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The Evolution of Mortise and Tenon Joints in Chinese Ancient Architecture

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Abstract:

Since the emergence of mortise and tenon joints in the Neolithic periods, it was renowned for its aesthetic value and strength, especially in Chinese traditional timber buildings. The use of mortise and tenon joints lasted for nearly 3000 years and is now experiencing a trend of decline due to the emergence of modern building materials like masonry, steel, and even nanomaterials. This paper begins with the origin of mortise and tenon structure from China, introduces the development stages of mortise and tenon joints in chronological order by introducing the forms of mortise and tenon structure in different dynasties and the application of these forms in typical examples, and concludes the evolutionary trends of mortise and tenon joints while analyzing what could be reflected from different forms of them in different stages. Lastly, by reviewing the decline of mortise and tenon joints in modern times, the paper will focus on the feasible ways of protecting this ancient technic. This paper will investigate the evolution of mortise and tenon joints from diverse aspects including historical background, technology, and social values in different periods, and highlight the significance of making efforts to protect this historical heritage by analyzing its historical and cultural values.

Keywords: Mortise and tenon joint; Chinese architecture; Historical evolution; Cultural heritage.

1. Introduction

Since the emergence of mortise and tenon joints in the Neolithic periods, it was renowned for its aesthetic value and strength, especially in Chinese traditional timber buildings. The use of mortise and tenon joints lasted for nearly 3000 years and is now experiencing a trend of decline due to the emergence of modern building materials like masonry, steel, and even nanomaterials. In other words, this traditional technique, which reflects the creativity and intelligence of human ancestors, is fading away from people's memories. Based on previous studies on the history of the mortise and tenon structure, which mainly focuses on each development stage separately, this paper aims to integrate these stages and conclude them into complete trends through the whole evolutionary period, not to mention studying deeply the technique which represents the Chinese culture heritage and human ingenuity and spreading

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it to more people to preserve this old technic.

2. Background

The mortise and tenon joint, also known as Sunmao in Chinese, is a technique that connects two pieces of wood or other materials.

There are many variations of this type of joint, and the basic mortise and tenon joint has two components: The mortise hole and the tenon tongue. As Fig. 1 shows, the tenon tongue acts as a rail and cuts exactly into the mortise hole. When the two blocks are connected either by gluing or friction.

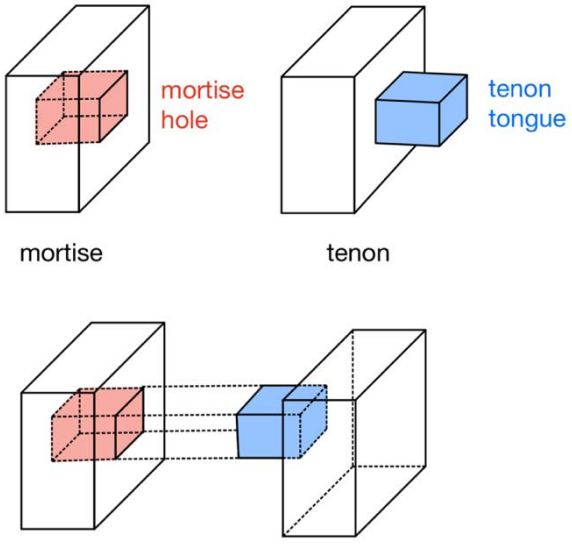

Fig. 1 The mortise hole and the tenon tongue

As Fig. 2 shows. The earliest mortise and tenon structure can date back to the Hemudu culture in China, Zhejiang Province.

Fig. 2 Hemudu culture architecture [1]

In Neolithic periods, inhabitants in Hemudu sites developed wood-frame structures and built the earliest stilt houses to protect themselves from vermin and flood. The components of a house were braced and connected by mortise and tenon joints as Fig. 3 shows [2].

Fig. 3 The components of a house of Hemudu culture [3]

The development of mortise and tenon structure in China could be divided into three different periods: The first part is from the Western Zhou Dynasty to Southern and Northern Dynasty, which marks the existence of mortise and tenon joints; and the second part is from Tang Dynasty to Song Dynasty, and the mortise and tenon joints were continuing to mature. The last part is from Ming Dynasty to modern times when mortise and tenon joints are on the decline as they are losing their practicability.

3. Analysis

3.1 High-Platform Buildings in Han Dynasty

3.1.1 Introduction of Han Dynasty

Han Dynasty (206 BCE—220 CE), a great imperial dynasty of China, was founded by Liu Bang. It copied the centralized system of Qin Dynasty and adapted Confucian ideology, which emphasizes moderation, virtue, and filial piety. It lasted longer than any other Chinese empire until it was replaced by three separate kingdoms, with only a short interruption when Wang Mang temporarily takes over the throne from 9 to 25 CE.

3.1.2 Example: Weiyang Palace

The architectural forms and techniques at the beginning of Han Dynasty are mostly inherited from the Qin Dynasty. To show their grandness, large scale buildings use rammed earth platforms to increase their height. Timber structures are then built on these platforms. Among these timber constructions, mortise and tenon joints were widely applied, which present in 3 main forms:

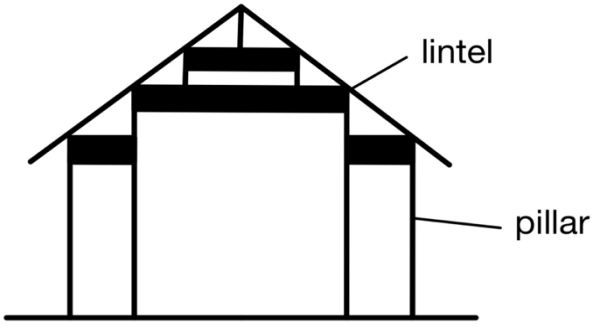

Fig. 4 Post and lintel construction

As shown in Fig. 4, in post and lintel construction, two pillars, or the post, support a third object—the lintel, which is laid horizontally on the two pillars. The pillars do not directly support the weight of the roof. Instead, the weight of the roof would be separately scattered to the lintels, and the pillars support the lintels, which improves the quality of a building.

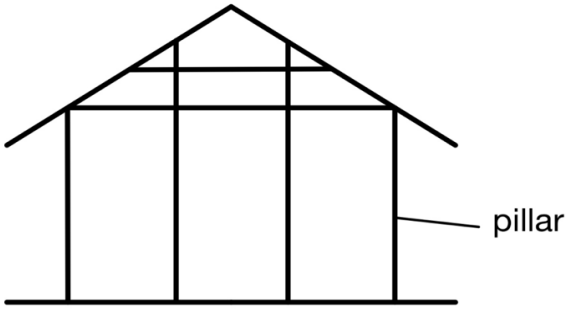

Fig. 5 Column and tie construction

Unlike post and lintel construction, column and tie construction in Fig. 5 uses pillars to directly support the weight of the roof without using lintels. Across the pillars are the cross beams that maintain the strength of the buildings.

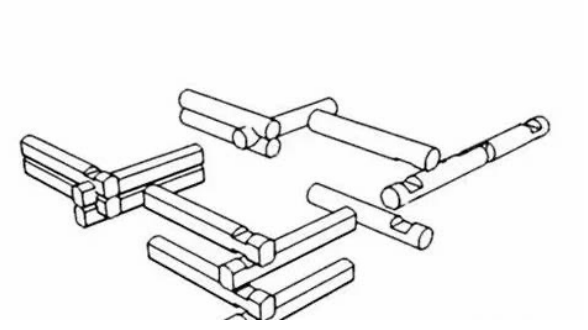

Fig. 6 Log cabin construction [4]

Without using pillars of lintels, log cabin construction uses multiple layers of wood and piles one layer over another as Fig. 6 shows. At the corner of each layer, the timber materials are connected using mortise and tenon joints. These stacked layers of wood would eventually form the basic construction of a building.

A typical example of a building in Han Dynasty is the Weiyang Palace. Located in Chang'an City (today's Xi'an), Weiyang Palace was first built in 200 BCE and was used as the accommodation of emperors of the Han Dynasty.

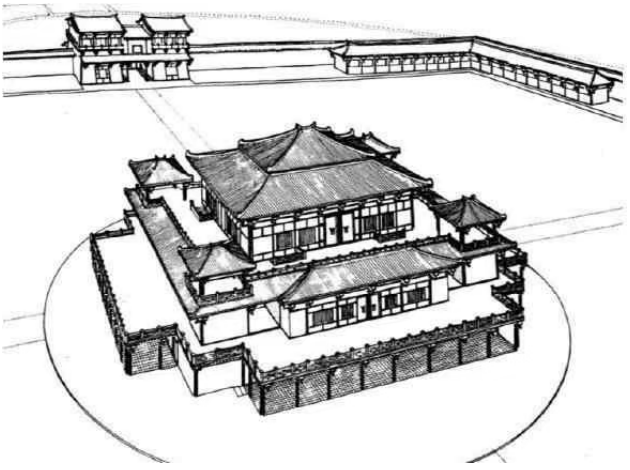

Fig. 7 The restored map of Weiyang Palace [5]

As shown in Fig. 7, Weiyang Palace takes up an area of about 5 km^2, and has the height of about 47 m. It is a typical high-platform building, which applies both rammed earth platforms and timber structures, highlighting the great scale of the building [6].

3.1.3 Characteristics

From this building, some historical facts about the political system of Han Dynasty could be reflected:

According to Xiao He, the chancellor of the Han Dynasty, "The emperor takes the four seas as his home, which is not powerful without magnificence." Similarly, as the home of the emperor, the Weiyang Palace highlights its greatness and magnificence, which represents the supremacy of the emperor. Also, the height of the palace represents the high status of the emperor, as well as the hierarchy of the Han Dynasty, which makes a distinction between the palace and the house of a civilian. All these facts show the centralization and imperial power of authority of Han Dynasty.

3.2 Buddhist Architecture in the Tang Dynasty

3.2.1 Introduction of Tang Dynasty

Beginning in 618 CE, Tang Dynasty successfully developed the form of government and administration and reached the peak of the development of economic, art, and military through ancient Chinese history in the early 8th century. However, rebellion broke out in the late 8th century, gradually making the Dynasty decline, and finally

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collapsed and was replaced by a scattering of independent kingdoms in 907.

3.2.2 Example: The Main Hall of Foguang Monastery

In this period, another type of structure was developed, Dougong. Dougong, also known as bracket sets, is a structure of interlocking wooden blocks. As a structure derived from the mortise and tenon structure, it is mainly applied for structural capacities.

If there is a roof, the first stage is to use two pillars to support it. But a problem has emerged: The middle part of the roof is too heavy. So many "arms" are derived from each single pillar. In this stage like Fig. 8 shows, a basic construction of dougong appeared. The wood arm is called a "gong", a bearing block. The end of the "gong", which connects with the roof directly, is called "dou", a cantilever bracket.

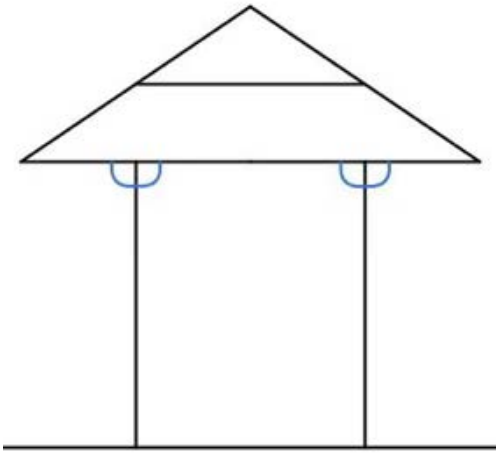

Fig. 8 Pillars and roof with single set of Dougong

In order to scatter the gravity of the roof more separately, and also to make the end of the roof a rain shelter, more sets of "dou" and "gong" are added as Fig. 9 shows. Each set of them is called "Tiao", the extension of brackets. Another function of their brackets is to increase the length of the eaves so that it would protect the main body of the roof from getting wet when raining.

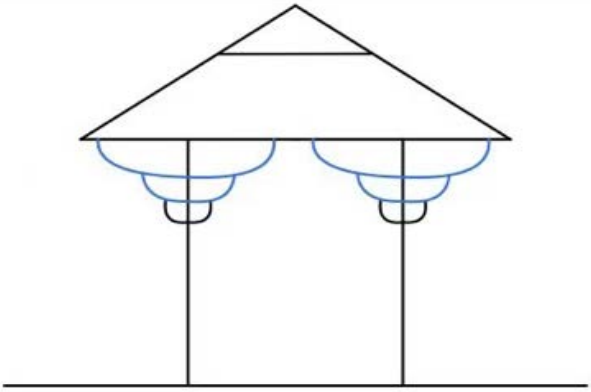

Fig. 9 Pillars and roof with multiple sets of Dougong

However, the outer part of the roof is still of great weight. So another change must be added. So a straight stick would be inserted between different layers of dou and gong like Fig 10 shows, which acts like a lever. Applied at the ends of the stick are the weight of the middle part of the roof and the outer part of the roof, while in the middle of the roof, there is a pivot, so that the whole lever is balanced. The stick is called "Ang", a lever arm.

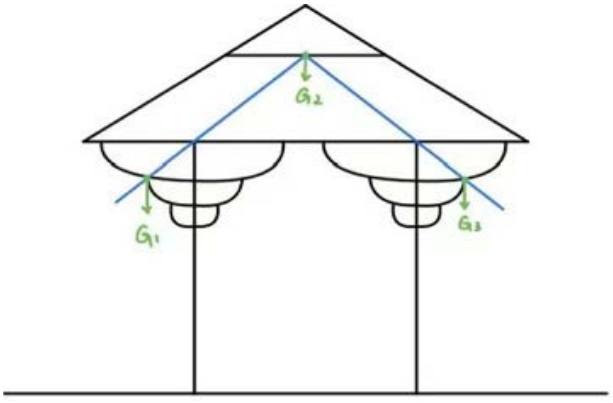

Fig. 10 The function of Ang

A typical example that applies the Dougong structure is the Main Hall of Fuguang Monastery as shown in Fig. 11. Foguang Monastery, built in 857 in Tang Dynasty, was rediscovered by Liang Sicheng in 1937. There are three kinds of outer brackets: The brackets on the column, the brackets on the corner and the brackets between the columns. There is only one brackets between 2 columns.

Fig. 11 The Main Hall of Foguang Monastery [7]

The height of the brackets is half of that of the columns. The cross-sectional area of each bracket is 210*300. The eave is 3.96 meters [8].

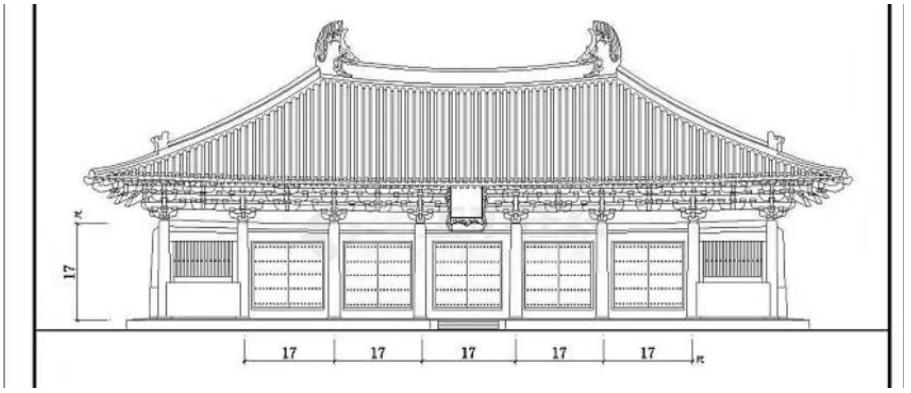

Fig. 12 The front view of the Main Hall of Foguang Monastery [9]

As shown in Fig. 12, a 7-pave bracket arch is applied, which means it has four tiao and four extension brackets. According to Yingzao Fashi, the number of paves is the number of extension brackets plus 3. The highest pave is 8 pave. The lower two brackets are constructed using Touxinzao, which means there is only one groove on the joint. The upper ones, in contrast, applies Jixinzao, which means there is a cross groove on the joint. Also, it is a double lever structure, which means there are two levers, two Ang [10].

According to the Yingzao Fashi, Different parts of the structure have different names. Columns, Brackets and Joints, are called Lu, Miao, and Ying accordingly, which means tree trunks, tree branches and flowers.

Looking back at the whole building, each column and set of brackets are like trees and flowers supporting the roof, which improves its aesthetic appearance while ensuring its capacity. Another point that is worth mentioning is the overhanging eaves, which extend the roof like the wings of a bird, In the corner of the building, which gives people a sense of freedom and lightness while maintaining its stateliness, which strikes a balance for viewers. All these elements give people a sense of harmony and peace.

3.2.3 Characteristics

This building reflects the aesthetic values of people in the Tang dynasty who preferred objects in fuller size, which is why the brackets are in such a large size.

The construction technology in the Tang Dynasty could also be reflected. Timber construction was prevailing at that period. Unlike the Roman Empire, which had mature technics for dealing with building stones, Chinese craftsman were not adept at them. Stone construction was well-developed in Roman Empire as Vesuvius Volcano offered them natural materials of early cement, and there were sufficient stone materials. In ancient China, for timber buildings, craftsmen have to consider the capacity of the whole building, and the water resistance of the building. So Dougong structure has emerged, with such a large size to enlarge the eaves.

3.3 Palace Architecture in Qing Dynasty

3.3.1 Introduction of Qing Dynasty

The last imperial dynasty of China. It was established in 1644 by Manchus and finally collapsed in 1912. Suffering from the defeats of the First and the Second Opium War,

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the Sino-Japanese War, and the Boxer Rebellion, not to mention the corruption and totalitarianism, the government granted concessions to foreign power and was finally destroyed by the Republican Revolution in 1911.

3.3.2 Exampe: The Hall of Supreme Harmony

Buildings in the Qing Dynasty still adopted the basic techniques of Dougong from previous periods. But the form has greatly changed. At the same time, a new feature of mortise and tenon joints has existed: the caisson, also called zaojing in Chinese. It is applied in the center of the ceilings of temples and palaces. It is a sunken panel raised above the level of palaces. It is a sunken panel raised above the level of the ceiling through the use of Dougong, interlocking different layers of timber structures like Fig. 13 shows. However, in this process, cross beams are not applied. The caisson is usually well-decorated.

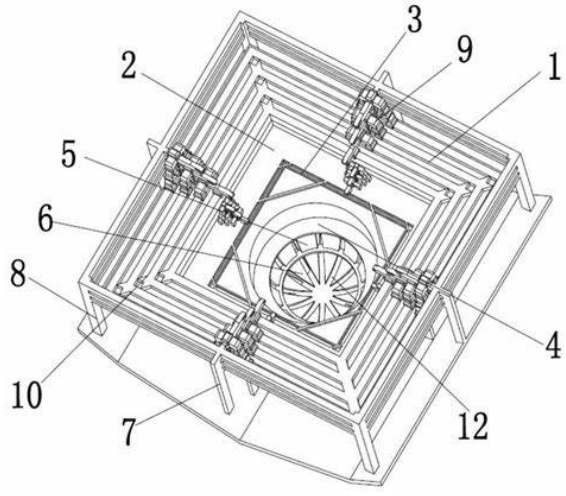

Fig. 13 Sketch map of caisson [11]

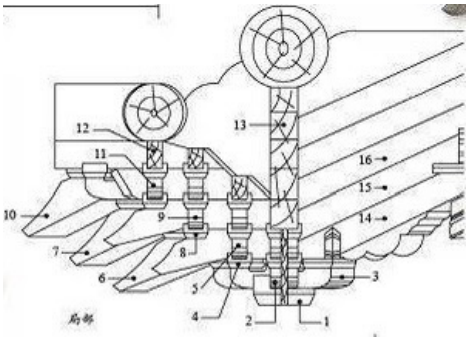

Fig. 14 The structure of Dougong in the Hall of Supreme Harmony [12]

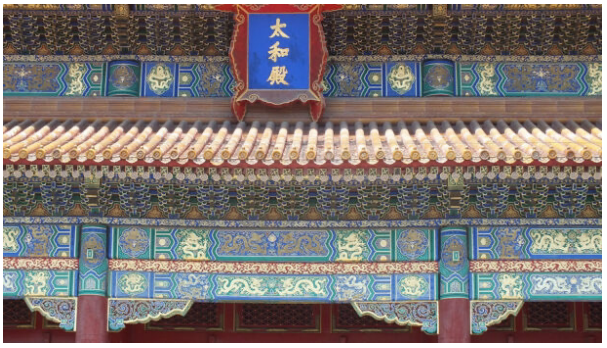

Fig. 15 The outlook of Dougong in the Hall of Supreme Harmony [13]

Taking a look at the Hall like Fig 14 and 15 shows, compared to the previous example, the Main Hall of Foguang Monastery, there is 8 bracket sets between the columns, and the height of the bracket sets is only about 1/5 height of the column, and the size of each of them is getting smaller, which makes there is almost no long eaves in the whole building. Another point is that the Ang, the lever in this place, is getting shorter, and it no longer supports the whole roof. Also, multiple pigments are applied and more arms are there to make up one bracket set.

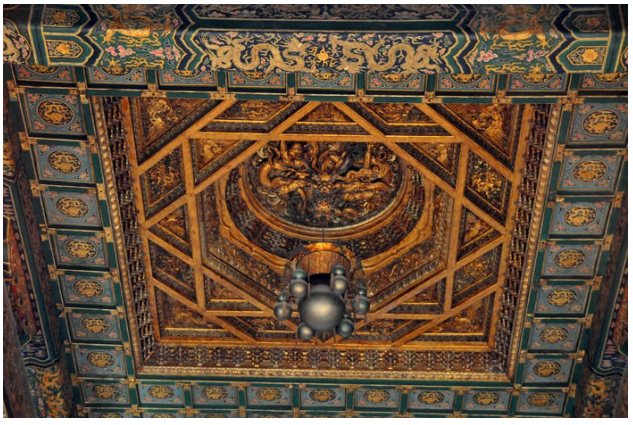

Fig. 16 The caisson of the Hall of Supreme Harmony [14]

The caisson of the hall, like Fig. 16 shows, is composed of three layers: the upper round layer, the middle octagonal layer, and the lower square layer.

The lower square layer is placed around the four sides of the hall, and by using mortise and tenon joints, beveled beams are connected and transformed into the octagonal layer in the middle. By using multiple small bracket sets in the inner part of the octagonal layer, a round layer is finally formed. The top of these layers are the cover plates, and there is a dragon hanging on the plate, holding a bead in its mouth [15].

The whole structure of the caisson gives the viewer a sense of order and harmony. The diamond-shaped frames and the dragon decorations are all symmetrically ar-

ranged, and each layer is vertically expanded. The ceiling gradually narrows from the bottom up, with each part of the skeleton transitioning and contracting evenly, forming a space with complexity without chaos.

3.3.3 Characteristics

From the comparison between the buildings in Qing Dynasty and Tang Dynasty, the difference of aesthetic values and technology could be inferred from the characteristics of these buildings.

Unlike people in Tang Dynasty, who loves objects on a fuller figure, people in Qing Dynasty tends to like the objects in higher complexity. Also, buildings in Qing dynasty tends to be more colorful than that of Tang Dynasty. So it could be referred that the aesthetic values in Qing Dynasty tends to be exaggerated and flaring. The main reason might be the difference in culture and race. Tang Dynasty was established by Hans, while the Qing Dynasty was established by Manchus, which have different kinds of values and aspects.

Furthermore, the differences in technology makes the different styles of buildings. In Tang Dynasty, the main function of Dougong structure is maintaining the stability of a building, and the artistic performance is only a derivative from it. While in Qing Dynasty, the Dougong structure is mainly used for decorative functions, which can be inferred from the abbreviated size of bracket sets and Ang, which have no load bearing functions. In Qing Dynasty, masonry is well-developed, which has greater capacity and water resistance than timber buildings, which is why load-bearing and water resisting functions is no longer needed when designing. Another reason for the decreased size of Dougong is that timber materials in great size was depleted at that time, In order to obtain timber materials, people in Qing Dynasty managed to excavate the tombs of emperors in Ming Dynasty.

4. Discussion

4.1 The Declining of Mortise and Tenon in China

Due to the introduction of western technology and art, many buildings in western styles has appeared in China at that time, and gradually replaced the traditional timber constructions. Also, many ancient buildings was destroyed during the World War II and Chinese Civil War. Thus, this ancient technology was abandoned by most people primarily.

Since the founding of the new Republic, the Chinese ancient buildings suffered from great destruction. In the Cultural Revolution from 1966 to 1976, under the movements of “destroying the four olds (old ideas, old culture, old customs and old habits)”, a vast number of ancient temples, academies and halls were severely damaged, including Beijing’s Confucius Temple and the Zhonghua Gate in Nanjing. Many scholars who studies ancient Chinese culture were also persecuted, like the Chinese architect and architectural historian Liang Sicheng, whose notes and scripts were damaged at that time.

From 1978, with the urbanization process, numberous ancient buildings were demolished due to urban expansion and development projects.

4.2 Suggestion

There are two aspects when considering about protecting mortise and tenon joints: preserving ancient timber buildings and cultural transmission.

Cultural transmission is to diffuse the knowledge of mortise and tenon structure by different ways. An approaching method is innovative designing. For example, mortise and tenon joints were applied in culture and creative product designing.

Fig. 17 Joint chopstick designed by Yuma Kano [16]

A representative work is a joint chopstick designed by Japanese artist Yuma Kano in Fig. 17, which combines two representative elements of East Asian culture: mortise and tenon joint and chopsticks [17].

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For preserving ancient buildings, the Chinese government has made efforts to develop new ways of protecting them. On September 9, 2021, the Chinese State Council released new guidelines for establishing protection systems of cultural heritage in both rural and urban areas by encouraging utilization and continuation of cultural heritage.

5. Conclusion

Through investigating the mortise and tenon joint forms and analyzing typical architectures in multiple dynasties, the mortise and tenon structure tends to be more and more complex due to the advance of technology and people's growing concept of beauty. From the supporting structures in Han Dynasty, to the Dougong structure in Tang Dynasty, which both considered the aesthetic values and supporting functions, and to the cassion in Qing Dynasty, which was completely a ornament indoors——they tend to be more decorative instead of practical. In the end, the paper introduces the nowadays situation of mortise and tenon joints——they keep declining after Qing Dynasty. However, different people and communities are making effort to preserve this technic through multiple ways.

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