

Review

Study on historical memorial archways in ancient Huizhou: Tangyue memorial archway group

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Memorial archways were built in ancient Huizhou as early as in 14th century. And they were regarded as culture symbols of Chinese ancient architectures of feudal society. Owing to the natural and man-made factors, many of them were damaged and even vanished. In this paper, the origin, evolution and culture connotation of Huizhou memorial archways were discussed with examples of existing Tangyue memorial archway group. Several risks to these memorial archways are presented, which can be categorized as natural reasons and man-made reasons. Weathering, flood, earthquake and landslide etc. are categorized as natural reasons while intended demolition, influences of adjacent modern constructions etc. are regarded as man-made reasons. Furthermore, the results of numerical analyses are presented to evaluate the building's potential seismic performance of the archway.

Key words: Memorial archway, Tangyue, risks, numerical analysis.

INTRODUCTION

Residence door, which is seemed as embryonic form of memorial archway, originally act as partition and entrance of yard. Then, some of residence doors evolved to symbols to distinguish different district when they were built in the entrance of streets or lanes. Later, some of them evolved to decorative and iconic buildings without their original function. Finally, they became mature as commonly accepted memorial archways in Song Dynasty (960-1279). The current concepts of memorial archways in Huizhou also appeared from that time. Owing to the natural and man-made reasons, many memorial archways disappeared without record. Today, a of total 129 memorial archways, which include 101 and half in She County, 14 in Jixi County, 8 in Xiuning County, 3 in Qimen County, 2 in Yi county and half in Wuyuan County, are scattered in the ancient Huizhou region since Song

dynasty. Here, the half means foundation relics in Zheng Village of She County or frame relics in Wuyuan County (Bian, 2003).

The assessment of seismic safety for archaeological heritages is important for improving their pertinent resistance. Based on the case study, one typical archway was modeled and analyzed. The aim of the analysis is to assess the behavior of the buildings under seismic excitation.

ARCHITECTURAL CHARACTERISTICS AND CULTURE FEATURES

The basic structural elements of memorial archways are columns and horizontal beams, which are essential

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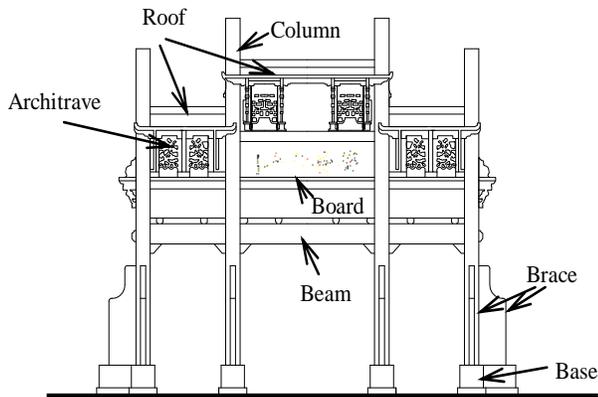


Figure 1. Typical memorial archway.

elements irrespective of their different styles and complicated structures. Columns and beams are typical architectural characteristic of memorial archways in view of building technology. Some of them were carved with complicated patterns, elegant and refined, while the others are simple and unembellished.

Flexible layout plan of columns, together with free combination of roofs, can provide broad development for diverse styles. A representative memorial archway consists of foundation, column, architrave, board, brace and roof (optional) sections, as illustrated in Figure 1. When it comes to architecture styles, columns going through roof and hipped roof were mostly adopted for memorial archways. The archways can also be divided to timber, stone and brick categories according to their materials. And the stone archways are predominant ones. In the initial stage, memorial archways were erected as iconic signs for tomb, road or just an entrance to street. Constructions of Memorial archways gradually became vital social activities in feudal society. And they were constructed after approval by the government and they were in honor of fame, morality, or chaste. Usually, each memorial archways is built in praise of one person or in memory of one event. However, one memorial archway can also be built for several causes.

Memorial archways of Huizhou are closely related to the local culture, economic and Confucian metaphysics and ethics. In modern society, as a physical solid culture symbol, memorial archways exhibit important academic values to study political, economic, clan and culture education systems of Huizhou in Ming Dynasty (1368-1644) and Qing Dynasty (1644-1911).

HISTORY INFORMATION OF TANGYUE MEMORIAL ARCHWAY GROUP

Tangyue memorial archway group, which locates in The County, consists of seven archways that are delegates of the famous archways groups in ancient Huizhou. The

archway group was arranged in a curved line (Figure 4). The memorial archway group, which vividly illustrates typical lives in ancient Huizhou, is closely related to the Clan with surname "Bao". Each memorial archway was built in praise family member(s) of the clan. Story details and built time of these archways are listed in Table 1 and Figure 2. Their social functions are to propagate feudal orthodox ideas of loyalty, filial piety, moral integrity and righteousness. Among seven memorial archways, three archways were in praise of their contribution the society, two archways were in praise of their moral integrity in family life and two archways were in praise of women chastity. All these memorial archways possess informative historical materials and they were protected by government as historic buildings.

RISKS TO MEMORIAL ARCHWAYS

The existing memorial archways are still under the threat of destruction. Since memorial archways are all standing outside and exposed in the air. They are directly affected by rain, wind and alternating temperatures. Such as weathering process together with worsen climate increase the vulnerability of archways. As a mountainous district, memorial archways sometimes are jeopardized by natural disasters, such as floods and landslides and the like. Earthquake risk is also an important menace to the ancient buildings. Recently observations in Wenchuan earthquake (2008) revealed many historic buildings were devastated (Figure 3). Necessary rehabilitations are necessary during the life cycle of historic buildings. Figure 4 illustrates the replaced columns were left near the original ones.

As a mountainous area with agriculture, some memorial archways were inappropriate used, such as retaining structure for haystack or pig bed. With the development of local economics, some constructions such as new houses, electricity transmission towers, agriculture development and the expansion of irrigation systems influenced the original features and eco environment of memorial archways. And even worse thing is that some people are ignorance and unawareness of the importance and vulnerability of memorial archways.

During the site investigation of Tangyue archway group, many degenerations and damaged locations were found and typical examples were shown from Figures 5 and 6. Dark red rusts were found on the face of stone material. Some growing plants and moss were also observed on the surface of Memorial archways due to outside field conditions. Nearly 2 mm width crack was found near the foundation of "Shangshu Memorial Archway". Similar crack was also found in the column of "Xiaozi Memorial Archway for Bao Fengchang". Large area of peeling off of column end is detrimental to the structural safety for whole structure (Figure 5). Brace is connected to foundation by steel anchors, which is important to the global integrity. However, some of them were lost or substituted

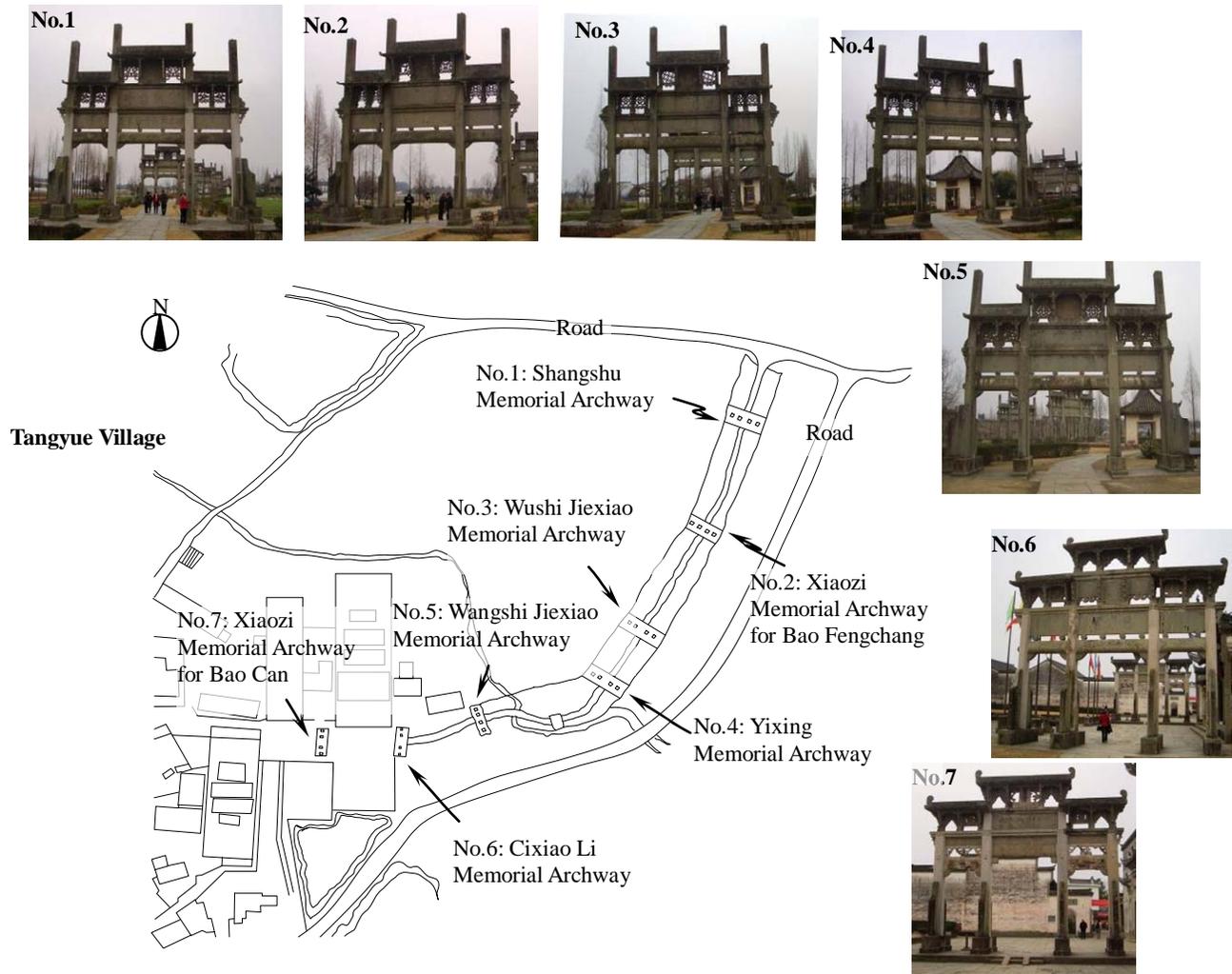


Figure 2. Tangyue archway group (Bao and Bao, 2008).

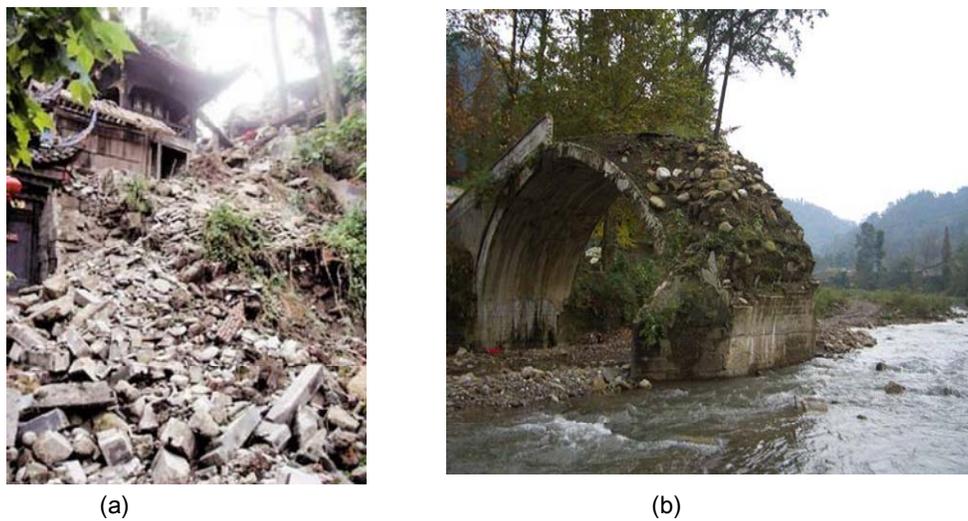


Figure 3. "Damaged historic buildings in Wenchuan earthquake (2008). (a) "Er Wang" Temple (b) Sino-French Bridge.

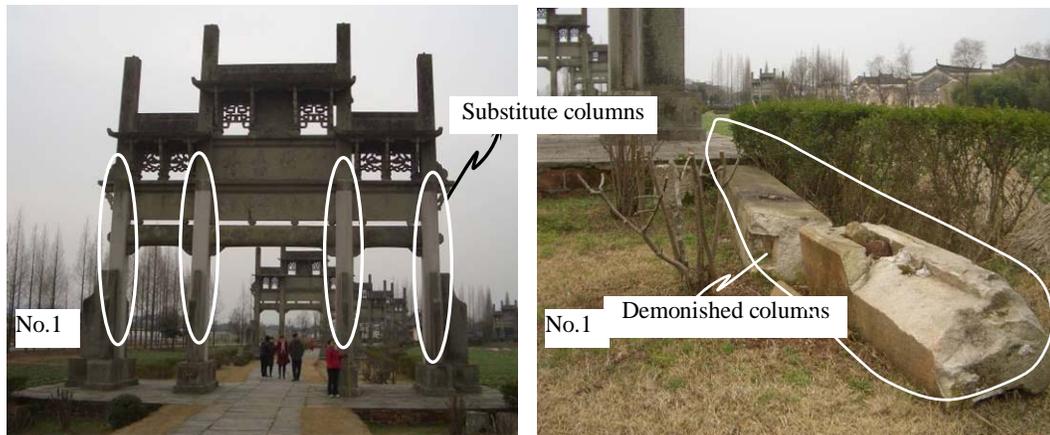


Figure 4. "Shangshu memorial archway" and demolished columns.

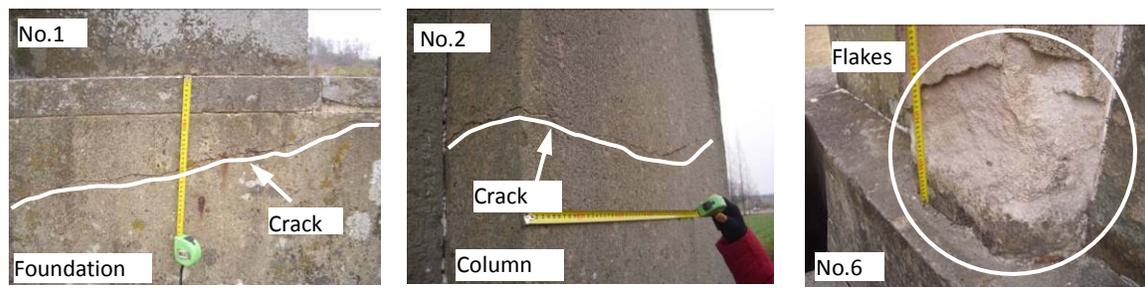


Figure 5. Cracks and flakes.

by lime, as shown in Figure 6.

Cement and lime materials were used which made their appearances are dissimilar from original stone material. Unknown epoxy material was also injected as repairing method. This can bring impairment to original features. Around 7mm gap was observed between column and lateral brace for "Xiaozhi Memorial Archway for Bao Fengchang". This may due to farm irrigation near foundation. Doodling was also found on the memorial archway surface.

NUMERICAL ANALYSIS OF MEMORIAL ARCHWAY

A commercial program was used (ANSYS) in order to execute the modal and time history analyses. The development of the three dimensional numerical model started with the generation of a geometry model based on the information taken from photo materials and measurements on site for No. 1 stone memorial archway presented in the previous section.

Shangshu memorial archway is a typical example of the memorial archways with symmetry configuration. It consists of four columns, which heights are 10.005 and 9.202 m respectively. Every two columns are connected by two beams. The columns rest separately on stone

bases. The dimensions of bases are 0.670 m × 2.502 m × 0.600 m. The cross section of columns is 0.430 m × 0.510 m. The cross section of lower beam is 0.410 m × 0.540 m, while cross section of upper beam is 0.410 m × 0.350 m. The thickness of stone braces is 0.170 m and their height is 2.640 m.

The masonry stone were simulated by three dimensional elements (SOLID65) and it is assumed that the structure is a homogeneous continuum. Figure 7 illustrates the numerical model with meshing.

The main mechanical parameters of the material model, which has been identified as granite, have been assumed on the basis of similar researches for stone structures (Giordano et al., 2002; Jiang et al., 2005; GB/T, 18601-2009, 2009). The mechanical parameters used in the analysis are summarized in Table 2.

Modal analysis was conducted in order to give a preliminary estimate of the dynamic response of the structure. The first natural frequency is computed to be 8.2588 Hz, which corresponds to a period of 0.1211 s. The first and third modal deformations are basically connected to bending in the two orthogonal directions. The first torsional shape is linked to the second natural frequency. Figure 8 illustrates the first four modes of the model.



Figure 6. Current state of brace connection.

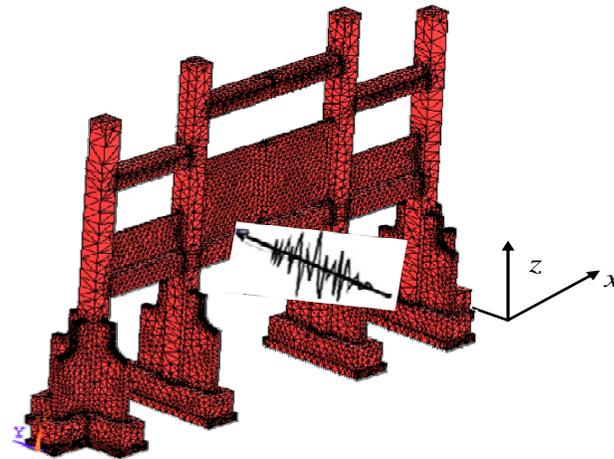


Figure 7. Finite element model of the memorial archway.

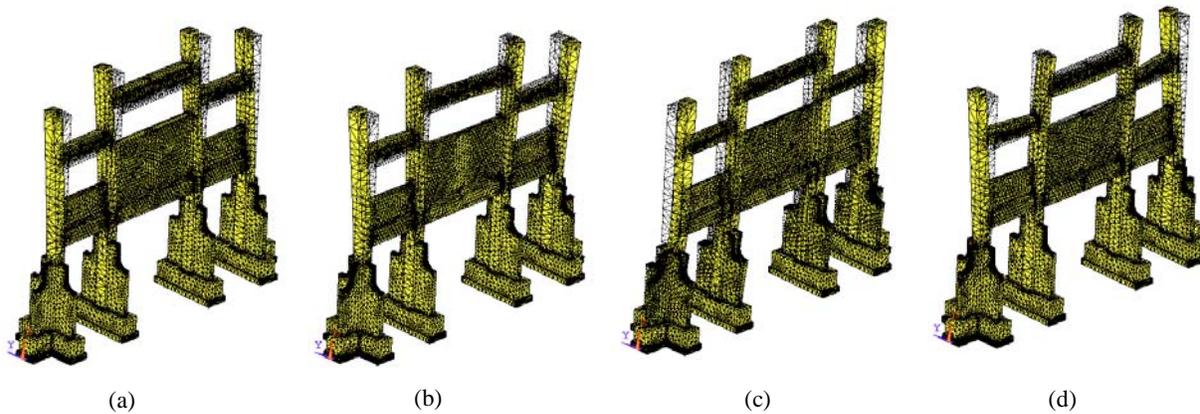


Figure 8. Four modes of the model. (a) The first mode (8.259Hz); (b) The second mode (14.715z); (c) The third mode (24.946Hz); (d) The fourth mode (26.538Hz)

Time history analysis was carried out under north-south component of El-Centro earthquake (Peknold version, 1940) having PGA 0.3 g available in the literature (Chopra, 1998). The accelerogram is applied in the y direction. The critical damping of 5% for masonry

buildings at fixed base condition is considered (Peña et al., 2010). The results indicate that the maximum top displacement is 1.7 mm, which is 1/5885 of the height. It is shown that the integrity of the memorial archway can be sustained under the current excitation.

Table 1. Tangyue archway group.

No.	Name	Built time	Remarks
1	Shangshu Memorial Archway	Built in 2nd Tianqi year of Ming Dynasty (1622 AD) and renovated in Qing Dynasty (1795 AD)	In praise of Xiangxian Bao for his contributions during Jiajing Period
2	Xiaozi Memorial Archway for Bao Fengchang	Built in 2nd Jiaqing year of Qing Dynasty (1797 AD)	In praise of Fengchang Bao for his fealty to parents
3	Wushi Jiexiao Memorial Archway	Built in 52nd Qianlong year of Qing Dynasty (1787 AD)	In praise of Wenyuan Bao's wife whose surname is Wu. Wu is Bao's second wife and become widow since 29. She brought up young son as step mother and remained a chaste widow until died
4	Yixing Memorial Archway	Built in 25th Jiaqing year of Qing Dynasty (1820 AD)	In praise of Shufang Bao and Jun Bao (father and son) for their great contribution and donation in terms of salt taxes, military supplies, and hydraulic construction projects and so on
5	Wangshi Jiexiao Memorial Archway	Built in 34th Qianlong year of Qing Dynasty (1769 AD)	In praise of Wenling Bao's wife for her raise of only son and chastity
6	Cixiao Li Memorial Archway	Built in Yongle year of Ming Dynasty (1420 AD) and renovated in 14th Qianlong year of Qing Dynasty (1749 AD)	In praise of Yanzhong Bao (father) and Shousong Bao (son). They were kidnapped by rebels and strove to die for each other.
7	Xiaozi Memorial Archway for Bao Can	Built in 13th Jiajing year of Ming Dynasty (1534 AD) and renovated in 14th Qianlong year of Qing Dynasty (1749 AD)	In praise of Can Bao for his fealty and great contribution to country of his grandson.

Table 2. Mechanical parameters.

Parameter	Value
Young's Modulus, E	0.8×10^5 MPa
Poisson ratio, ν	0.125
Density	2700 kg/m ³
Tensile strength	23 MPa
Compressive strength	230 MPa

DISCUSSION

Memorial archways are characterized by a historic architectural characteristics and culture features. Based on the performed case analyses with site investigations, some risks to the memorial archways were also illustrated. These risks include, but are not limited to, floods, landslides, earthquake and human's activities. Site investigations indicates several memorial archways were damaged after hundreds years of service. Essential rehabilitations are in urgent need. However, the methodology

for repair and strengthening of these historic buildings may need more professional techniques that should not affect the architecture performance. Cracks in the base should be repaired by appropriate materials. Settlement of the existing buildings may be prevented by injection of the foundation.

Stone masonry is liable to collapse under external excitations. Special attention was paid to the seismic vulnerability of memorial archways. Modal analysis indicates the basic structural information for the memorial archways. However, site measurement and monitoring are necessary for the aged structures. Time history analysis is adopted to analyze the fragility of the structures. This is an effective way to assess the seismic behavior.

Ancient memorial archways are embolic buildings of Chinese feudal society. In current situation, the survey of the similar archways should be extended to the whole region of ancient Huizhou. Further investigations should focus on the disclosure of the reservation significance to the public and the preservation practice of these heritage buildings.

CONCLUSIONS

The present study attempts to illustrate the history, culture connotation and risks of memorial archways in ancient Huizhou. A brief history of memorial archways is presented. Many memorial archways were built during Ming and Qing Dynasty. They are combining results of the Huizhou's long history, clan organization system and economic circumstance. Some risks to memorial archways were analyzed with example of Tangyue Memorial Archway Group. This indicates many efforts are still required to preserve these relics. The numerical analysis will help to assess the vulnerability of historic buildings and may form a basis to strengthen and retrofit these buildings with high national and global value.

Conflict of Interests

The author has not declared any conflict of interests.

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