Research Progresses and Needs on Fire Safety of Rural Building in Southern Region of China

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Abstract. In recent decades, numerous rural buildings, especially residential ones in southern region of China, have been damaged seriously even destroyed totally by fire hazards. Fires in rural buildings can result in significant losses of life, property, and cultural heritage. Therefore, fire hazards in villages and towns are becoming a growing concern from common people, related experts, to central government. There are few literature on research of rural buildings exposed to fires in China. In this paper, several typical rural building fire cases are introduced firstly. Mechanism of fire spread and structure collapse is qualitatively investigated secondly. Some research progresses and needs on rural building fire in China are given thirdly. The authors hope this paper may provide valuable information for people who hope to learn about the current situation, research progresses and needs on fire safety of rural buildings in China.

1. Introduction
China has a total land area of 9.6 million squares kilometers. The distance from east to west measures over 5,200 kilometers, and from north to south, over 5,500 kilometers. Geographically, China can be divided into four parts: northern region, southern region, northwest region, and Qinghai-Tibet region. According to data in Chinese statistical bulletin on urban and rural construction of 2016, 756 million rural residents live in 20,883 villages or towns, with a total floor space of residential buildings 24,620 million square meters. 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, especially the used as roofing material(figure 1), because mountains are full of trees and bamboo owing to higher atmospheric temperature and abundant rain[1].

Figure 1. Typical rural timber buildings in southern region of China
In southern region of China, residential buildings are usually two or three floors timber buildings. Because of no rigid needs for warmth of rooms, wood are not only used as main roof materials but also 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 are very small(figure 2), most rural buildings are faced with serious fire hazard threats[2].

![Figure 2. Blocks of timber buildings in southern region of China](image)

2. Typical fire incidents of Chinese rural buildings

In southern region of China, because wood is main construction materials, as well as the distances between buildings are small, rural buildings are more likely to catch fires and spread to adjacent ones. In last few decades, numerous rural buildings, especially residential ones in southern region of China, have been damaged seriously even destroyed totally by fires. Some typical fire cases are briefly described as follows.

Jinzhu zhuang village, locates in Longji county, Guangxi zhuang autonomous region. There were 98 family, more than 430 people, lived in the Jinzhu zhuang village, in which all constructions were wooden stilted buildings with a distinct zhuang style(figure 3(a)). Around 8:00 PM on November 30, 2017, the village cached fire(figure 3(b)). To prevent fire spreading from one building to another one, the residents had to tear down nearby houses. Twenty eight resident buildings were destroyed totally, and fortunately, no people lost lives.

![Figure 3. Timber buildings in Jinzhu zhuang village, Longji county, Guangxi, China](image)

Dukezong ancient town(figure 4(a)), locates in Shangri-La city of Yunnan province of China. The ancient town has a history of 1,300 years, during which it has experienced both the flames of war and prosperity of frontier trade, and is the largest and best-preserved Tibetan town in China. On January 11, 2014, 343 buildings in Dukezong ancient town were burned down by a huge fire(figure 4(b)). Most buildings that we can see today are rebuilt in the last few years after fire.
Judong village is a famous ancient village of dong people (figure 5(a)), in Congjiang county, Guizhou province. Around 2:10 am, on November 10, 2005, a serious fire broke out in Judong village, in which eighty three wooden residential buildings were gutted completely (figure 5(b)), and three people lost their lives unfortunately.

3. Mechanism Fires Spreading in and among Buildings

3.1 Main causes of fire hazards in rural resident buildings
Faulty electric wire without fire proof conduit and careless using fire in kitchen are the main causes of fire-related hazards in Chinese rural areas. Usually, the diameter of electric wires are not big enough, in addition to and material of them are aluminum rather than copper. Figure 6 shows the typical electric wires used in villages of Guizhou province. In most southern villages of China, wood, shrubs and weeds are main fuel for cooking. Figure 7 shows the typical kitchen range in villages of Guangxi zhuang autonomous region.

3.2 Mechanism of fire spreading inside buildings
In the interior of most rural houses, there are no active fire-fighting facilities, as a result, once a fire breaks out, it is difficult to find and put out automatically. Interior of rural resident buildings are full of
furniture, most of which are combustible, and fire spreads easily among them (figure 8). Meanwhile, almost all combustible building materials have no fire-resistant paint on the surfaces, and those wooden floors, walls, beams, etc. will burn (figure 9). In addition, the building itself is not tight, oxygen supply is sufficient, as a consequence, the fire can expand rapidly.

3.3 Mechanism of fire spreading among buildings
Fire spread among buildings in three main ways. Firstly, fire can spread through window overflow from burning building to ignite wooden walls, curtains or other combustible materials of adjacent building (figure 10).

Secondly, burning flying debris, fall into the adjacent building through the opening on the wall (figure 11), and ignite indoor materials, as a result, the fire spread to adjacent building [4].

Thirdly, in the case of high wind, large burning brand (figure 12) may fly to the roof of adjacent buildings, especially fly onto broken tiles, where the burning block ignites the combustible materials down below the roof tiles, leading to the spread of fire through the roof.

4. Mechanism of Rural Buildings Collapse in Fires
Wood is the main building materials used in villages and towns of southern Chinese. Unlike concrete and steel, wood can burn when exposed to fires. As a result, timber buildings are more prone to collapse during fires. Because of the size of cross section of columns, beams, and rafters, those main
structural members have vastly different fire resistance. The cross section size of rafters are smaller compared to that of columns and beams, so rafters are easy to be broken in fires.

In southern region of China, there are two kinds of typical roofs, which are widely used in wood and brick-wood structures: (1) Cold spread tile roof (figure 13); (2) Timber wattle-tile roof (figure 14).

A large number of fire cases demonstrate that the roofs were burned through first (figure 15), tiles fall down (figure 16), causing the fire to grow, then whole roofs collapse, and the fires may spread to other buildings. So, the fire resistance of a roofs determines the fire-resistant time of whole rural buildings. How to improve the fire resistance of roof is a problem that needs further research.

5. Research Progresses and Further Research Needs

5.1. Research progresses
Chinese scientific and technological workers, fire-fighting companies, and rural craftsmen, have conducted a large number of studies on the fire safety of rural buildings and made the following progresses:

- Economical and practical fire detection technology, suggested by State Key Laboratory of Fire Science, University of Science and Technology of China[5].
- Simple and feasible fire extinguishing technology, produced by Institute of Building Fire Research, China Academy of Building Research.
- In terms of flame retardant technology, a new transparent fireproof paint for timber buildings has been developed by Fujian Zhangping Well-known Fireproof Technology Co., Ltd.
- "Low technology" and "suitability technology"[6] to improve fire resistance of roof and floor, proposed by School of Civil Engineering, Shenyang Jianzhu University.

5.2. Further research needs
To improve the fire safety level of rural buildings in southern region of China, further research is urgently needed in the following aspects:
● Compile fire resistance standards for building components in villages and towns, and stipulate fire resistance limits for building components such as columns, beams, roofs and floors.
● Preparing standards for housing construction, including selection of materials; opening setting position and size; code for kitchen fire; electricity system guarantee.
● Rural regional fire planning standards, including fire prevention distance between buildings; construction of fire fighting teams; fire water source setting; fire protection equipment support.
● Efficient training and education method on fire safety for rural residents.

6. Conclusions
This paper seeks to describe the current situation and fire safety problems of rural constructions in southern region of China, analyse the mechanism of fire spread in and among wooden buildings, investigate the causes of timber buildings collapse in fires, review the research progress on fire safety of rural buildings, and identify the research needs to improve fire safety performance of rural wood buildings in China. Based on contents presented in this paper, following conclusions can be derived:
(1) In southern region of China, there are large number of wooden buildings are threatened by fires. (2) Due to the lack of economic development, there is an urgent need for fire prevention technology suitable for local conditions. (3) Comprehensive consideration of safety education, fire facilities, regional planning, housing design and other aspects, is the only way to ensure the fire safety of villages and towns in southern region of China.

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