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Full Scale Test on Fire Spread and Control of Wooden Buildings

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Abstract

Wood was widely used for ancient buildings in China, though it is very easy to burn, which causes big trouble for fire preventing. The paper introduced the full scale fire tests in Lijiang ancient town, Yunnan province. A series of full scale fire tests with different fire locations in building, different fuel and different type of ceiling were conducted on wooden building. The effect of water spray on preventing fire spread in wooden building was also studied. It shows that: a). It is easier for fire spread when the fire origin is near the wooden wall; b). Once the inflammable material like foam mattress burned, the fire is very easy to spread over the wooden building; c). If there is ceiling in the wooden building, it can block the fire plume and hot smoke flowing into the adjoining room through the upper space between two rooms; d). Water sprinkler system takes a good effect on preventing fire spread in wooden building, it should be installed in important wooden buildings, such as historical buildings.

1. Introduction

Most of historical buildings in China and other East Asian countries are made of wood. These buildings are dry and very easy to burn. There are a series of fire hazard for wooden historical buildings, such as high fire load and low fire resistance rating.

The historical buildings are irreproducible, many valuable historical relics were burnout after fire. More than 100 historical buildings ruined by fire in China since 1949, and many valuable historical relics were never found again. The research of preventing fire spread in wooden buildings is very important for historical buildings’ protection.

Since the fire prevention in historical buildings (especially wooden historical buildings) is very important, many researchers carried out their researches, such as Namba[1] studied the fire spread model of wooden buildings in...
Japan in 1986; Hakkarainen[2] studied the fire safety of wooden facades for sprinklered multi-storey houses in 1996; Song[3] studied the character of historical building fire in China in 2004; Sun[4] studied the ignition characteristics of timber widely used in Tibet's historical buildings in 2006; Zhuang[5] evaluated the fire risk of the famous historical building Potala Palace of China in 2007.

In this paper, a series of full scale fire tests were conducted on a wooden building, concerning to different fire locations in building, different fuel and different type of ceiling, in order to study the spread of fire in wooden buildings. Further more, the effect of water sprinkler on preventing fire spread in wooden building was also studied. All the full scale fire tests provide reliable fundamental data for fire prevention and fire extinguishing of wooden buildings.

2. Experimental

The tests were conducted on a waste wooden building in Lijiang, Yunnan Province, China. There were 5 rooms in the wooden building, every room had a width of 3.0m and a depth of 5.7m. The top of the building was 4.5m high. The door of each room was 0.9m in width and 2.0m in height. Some of the rooms had ceiling at 3.0m above ground level, as shown in Fig.1.

In the tests, two kinds of fuel were used, one was raw wood, the other was common furniture (including table, chair, cabinet, bed, foam mattress, sheet and clothes). A digital video camera was used to record the process of fire and smoke spreading. In order to study the distribution of temperature in different region, four Thermal Couple Clusters (TCC) were used to measure the temperature of fire room and its adjoining room at different height. Thermal Couple Cluster A (TCC-A) was placed to centre of the fire room, TCC-B was placed to the centre of its adjoining room, TCC-C was placed to the door opening of the fire room, TCC-D was placed to the door opening of its adjoining room, as shown in Fig.2. Each TCC was consists by 8 thermal couples of K-Type, which can measure the temperature of different height.

![Diagram of wooden building](image1)

![Diagram of Thermal Couple Cluster](image2)
Four influence factors on fire spread were considered in the tests, they were:
- Whether there was a water sprinkler system
- The kind of fuel
- The location of fire origin in building
- Whether there was ceiling in the room

Six full scale tests were conducted, the conditions are as shown in Table 1

Table 1. Summary of conditions for all tests

| Test No | Fuel  | Location of fire | Ceiling | Sprinkler | Door | Time for fire spread to adjoining room |
|---------|-------|------------------|---------|-----------|------|----------------------------------------|
| 1       | Raw Wood | Corner       | With    | With      | Open | N/A                                    |
| 2       | Raw Wood | Corner       | With    | Without   | Open | N/A                                    |
| 3       | Furniture | Corner       | Without | Without   | Open | 15min                                  |
| 4       | Furniture | Corner       | With    | Without   | Open | 27min                                  |
| 5       | Raw Wood | Corner       | Without | Without   | Open | 23min                                  |
| 6       | Raw Wood | Centre       | Without | Without   | Open | 33min                                  |

3. Results and Discussion

3.1. Effect of water sprinkler system on preventing fire growth and spread

Test 1 and Test 2 were similar in fuel, location of fire in building, type of ceiling. However, there was sprinkler system with a common nozzle typed ZSTP-15, RTI=80(m·s)^{1/2} only in Test 1. The temperatures of typical position were as shown in Fig. 3.

In Test 2, the temperature of the fire room increased persistently (Test2-A). There was sprinkler system in Test 1, when the temperature of the fire room increased to a certain level, the sprinkler began to spray water, then the temperature decreased quickly (Test1-A). The sprinkler system take a good effect on preventing fire growth and spread. Because the two tests were used to prove the effect of sprinkler, they didn’t take long time. 1500s after ignition, the tests were finished, and the fire didn’t spread to the adjoining room.

![Fig. 3. Comparison of fire growth between “with” and “without” sprinkler.](image1)

![Fig. 4. Comparison of fire growth between raw wood and furniture.](image2)
3.2. Effect of fuel kind on preventing fire grow and spread

Test 3 and Test 5 were similar in type of ceiling and location of fire in building. However, they were different in fuel. The fuel in Test 5 was raw wood, while the fuel in Test 3 was common furniture (including table, chair, cabinet, bed, foam mattress, sheet and clothes). The temperatures of typical position were as shown in Fig. 4.

In Test 3, the fuel included inflammable like foam mattress, sheet and clothes. At the beginning, the burning rate was very fast, the fire size increased rapidly, the temperature of the fire room increased reached 250 °C in a short time (Test3-A), the fire spread to the adjoining room very soon (Test3-B).

In Test 5, the fuel was raw wood. At the beginning, the burning rate was not very fast, while the fire size increased continuously and reached the maximum at about 1500s, the temperature of the fire room exceeded 1000 °C, the fire spread to the adjoining room finally (Test5-B).

Thus, if there was inflammable like foam mattress, sheet and clothes in the room, the fire size increased rapidly at the beginning, it was easier to spread fire and more dangerous than only fuel of raw wood in the room. In this case, the fire control and extinguishment were difficult.

3.3. Effect of ceiling on preventing fire grow and spread

Test 3 and Test 4 were similar in fuel kind and location of fire in building. However, they were different in ceiling type. In Test 3, there was no ceiling. The room can communicate with each other through their upper spaces. While there were plaster board ceilings in Test 4. The rooms were separated before the plaster board ceiling burnout. The temperatures of typical position were as shown in Fig. 5.

In Test 3, there was no ceiling. The fire plume and hot smoke could flow from the fire room to the adjoining room easily, through the upper channel of each room. The temperatures of the fire room (Test3-A) and adjoining room (Test3-B) rose synchronously, and the adjoining one caught fire at about 900s..

In Test 4, there were plaster board ceilings. The fire plume and hot smoke filled the fire room, and the smoke layer height descended gradually. A part of fire flame was in the smoke layer, and was hard to react with oxygen. Therefore, the temperature rose slowly. When the plaster board ceiling was burnout, the hot smoke flowed from the fire room to the adjoining room, and the adjoining one caught fire. Besides, after the hot smoke get out the fire room, the smoke layer height ascended again, and the fire flame could react with oxygen easily, the burning rate increased and the temperature rose rapidly. According to Fig. 6, the temperature changes of adjoining room (Test4-B) lagged behind the one of ignition. It meant the ceiling delayed the fire spread.

Fig. 5. Comparison of fire growth between “with” and “without” ceiling. Fig. 6. Comparison of fire growth between different fire location.
3.4. Effect of fire location on preventing fire grow and spread

Test 5 and Test 6 were similar in fuel kind and type of ceiling. However, they were different in fire location. The fire origin was at the corner of room in Test 5, and was at the center of room in Test 6. The temperatures of typical position were as shown in Fig. 6.

In Test 5, the fire origin was at the corner of room. At the beginning, the temperature of both the fire room and the adjoining one rose gradually. After a period of burning (about 1500s), the wall of room was ignited, the fire size increased and temperature rose rapidly.

In Test 6, the fire origin was at the center of room. The hot smoke produced by combustion flow to other rooms through the upper channel, the wall of the fire room was not easy to burn, and the fire size didn’t increased rapidly but gradually. Besides, due to the distance between the fire origin and wall, it took a longer time (about 2000s) for fire spreading to the adjoining room than the case of fire origin at the corner.

Thus, it is unwise to put combustible at the corner of a room, which will accelerate the fire spread between rooms.

4. Conclusions

There are tens of thousands historical buildings in East Asian countries, most of them are wooden buildings. These buildings are the valued inheritance from our ancestors, and need well protection. In order to protect the historical buildings (especially wooden buildings) against fire, some influence factors were studied according to the data of full scale fire tests in this paper. Results showed that:

- Water sprinkler system takes a good effect on preventing fire spread in wooden building, it should be installed in important wooden buildings, such as historical buildings;
- Once the inflammable material like foam mattress is burned, the fire is very easy to spread over the wooden building;
- It is easier for fire spread when the fire origin is near the wooden wall;
- If there is ceiling in the wooden building, it can block the fire plume and hot smoke flowing into the adjoining room through the upper space between two rooms. It is useful for delaying the fire spread.

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