Fire-resistance Improvement of Vernacular Timber Architecture in a Historical Dong Village in China: A Case Study in Dali

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Abstract

The Dong villages represent villages in the cultural landscape of Chinese ethnic minorities. However, these Dong villages have timber buildings in a compact layout that is highly vulnerable to fire accidents. Thus, the aim of this study is to investigate the activities of the local people in Dali Village regarding the improvement of their buildings' fire-resistance. Without sufficient firefighting water resources and facilities, the village of Dali shows the typical vulnerabilities of Dong villages to fire accidents. Moreover, the traditional cooking space and old electrical wiring aggravate the fire risk.

The conclusions are as follows. Firstly, the local government replaced the aged electrical wiring and transformed the traditional ground oven into a brick oven, which reduced the fire risk from the local people's perspective. However, our investigation did not consider it to be fully effective. 84% of the households surveyed still use a ground oven because the brick oven is too big for the needs of most families. In addition, 36% still have timber walls surrounding the brick ovens. Secondly, 21% of the households have only replaced the first storeys of their timber buildings with brick or concrete; 79% have not conducted any fire-resistance improvement. From the perspective of the local people, the main reasons for their limited improvement activities can be attributed to insufficient financial capacity and lack of technical knowledge on fire-resistance building improvement. On the whole, the fire-resistance improvement activities in Dali Village are limited.

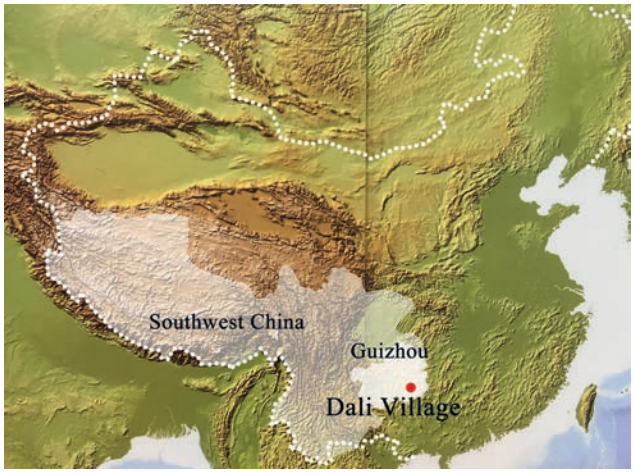

Fig. 1 (a) The location of Dali Dong village (The maps were redrawn with reference to [24])

1. Introduction

1.1 Research background

The Dong ethnic minority, which is the 12th largest ethnic minority in China in terms of population, lives mainly in the mountainous area of Southwest China. Twenty Dong villages encompassing the settlements with cultural traditions of the Dong ethnic minority have been included in the Tentative List of properties for consideration of being nominated to the World Heritage List because of their Outstanding Universal Value [1]. However, these Dong villages are extremely prone to fire due to the compact layout of their timber buildings. Among the 33 major fire accidents which occurred in historical villages in China during the last two decades, 25 fire accidents happened in Dong villages [2]. Moreover, one was in one of the Dong villages on the World Heritage Tentative List, while others were in registered Chinese historical villages. The fires caused not only the loss of cherished historical buildings and landscapes, but also considerably disrupted the communities' socio-cultural environment. Therefore, it can be said that fire-resistance improvement of vernacular timber architecture in a historical Dong village is an urgent topic.

1.2 Research purpose and objectives

The aim of this study is to clarify the activities of the local government and the local people regarding fire-resistance building improvement in the typical Dong village of Dali, which is one of 20 Dong villages on China's World Heritage Tentative List. The research aims to contribute to extracting specifically targeted countermeasures for fire-resistance enhancement.

1.3 Previous studies and positioning of this research

The fire protection of historical buildings is an established research topic [3, 4, 5, 6]. A number of studies focused on the enhancement of timber architecture fire-resistance, for

Fig. 1 (b) Dali Village

instance, the fire-retardant treatment on timber facades, pillars and beams; fire-resistant coating on roofs and eaves; and the section and structural node design and technique [7, 8, 9]. Some studies focused on fire protection facilities and the improvement of the equipment, for instance, the installation and maintenance of automatic fire alarm systems, automatic spray, firefighting hydrant, sprinkling fire extinguishing systems, etc [10, 11].

Researchers have also paid attention to the fire protection of the Miao and Dong villages. Some discussed indigenous knowledge of traditional firefighting water systems [18, 2, 17, 19, 20]. Other studies analysed the vulnerabilities, such as the remarkably low fire-resistant compact wooden buildings without fire compartmentalisation, the traditional use of firewood, the aged electrical wiring system, the insufficient firefighting water resources, the insufficient firefighting facilities, etc [2, 12, 13, 14, 18, 19, 21, 22]. Some studies proposed fire countermeasures, improving the infrastructure and firefighting facilities, and enhancing the fire resistance of traditional wooden buildings [12, 13, 14, 15, 16, 18, 19, 23].

Most of the previous studies focused on the general situation of facility improvement, since the facility utilisation in Dong villages represents limitations at the present stage. As previously stated, a study focusing on the fire-resistance of timber architecture in a specific historical Dong village is necessary.

1.4 Research Methods

In order to investigate the fire-resistance building improvement activities in Dali Village, this study conducted research activities as follows (Table 1). This research is based on literature review and on field surveys conducted in July 2015 and in February 2016, which included interview surveys, spatially uniform sampling questionnaire and measurement surveys.

2. Vernacular timber architecture and fire accidents in Dali Village

2.1 Location of Dali Village

Located in the southeast autonomous prefecture of Miao and Dong Minority in Southeast Guizhou (Fig. 1), Dali Village, which was built during the 1730s, has 309 households and 1,308 Dong ethnic minority residents at present. Most of the Dong people rely on traditional terrace agriculture.

2.2 Vernacular timber architecture and fire accidents in Dali Village

Residing close to the water is the most important settlement pattern of Dong Villages. The houses are distributed on mountain slopes along rivers [1]. Dali Village is situated in a mountain valley surrounded by woodland (Fig. 1(b); Fig. 3). The

Methods	Date	Object	Total sample size			Contents
Structured Interview	July 2015	Scholars	5			Village conservation planning and programme;
	Feb. 2016	Village leaders	2			Disaster history; fire protection countermeasures;
Questionnaire	July 2015	Villagers	Delivered	Collected	Valid	Disaster experience; disaster-resistant building improvement;
			115	115	115	
Measurement	July 2015	Residential houses	27			Materials, structure, layout, section of the houses; spatial usage
	Feb. 2016					Fire-resistance improvement; fire utilisation; water reserve

Table 1. Outline of Field Survey

Fig. 2 (a) Residential building
Fig.2 (c) Drum tower

Fig. 2 (b) One of the five shelter bridges
Fig.2 (d) One of the eight granaries

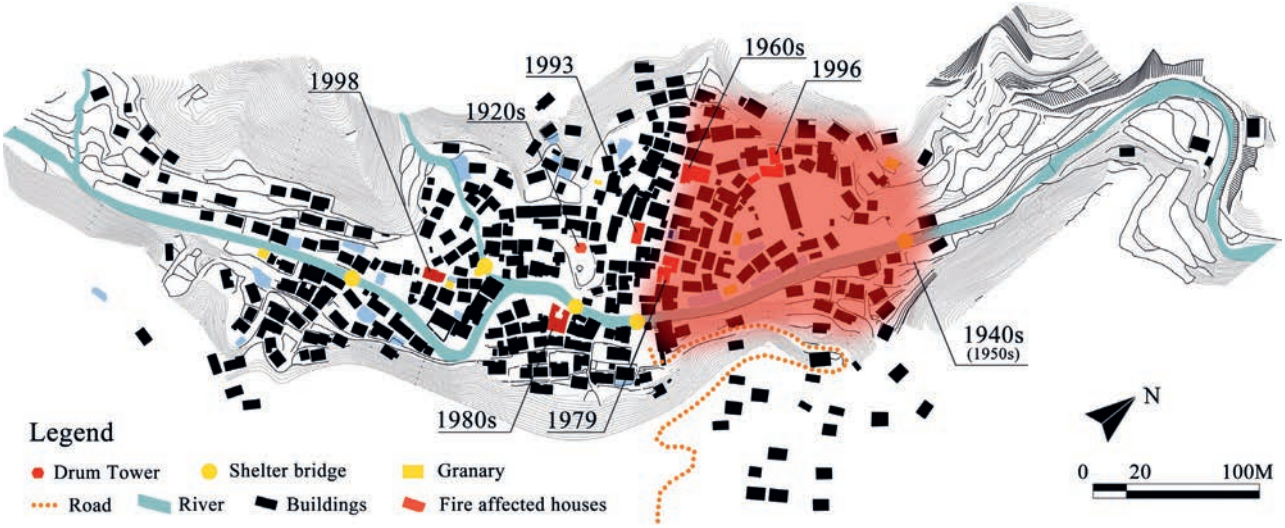

Fig. 3 Layout of Dali Village and fire accident spots (The basic topographic map data was provided by the Dali Conservation Program Office; There are two accounts about the year when the huge fire accident occurred, based on interviews: 1940s and 1950s.)

traditional architecture includes 300 residential buildings (Fig. 2(a)), and public buildings such as the drum tower (Fig. 2(b)), five shelter bridges (Fig. 2(c)), and eight granaries (Fig. 2(d)). The original traditional architecture is composed of tile-paved roofs and of timber structures, walls, floors and ceilings without fire-retardant coating interiorly and exteriorly. Without sufficient firefighting water resources and facilities, Dali Village exhibits the typical vulnerabilities of Dong villages to fire accidents. Moreover, the traditional cooking space with a ground oven surrounded by wooden walls and the aged electrical wiring aggravate the fire risk. Since the Dong ethnic minority had no written language until 1958 [25], Dali Village has no fire accident record, and limited information was collected in interviews based on the memory of the village's elder people. Within the last 100 years, Dali Village was affected by eight major fire accidents (Fig. 3). Nearly half of the village was burned by fire accidents in the 1940s and 1950s.

2.3 The fire protection regulations in Dali Village

Regarding the fire safety of these rural villages, there is no planning and building code that could be applied. Therefore, Guizhou provincial government issued "fire protection regulations" [26] in 2002 for these rural villages. The regulation encourages the local people to transform the wooden buildings with fire-resistant material. However, the regulation paid no attention to the heritage particularities and to the conservation of historical Dong villages. Consequently, in terms of practicality, no rules could be referred to on the community level during the fire-resistant building improvement.

Since interviews with scholars have confirmed that the public buildings, such as the drum tower, the shelter bridges, and the granaries are renewed by the local government without considering fire-resistance enhancement, this study will only focus on the 300 residential buildings.

Fig. 4 (a) The open-fire oven surrounded by wooden walls in the traditional cooking space

Fig. 4 (b) The transformed brick oven surrounded by brick walls

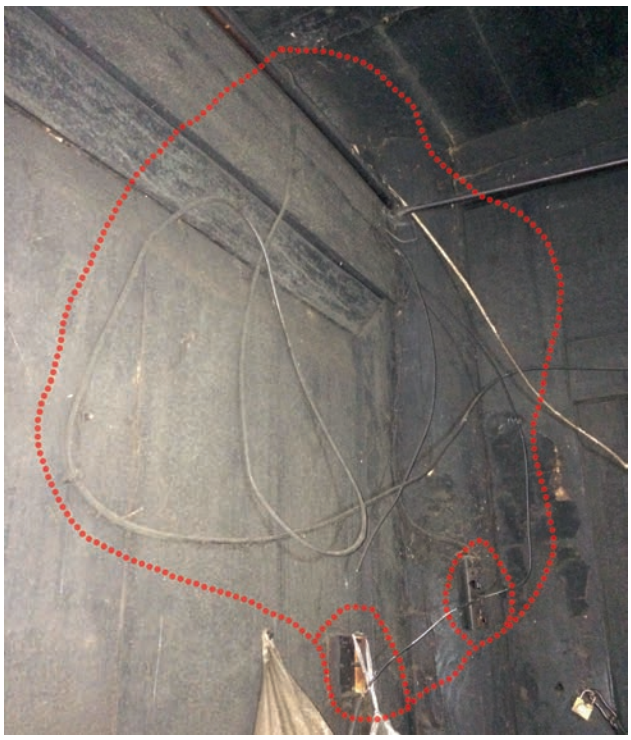

Fig. 4 (c) The meandering aged electrical wiring assembled during the 1980s

Fig. 4 (d) The improved electrical wiring

3. Fire-resistant cooking space and electricity wiring improvement by local governments

As the previous studies have pointed out, the traditional open fire ground oven and aged electricity wiring are two of the main causes for fire accidents in Dong villages. Targeting on these two specific causes, the local government is pressing ahead with fire-resistance building improvement projects in rural villages, by providing not only financial support but also materials and skilled workers. This section will investigate the improvements and their effects in Dali Village.

The transformation of the cooking oven was conducted in 2008. The original open-fire oven surrounded by wooden walls in the traditional cooking space (Fig. 4(a)) in each household was replaced by a brick oven surrounded by brick walls (Fig. 4(b)). In addition, the electrical wiring installed in the 1980s was already aged and meandering after modifications by the local people (Fig. 4(c)). Therefore, the local government implemented projects to replace the electrical wiring (Fig. 4(d)) in each household in 2008 and 2015. According to the interview in 24 households, all of them believe that the projects reduced the fire risk (Fig. 4(e)).

However, our investigation showed that the oven replacement was not considered to be fully effective.

84% of the households surveyed still use a ground oven (Fig. 5(a)), 44% use a gas oven instead of a brick oven (Fig. 5(b)), 32% use an induction cooker instead of a brick oven (Fig. 5(c)), because the brick oven is too big for the needs of most families, since the young members usually leave the village for work. In addition, while the walls surrounding the brick oven were rebuilt with brick in 64% of the households, 36% still have timber walls (Fig. 5(d)).

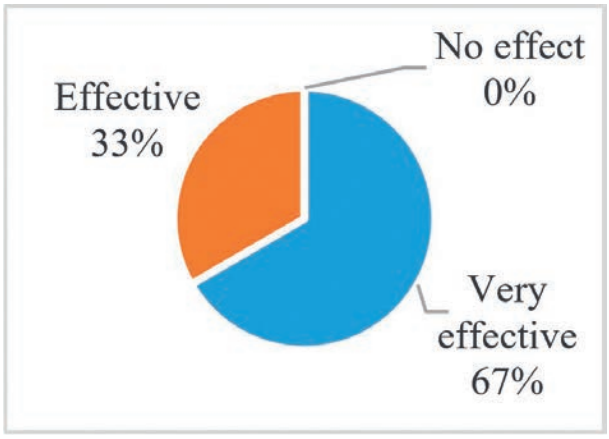

Fig. 4 (e) The local people's perspective of the effect of two projects

4. Fire-resistance building improvement by local people

4.1 Fire-resistant building transformation

Among the 269 buildings investigated in Dali Village, 21% were transformed, and 79% still keep the traditional styles (Table 2). Moreover, all transformed buildings retain the upper storeys in their original wooden materials and form, and have only transformed the first storeys using four different types (Fig. 6). In the buildings of type 1, the wooden pillars and beams remain,

Fig. 5 (a) Ground oven
Fig. 5 (c) Induction cooker

Fig. 5 (b) Gas oven
Fig. 5 (d) Timber walls

while the wooden walls were replaced by bricks (Fig. 6(a)). In the buildings of type 2, the pillars and walls were all rebuilt with bricks, while the wooden beams were not altered (Fig. 6(b)). This could be regarded as if the original wooden building was directly uplifted and put on a new brick structure. The buildings of type 3 have confined brick pillars, reinforced concrete ring beams, and brick walls (Fig. 6(c)). The structures of the buildings of type 4 are composed of reinforced concrete pillars, ring beams, and brick walls (Fig. 6(d)). The transformation may have enhanced the fire resistance of these buildings to some extent; nevertheless, it seriously affected the original architectural characteristics and appearance of this historic village.

4.2 Fire-resistant exterior coating

The fire-resistant exterior coating on a building's roof, eaves, and facade will slow down the speed of the spread of fire and

Types		Pillar	Beam	Wall	Abbreviation	Amount	Percentage
Buildings not transformed (original)		Wood	Wood	Wood	W-W-W	212	79%
Transformed buildings	Type 1	Wood	Wood	Brick	W-W-B	22	8%
	Type 2	Brick	Wood	Brick	B-W-B	25	9%
	Type 3	Brick	RC	Brick	B-RC-B	6	2%
	Type 4	RC	RC	Brick	RC-RC-B	4	1%

Table 2. Four types of first-story fire-resistant building material transformation (N=269)

will protect the building from being affected by fire from other buildings. All the residential buildings investigated in Dali Village were built with traditional wooden roof trusses covered with grey clay tiles (Table 3, Fig. 7 (a)), but the eaves are without fire-resistant coating (Table 3; Fig. 7 (b)). The facades of the traditional wooden buildings without transformation have no fire-resistant coating (Fig. 2(a)), while 27% of the transformed buildings have no coating on brick walls (Fig. 7(c)), and 73% have cement mortar or ceramic tile coating (Fig. 7(d), (e)). However, the upper storeys of all the transformed buildings still retain their wooden facade without fire-resistant coating.

4.3 Difficulty of implementing fire-resistant building improvement activities

To understand the reason for the local people's inactivity or limited activities, this study investigated the difficulty of im-

Fig. 6 (a) Type 1
Fig. 6 (b) Type 2
Fig. 6 (c) Type 3
Fig. 6 (d) Type 4

Types	Roof	Eave	Facades	
			First storey	Upper storeys
Buildings not transformed (212)	100% covered with gray clay tiles	0%	0%	0%
Transformed buildings (48)			73%	0%

Table 3. Fire-resistant exterior coating of buildings in Dali Village (N=260)

plementing fire-resistant building improvement through a questionnaire survey. It was found that 49% of the respondents were hampered by insufficient financial capacity and 20% claimed that they lacked knowledge of fire-resistant building technologies. Moreover, 25% believed that improvement activities are not necessary (Fig. 8) and they insisted that fire prevention awareness in combination with fire-utilisation behaviour in daily life is much more important and effective than building improvement. This suggests that their underestimation of the importance of building improvement is due to a lack of knowledge of the effect of fire-resistance building technology.

5. Conclusion

The purpose of this study is to investigate the fire-resistance building improvement activities of the local government and local people in Dali Village. The conclusions are as follows: Firstly, the local government replaced the aged electrical wiring and replaced the traditional ground oven by a brick oven, which reduced the fire risk according from the local people's perspective. However, our investigation came to the conclusion that the oven transformation was not fully effective. Almost all households surveyed still use a ground oven, a gas oven, or an induction cooker instead of the brick oven, because the brick oven is too big for most families' needs, since the young members usually leave the village for work. In addition, while the walls surrounding the brick oven were rebuilt with brick in 64% of the households, 36% still have timber walls. Secondly, without regulation and guidance, 21% of the households only replaced the first storeys of the timber buildings with brick or concrete. 79% did not conduct any fire-resistance improvement. From the perspective of the local people, the main reasons for their limited improvement activities can be attributed to insufficient financial capacities and a lack

Fig. 7 (a) Building roofs paved with gray clay tiles in entire Dali Village

Fig. 7 (b) Wooden roof trusses and eaves without fire-resistant coating in entire Dali Village
Fig. 7 (c) Transformed building with brick façade
Fig. 7 (d) Transformed building with brick façade and cement mortar coating
Fig. 7 (e) Transformed building with brick façade and ceramic tile coating

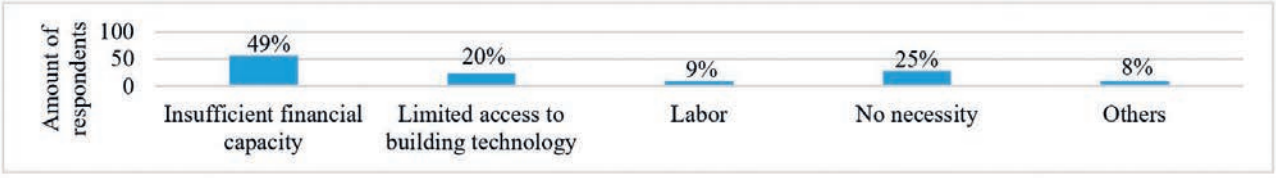

Fig. 8 The difficulties of the local people in implementing fire-resistant building improvement (N=114)

of technical knowledge of fire-resistance building improvement.

On the whole, the fire-resistance building improvement activities in Dali Village are limited. Regulations and technical support addressing not only fire-risk reduction but also local customs and heritage conservation are needed.

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