhile paifangs were built at both ends of the bridges. All the bridges are equipped with the eaves to protect the lower structures from rain and all the roofs of Anhua bridges are shown in Fig. 16.

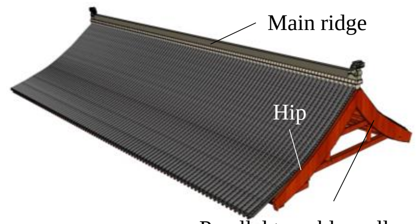


(a) Hip roof

(b) Gable and hip roof



(c) Overhanging gable roof



(d) Flush gable roof

Fig. 15. Chinese ancient wood architectures

(a) Fugu Bridge

(b) Fuxing Bridge

(c) Madu Bridge

(d) Sixian Bridge

(e) Shiyi Bridge

(f) Yanzi Bridge

(g) Yixi Bridge

(h) Yongxi Bridge

Fig. 16. Roofs of Anhua covered bridges

CULTRAL BACKGROUND OF TOTEMS AND ANCIENT BELIEFS REFLECTED ON THE BRIDGE

It is worth mentioning that totems, commonly carved in the Anhua covered bridges, has a close tie with the culture and beliefs, are shown in Fig. 17. According to the most famous chapter, “On the Equality of Things”, of a Chinese ancient book Zhuangzi, titled with the name of the author, a household ancient Chinese philosopher, centipedes are the natural enemies of snakes. In some folktales, the snake was regarded as a dragon, which represented the devil from the river, and in some fairy tales, it was also depicted as the main cause of floods. Thus, the centipedes were carved in the piers, as a wish in mind from the natives to protect the bridges from floods. In addition, the lion was deemed as a lucky mascot, a representative symbol of wisdom and power. Therefore, people in those times preferred to place the stone lions in front of the important architectures including houses owned by the wealthy and the most important infrastructures such as the bridges in the region, as a reflection of the expectation that lions could protect the architectures from the attacks of outside monsters. The lion is also a metaphor used to illustrate the power with prestige and wisdom when facing challenges.

Apart from totems, people of that era worshipped various deities, as well as ancestors. The bridge is not an exception. A shrine was always placed in the middle of a corridor, in which a specifically carved statue for worship was exhibited. The roof over the shrine was also particularly designed to make the architecture much more artistic. The shrine and roof are presented in Fig. 18.

(a) carved centipede on the pier **(b)** stone lions

Fig. 17. Totems of the Anhua covered bridges

(a) shrine and the carving **(b)** special design of roof

Fig. 18. The shrine and roof

CONCLUSIONS

This paper comprehensively reviewed the bridges in Anhua province of China, especially for the eight that have been listed as historical and cultural heritage sites protected at the provincial or the national level. The bridges are discussed from the background of the constructions and details of the structures, as well as the cultural background of the decorations on the bridges.

Historically, these bridges were constructed at the production area of dark tea, Anhua, thanks to the “Tea-Horse Trade” policy. Details of the bridges including the locations and the dimensions were covered, as well as the main structures such as the cantilever systems, the corridors, and the roofs.

The cultural background of the decorations and the religious beliefs reflected on the bridges were also mentioned, to profoundly introduce these architectures with long histories. The historical and cultural background and the construction style encourage people to know more about the building heritage. Therefore, this study is referable for future heritage preservation given the comprehensive introductions of these heritage sites.

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