

The Analysis of Impact on Fire Resistance of Mortise-tenon Joint in Different Connection Mode

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Abstract. In order to analysis of impact on fire resistance of mortise-tenon joint in different connection mode, four types of mortise-tenon Joints models are made by *Pinus yunnanensis*. And the combustion phenomena and carbonization of mortise-tenon joint are studied. Results of experiment show that the sequence of fire resistance in descending order is: Mantou mortise-tenon Joint, dovetail Joint, Ban mortise-tenon joint, Shizigutou mortise-tenon joint. The results can provide the theoretical base for fire protection of classical wood construction.

Keywords: mortise-tenon joint; connection mode; charring rate; temperature.

1. Introduction

Northwestern Yunnan Province retains a large number of traditional wooden buildings, which is a rare gathering place of traditional wooden buildings. In recent years, fires have occurred frequently in traditional buildings in Yunnan Province, so it is very important to strengthen the fire protection of traditional wooden buildings. At present, China's fire protection research on traditional wooden buildings mainly focuses on passive fire protection measures, such as Zhang Yang, etc., respectively, the use of paper-faced gypsum board and a new type of ultra-thin fireproofing coatings on the fire protection of Lijiang's ancient buildings to carry out experimental research [1]; Yang Chunze use of the FDS software for different heights of the firewall in the combustion of a single wooden building in a single building under the temperature distribution of the roof of the building under the different wind speeds [2]; Dai Rui et al. combined with a comparative analysis of brick and wood-framed buildings in a historical neighborhood in Kunming to calculate the heat release rate of typical rooms of brick and wood-framed ancient buildings in the neighborhood when fire occurs [3].

In traditional wooden buildings, mortise and tenon nodes, as the key stress parts, their fire resistance performance is a key factor in the fire prevention of traditional wooden buildings [4-5]. The mortise and tenon is composed of multiple pieces, with a short burn resistance time and fast loss of action. Currently, the research on mortise and tenon nodes is mostly in the aspect of seismic resistance and reinforcement [6-10], while the analysis of their fire resistance performance is relatively less. This paper mainly analyzes the effect of different connection methods on the fire resistance of mortise and tenon nodes. Although the volume of mortise and tenon nodes in wooden buildings is small, there are many connection methods, so this paper selects the most common four mortise and tenon connection methods, and evaluates the effect of different connection methods on the fire resistance of mortise and tenon nodes through the combustion test of the nodes.

2. Experimental design

2.1 Experimental materials

Pinus yunnanensis, a common material for local traditional architecture in Yunnan, was selected to make dovetail tenons, as shown in Figure 1. Dovetail tenon is mostly used in the intersection of square and column, the overall performance of the structure is better. The timbers used are all 40×40mm square timbers with a length of 200mm.



Figure 1 Dovetail tenon

With reference to the "finish type fireproof coating fire performance classification and test method" GB/T 12441-2005 test piece for single-sided coating and its wet coating ratio of 250 g/m². divided into not coated with any protection of vertical combustion, not coated with any protection of node combustion, according to the 250 g/m² coated nodes are not coated with vertical combustion, according to the 250 g/m² coated nodes are not coated with node combustion, according to 250 g/m² coated node Nodes coated with vertical burning, nodes coated with nodes burning at 250 g/m², nodes coated with nodes burning at 500 g/m², nodes not coated with vertical burning, nodes coated with nodes burning at 500 g/m², nodes coated with nodes burning vertically, nodes coated with nodes burning vertically, nodes coated with varnish burning vertically, nodes coated with varnish burning at 500 g/m².

After calculation, the surface area of dovetail mortise and tenon nodes without finish fireproofing coating is 0.0576 m², and the mass of finish fireproofing coating used is 14.4 g when it is coated according to 250 g/m², and 28.90 g when it is coated according to 500 g/m². The surface area of dovetail mortise and tenon nodes coated with finish fireproofing coating is 0.06465 m², and the surface area of dovetail mortise and tenon nodes coated with finish fireproofing coating is 0.06465 m², according to 250 g/m². The surface area of dovetail and mortise nodes coated with finish type fireproofing coating is 0.06465 m², and the mass of finish type fireproofing coating used is 16.16 g when coated at 250 g/m², and 32.33 g when coated at 500 g/m².

The number of experimental materials is shown in the work table below.

Table 1 Experimental working condition table

serial number		Coating method	Surface area/ m ²	Coating mass/g	ignition position
A	A1	uncoated	0.0576	0	base of column
	A2	uncoated	0.0576	0	nodal
	B1	250 g/m ² without node coating	0.0576	14.4	base of column
B	B2	250 g/m ² without node coating	0.0576	14.4	nodal
	B3	Nodal coating at 250 g/m ²	0.06465	16.16	base of column
	B4	Nodal coating at 250 g/m ²	0.06465	16.16	nodal
	C1	500 g/m ² without node coating	0.0576	28.8	base of column
C	C2	500 g/m ² without node coating	0.0576	28.8	nodal
	C3	Nodal coating at 500 g/m ²	0.06465	32.33	base of column
	C4	Nodal coating at 500 g/m ²	0.06465	32.33	nodal
D	D1	varnish	0.0576	surface coating	base of column
	D2	varnish	0.0576	surface coating	nodal

2.2 Experimental installation

The experimental installation consists of ignition equipment, bracket, infrared thermometer, electric heater, digital radiation thermometer, stopwatch, and its structural form is shown in Figure 2.

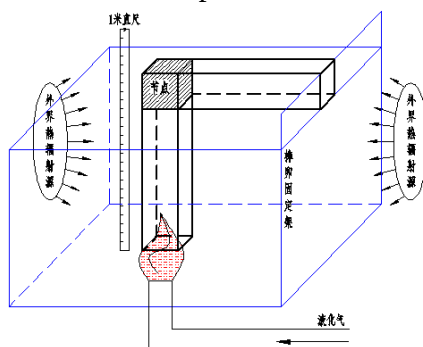


Figure 3 Schematic diagram of the test setup

The four mortise and tenon structures were dried and dehydrated beforehand at 105°C for 8 hours. Before the start of the experiment, the ambient temperature was 20°C. After the start of the timing, the two sides of the mortise and tenon were radiantly heated by electric heaters, and the radiation value of each electric heater was 2kw/m², i.e., the total value of the radiation was 4kw/m². the initial temperature at the nodes of the mortise and tenon before the start of the test was 53~58°C.

The experimental environment was indoor, simulating a fire environment. The dovetails were dried beforehand at 105 °C for 8 hours. The specimens coated with finish-type fireproof coating were dried for 24 h. Before the start of the experiment, the ambient temperature was 20 °C. After the start of the timer, two electric heaters were used to radiantly heat both sides of the mortise and tenon with the radiation value of 2 kw/m² for each heater, i.e., the total value of the radiation was 4 kw/m², and the temperature after the radiation was 53 °C to 58 °C.

3. Results and Analysis

3.1 Changes in combustion temperature of mortise and tenon nodes

(1) The combustion temperature variation of working conditions A1, B1, C1 and D1 is shown in Fig.

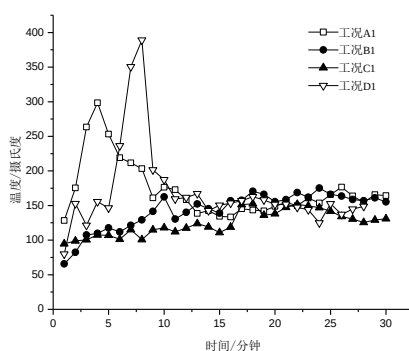


Fig. 4 Temperature versus time for four coating methods

Working condition A1 temperature change analysis, there is a peak flame temperature between 1-10 min to reach a maximum of 298.4°C. This is due to the fact that our mortise and tenon is made of Yunnan pine, which is rich in oil. The pine oil is baked out during the combustion process and becomes more flammable. So there is a peak. And the temperature is relatively stable after ten minutes.

Work condition B1 temperature change analysis, 1-10 min temperature is rising trend, by the influence of anti-finish type fire coating temperature growth is slow. And 10-11 min temperature dropped some, and 11 min after the temperature is relatively stable, the highest value of temperature in the whole process is 175.3 °C. Working condition C1 temperature change analysis, 1-18 min

temperature increases slowly. After 18 min the temperature is relatively stable, and the highest value of temperature in the whole process is 152.5 °C. This is due to the finish-type fireproofing coatings in the combustion process expansion foam, blocking the flame and tenon direct contact, heat transfer rate slows down. The back of the temperature fluctuation is basically smaller.

Condition D1 temperature change analysis, 1-11 min temperature gradually increased, fluctuations are large. This is because the varnish used in our experiment is not fireproof varnish, which has a certain combustion-assisting effect. So the temperature rises faster. And with the growth of the burning time, the grease in the tenon is baked out to help combustion, is the temperature rises sharply to reach the highest value. With the reduction of grease, the temperature decreases in 11-14 min. After that the temperature was basically unchanged. 29 min when the tenon nodes were burned. The highest value of temperature during the whole process was 389 °C. (2) Work conditions A2, B2, C2, D2 combustion temperature changes are shown in Fig.

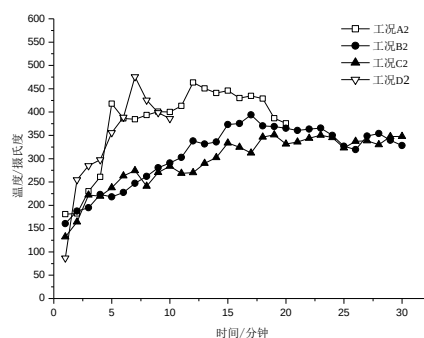


Fig. 5 Temperature versus time for four coating methods

Temperature change analysis of working condition A2, 20 min nodes are burned, and in this process, the temperature increase is relatively large.

Temperature change analysis of working condition B2, 30 min mortise and tenon nodes are not burned. 1-17 min temperature gradually increases, in this process, the finish fireproof coating with the growth of combustion time, slowly expanding foam. 17-30 min temperature change is not big, relatively stable.

The temperature change analysis of working condition C2, 1-20 min temperature gradually increased, slow change. In this process, the decorative fireproof coating gradually absorbs heat and expands and foams. 20-30 min temperature is relatively stable.

Temperature change analysis of working condition D2, 10 min when the mortise and tenon node is burned. The temperature change during this process was large. This is due to the fact that the varnish used in our experiments is not a fireproof varnish and has a certain combustion-inducing effect. So the temperature rises faster. And with the growth of the burning time, the grease in the mortise is baked out to fuel the fire, and the mortise nodes are quickly burned. (3) The combustion temperature changes of working conditions A1, B3 and C3 are shown in Fig.

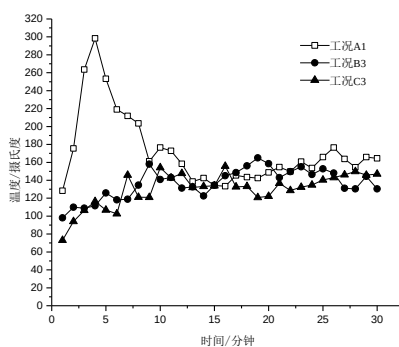


Fig. 6 Temperature versus time for three coating methods

The temperature change analysis of working condition A1 shows that there is a peak flame temperature between 1-10 min to reach the maximum. The highest value of temperature during the whole process is 298.4 °C. This is due to the fact that our mortise and tenon is made of Yunnan pine, which is rich in oil. The pine oil is baked out during the combustion process and becomes more flammable. So there is a peak. And the temperature is relatively stable after ten minutes. Temperature change analysis of working condition B3, burning 30 min, mortise and tenon nodes are not burned. 1-9 min temperature gradually increase, affected by the finish type fireproofing coating temperature growth rate is slow. During this process, the finish type fireproof coating gradually expands and foams with the growth of burning time. 9-30 min temperature change is not big and relatively stable. Temperature change analysis of working condition C3, 1-10 min the temperature gradually increases, affected by the finish type fireproof coating temperature growth rate is slow. This process of finish-type fireproof coating, gradually expanding foam, 10-30 min temperature change is not much relatively stable. This is due to the expansion and foaming of the finish type fireproofing coating, slowing down the heat transfer rate.

(4) 4 conditions A2, B4, C4 combustion temperature changes as shown in Figure.

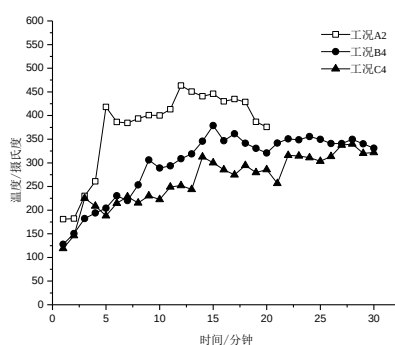


Fig. 7 Temperature versus time for four coating methods

The temperature change analysis of working condition A2 shows that the 20 min node is burned out and the temperature increase is relatively large during the process. Temperature change analysis of working condition B4, the node is not burned, 1-15 min temperature gradually increased, affected by the finish type fireproof coating, the temperature increase is not large, this process, the finish type fireproof coating with the growth of combustion time, gradually expanding foam. 15-30 min temperature change is not large. This is due to the expansion and foaming of the finish type fireproofing coating slows down the heat transfer rate. The temperature change analysis of working condition C4, the temperature gradually increased from 1-14 min. Affected by the finish-type fireproofing coating, the temperature increase is not large, this process, the finish-type fireproofing coating with the growth of combustion time, gradually expanding foam. 14-30 min temperature change is small, relatively stable. This is due to the expansion of the finish type fireproof coating foaming slow down the heat transfer rate.

3.2 Quantitative analysis of tenon burning temperature changes

By analyzing the maximum temperatures of various cases in the above graphs, it is concluded that: To summarize: temperature change amplitude analysis, condition D1>A1>B1>C1; condition D2>A2>B2>C2; condition A1>B3>C3; condition A2>B4>C4. temperature change amplitude of condition D>A>B>C. and the amplitude of temperature change of condition D is not a multiple of the temperature change of condition A; temperature change amplitude of condition A is not a multiple of the temperature change of condition B; temperature change amplitude of condition B is not a multiple of the temperature change of condition C. The temperature change of condition D is not a multiple of the temperature change of condition A; temperature change amplitude of condition B is not a multiple of the temperature change of condition B; temperature change amplitude of condition B is not a multiple of condition C. The magnitude of temperature change in Case D is not a multiple

of Case A; the magnitude of temperature change in Case A is not a multiple of Case B; the magnitude of temperature change in Case B is not a multiple of Case C.

4. Discussion

(1) In the experimental process, it is required to be carried out in a closed space, but although our experiment is carried out in a relatively closed space, the space is large, there is a lot of smoke in the process of the experiment, the door and the window are in the open state, and by the unstable influence of indoor and outdoor air flow rate, the experiment has a certain degree of error.

(2) The phenomenon of uneven coating is inevitable in the coating process of finish-type fireproof coating. There is a certain error.

(3) Although each component is made of Yunnan pine, the oil contained in each component is different, which will have some influence on the experimental data.

(4) There is a certain error when adjusting the flame height during the experiment.

Acknowledgement

This work is supported by the Innovation and Entrepreneurship Project of University Students in Yunnan Province, China ‘The Analysis of Impact on Fire Resistance of Mortise-tenon Joint in Different Connection Mode’. Item Number:20200651017.

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