Mechanism and Preventive Measures of External Fire Spread in Southwest Chinese Traditional Villages

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Abstract. Rural building fires, especially catastrophic ones that destroy a large number of houses even total village in southern regions of China, are becoming a growing concern from common people to local governments. There is a few literature on research progress of large scale rural building fires in China. In this paper, several typical massively rural building fire cases are described firstly. Mechanism of external fire spread among rural wooden buildings is qualitatively analyzed secondly. Some important preventive measures, such as sandwich panels with inner galvanized sheet, are suggested thirdly. The authors hope this paper may provide valuable information and enlightenment for people who hope to learn about the current situation, research progresses and preventive measures of external fire spread in southwest Chinese traditional villages.

1. Introduction

In southern region of China, such as Guangxi zhuang autonomous region, Guizhou province, and Yunnan province, wood is the main material used in rural residential buildings, which are usually two or three floors height. Because of no rigid needs for warmth of rooms, wood is not only used as main roof materials but also main wall materials. Due to the lack of unified construction plan, scientific architectural and structural design scheme, advanced construction technology, high performance building materials, and adequate fire protection facilities, as a result, the distance between houses is very small, most rural buildings are faced with serious fire hazard threats.

In last few decades, some villages in southern region of China, have been destroyed most even all of them by fires. Some typical fire cases are briefly described here.

Linlue village (figure 1(a)), locates in Sanjiang county, Guangxi zhuang autonomous region of China. Approximately 2:00 AM local time on November 6, 2009, 196 residential buildings in Linlue village were burned down by a huge fire (figure 1(b)), and five people lost their lives.

Baojing village is a famous ancient village of Dong minority people, with more than 300 years history (figure 2(a)), in Zhenyuan county, Guizhou province, China. At about 23:30 PM, on January 25, 2014, a serious fire break out in Baojing village, in which one hundred and eighty-four wooden residential buildings were gutted completely (figure 2(b)).

Hulu village (figure 3(a)), locates in the town of the same name in Baojing county in Central China’s Hunan province. Almost all traditional wooden buildings were burned at roughly 7:50 PM local time on October 5, 2019. To prevent fire spreading from one building to another one, six
buildings were tear down, besides 62 buildings were destroyed by fire directly (figure 3(b)). A total of 283 people lost their homes, and fortunately, no one lost life.

![Figure 1. Linlue village, Sanjiang county, Guangxi zhuang autonomous region, China](image1)

![Figure 2. Baojing village, Zhenyuan county, Guizhou province, China](image2)

![Figure 3. Hulu village, Baojing county, Hunan Province, China](image3)

2. Mechanism of External Fire Spreading between Traditional Chinese Wooden Buildings

2.1 Direct flame contact

Chinese southwest region, such as Guizhou province, there's very little flat ground, as a result, residential wooden buildings are close to each other (figure 4). In some special case, the distance of two adjacent buildings may be less than one meter. Once a building catch fire, flame will shot out from wide opening on the gable or holes on burned through wood wall panels, the adjacent ones should be ignited by horizontal flame contact (figure 5). Most external fire spreads between adjacent wooden buildings happened via this way, because the length of horizontal flames may reach more than 20m [1]. It is necessary to plug the opening on gables to restrain flame overflow and improve the fire resistance of the wood wallboard for avoiding or delaying horizontal fires spread to adjacent buildings.
In a lot of villages of southwest China, wooden buildings were constructed along a slope (figure 6). In fire cases, wind can make flame inclined, and the inclined flame from the holes on roof may spread fire to adjacent wooden buildings located on a high position of the slope (figure 7). Therefore, it is needed to improve the fire resistance of the roofs to prevent them from burning through and spilling flames.

2.2 Thermal radiation ignites wood wall panels of adjacent buildings
In Chinese southwest region, the external wall of wooden buildings are usually made of local wood panels (figure 8), and sometimes, firewood for cooking and heating is stacked outside the walls (figure 9). In a fire sense, when radiation flux values emitted from burning building reach a certain level, the wood wall panels or firewood may be ignited, and as a result, fire spread to neighbour's building.

2.3 Flames radiate through glass windows and ignite indoor curtains and other objects
Curtains located behind normal single pane glass windows (figure 10) adjacent to a burning building can be ignited and burn due to radiant heat. Radiant heat coming through windows can ignite the
curtains inside building within minutes. A laboratory test indicated that 100% cotton curtain that hung on the non-radiant heat side of dual pane annealed glass window, ignited more than a minute after the upper section of the window fell out (figure 11) [2].

There’s an suggested way to help prevent this phenomenon, namely, use composite baffle with inner galvanized sheet cover glass windows.

Figure 10. Glass windows and curtains
Figure 11. Glass breaks first, and then cotton curtain ignites

2.4 Fire debris fly into adjacent buildings through windows, doors, and other openings

There are many routes on outer boundaries of Chinese traditional wooden residential buildings, through which burning debris may fly into (figure 12). A lot of fire debris generated from burning wooden buildings may fly into adjacent building, especially under strong wind conditions.

Figure 12. Main routes on outer boundaries of Chinese traditional wooden residential buildings, through which burning debris may fly into
As mentioned above, fire spread among buildings in four main ways. In fact, two or more of these ways may work simultaneously. Therefore, to prevent external fire spreading in southwest Chinese traditional villages, the suitability control techniques that can block four pathways of external fire spread must be provided.

3. Mechanism of Fire Spreading to Distant Buildings by Flying Debris
In the case of strong wind, large burning brand may fly down wind to distant buildings, which greatly increases the difficulty of prevention of external fire spread.

At about 13:15 PM, on February 13, 2012, a serious fire in Xinfeng village, Tongdao county, Hunan Province. It was presumed that one of the reasons was strong wind which blow flying debris far away and set fire to distant wooden buildings (figure 13).

![Figure 13. Fire in Xinfeng Villages](image)

A fire in Laerdalsøyri, Norway, on January 18–19 2014, strong winds quickly spread the fire in area A to downwind area B over long distances (200m) by embers and firebrand (figure 14).

A fire broke out from a restaurant in Itoigawa city, Niigata, Japan, around 10:20 am on December 22, 2016. One hundred and forty seven (147) structures were damaged by the fire, with 120 of 147 destroyed. Firebrands were lofted over a large area and ignited around 10 structures (figure 15) [3].

![Figure 14. Fire spread from A to B by embers and firebrand](image)

![Figure 15. Ignition caused by firebrands [3](image)

4. Fire Protection Technology for Villages of Traditional Wooden Buildings
Based on the understanding of mechanism of external fire spreading between traditional Chinese wooden buildings, some suitable structural measures are suggested.
4.1 Sandwich panels with inner galvanized sheet between two layers of wood boards

Figure 16(a) illustrate the sandwich panels, that carpenters in villages can make with simple tools such as nails, hammers and saws (figure 16(b)). Due to the inner galvanized sheet, the fire resistance of sandwich panels has been significantly improved. The second important feature of sandwich panels is to keep the external appearance and internal vision of the wooden structure unchanged.

A wooden building in Gaonan village, Rongjiang county, Guizhou province, China, part of whose general single layer wood wall panels were transformed sandwich panels with inner 0.4mm thick galvanized sheet (figure 17(a)). On August 23, 2020, fire test was conducted on the wooden building, by the end of test, sandwich panels was still intact (figure 17(b)), meanwhile all general wood wall panels were total burned.

4.2 Using sandwich panels with inner galvanized sheet in roofs

Figure 18 shows the the most common roof system used in southwest Chinese traditional wooden building in rural areas. Because there are no wood boards under the tiles, the black tiles can be seen from inside of the building. Due to rafters are thin and narrow, this kind of roof system is easy to burn through in a fire, as a result, flames shot through the roof and spread fire to neighbour's building locate on a high position. According to the experimental results of the wall panels, it can be inferred that roof system using sandwich panels with inner galvanized sheet (figure 19) will have better fire resistance than the existing commonly used roof system.
4.3 Using sandwich panels cover windows
In European countries, people like to put wooden baffles on the outside to protect windows (figure 20). If the normal baffles are replaced with sandwich panels with inner galvanized sheet, the sandwich baffles can not only restrain the overflow of indoor flames, but also prevent external fire from spreading into the room through the window (figure 21).

4.4 Shutters with mental meshes at gables
Southwest China was hot and humid, and early buildings needed natural ventilation, so large openings were left on the top of gables (figure 22). To prevent fire spread through these openings, it is suggested that metal mesh is installed behind the shutters to allow only tiny flying debris to enter (figure 23).
4.5 Divide a larger village into distant smaller groups

It is suggested, in many papers [4,5], that a larger village should be divided into several relatively smaller parts in which the total number of buildings is no more than fifty. The aim of this suggestion is to avoid total destruction of all buildings in a village due to external fire spread. A villages shown in figure 24, were naturally divided into two distant parts, and the probability of fire spread between different parts has been greatly reduced. It is worth to point that it is hard to divide a existing traditional village into several distant smaller zones. We should lay emphasis on limiting the size of zones when plan a new village due to removal or rebuild a existing village.

![Figure 24. Two parts of a traditional village in Guizhou province](image)

5. Conclusions

This paper seeks to find the mechanism of external fire spread in southwest Chinese traditional villages, and then suggests some suitable technical measures to dramatically reduce the probability of fire that destroys whole village. Sandwich panel with inner galvanized sheet is a new suitable technical measure suggested by first author, that not only can restrain flame in buildings, but also can prevent the invasion of adjacent burning buildings, as a result, slow fire spread in a village. It is believed that the technical measures proposed in this paper, in combination with other measures such as transparent fire retardant liquid, will effectively delay the spread of fires between buildings and thus reduce the occurrence of tragedy that fire destroys a village totally.

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