

DISASTER PREVENTION AND MITIGATION STRATEGIES FOR ARCHITECTURE HERITAGE CONCENTRATED AREAS IN CHINA

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Abstract

This paper draws upon preliminary research into the insufficiencies of the status quo of the disaster prevention and mitigation in architecture heritage areas in China. It summarizes how the common hazards, which are various threats to the survival and development of the historical architectural heritage, such as fire, geological disasters and meteorological disasters occurs and their characteristics, and also analyses their impact on heritage. The paper also focuses on the disaster-prone parts of architecture heritage, exploring the proposals for evaluations of disaster-risk-factors, and the preliminary strategies that promote historic architecture heritage related to disaster prevention and mitigation, so that people can enhance the security capabilities for architecture heritage. This enables strategies to limit the impact of the disaster, improve historic buildings anti-disaster systems, provide the theory and technical basis to the relevant departments for standards and regulations for architecture heritages' conservation and security. The ultimate aim is to ensure the long-lasting and safe existence and development of architectural heritage.

Keywords: *Architecture heritage; disaster prevention and mitigation strategies; China.*

INTRODUCTION

As a country with a long history and an ancient civilization, China has millions of examples of architectural and cultural heritage, which are a precious legacy left by our ancestors and are significant historical and cultural resources. However, at present, the existence and development of these heritages are threatened by many problems caused by a heavy tourism burden, serious damage because of insufficient maintenance funds, poor prevention against natural disaster and frequent accidents. Especially, in cultural heritage concentrated areas, such features as small spaces and narrow streets, high building density and population, low quality of infrastructure, serious deterioration of building quality, and low ignition point of brick-wood structures leads to very weak disaster prevention capacity of architecture heritage clusters. In recent years, much significant architectural heritage and historic areas have been ruined by earthquakes, fires, floods or mudslides, resulting in irreparable loss. For example, on March 11 2013, a fire broke out on Guangyi Street and Xianwen Alley of Lijiang Old Town, which lasted 3 hours and burned 107 buildings; on April 19, 2013, a historical building in Fenghuang Old Town was burned to ashes; earthquakes on April 20, 2013 in Ya'an of Sichuan Province damaged 102 heritage sites; a catastrophic flood starting from July 3, 2013 in Yan'an caused serious damage to 110 heritage sites. Architecture heritage in China faces a worrying situation in terms of disaster prevention, facing many challenges such as complicated disaster types, high frequency, and great severity. Therefore, it is vital for the sustainable development of this valuable heritage to improve their disaster resistance and enhance their comprehensive safety level.

Studies on disaster prevention strategies of architecture heritage mainly aim to find out how to reduce the damage of architecture heritage and how to improve the sustainability of

architecture heritage without damaging the historical authenticity by analysing the causes for frequent disasters. Although occurrence of disasters and the damage of architecture heritage have diversified causes, there are considerable similarities in the place of occurrence of disasters and the severities of damage to historical buildings. In addition, all disasters are not inevitable, and even if the occurrence of disaster is inevitable, it is possible to minimize the damages caused to the architecture heritage.

In this paper, cases of architecture heritage disasters occurring after the 1980s are studied, as many data files during the Cultural Revolution were destroyed. In addition, the social development conditions and population density before this time were very different and this may adversely impact upon the conclusion of reasonable study results. With respect to the contents of study, this paper focuses on unexpected disasters, including fire, unexpected geological disasters (earthquake, collapse, landslide and mudslide), unexpected meteorological disasters (flood, windstorm, lightning disaster and snow disaster), and so on.

STATUS QUO OF SAFETY PROTECTION OF ARCHITECTURE HERITAGE AND COMMON DISASTERS

Some Chinese scholars summarized the condition of the safety protection of architecture heritage in China as 'seven insufficiencies', that is: insufficiency in awareness, insufficiency in legislation, insufficiency in system, insufficiency in technology, insufficiency in planning, insufficiency in ability, and insufficiency in environment (Yang, 2003). Along with the advance of urbanization, there are more and more contradictions in the protection and development of architecture heritage concentrated areas. The status quo has the following features:

Architecture conditions

Firstly, in most Chinese residential buildings of wood or brick-wood structure there are often many positions where wood structure is directly exposed to air, resulting in a low fire resistance rating and easy spontaneous combustion or ignition in dry air, continued high temperature, lightning strike or open fire. Secondly, most buildings in historic districts were built by the residents themselves, and lack necessary earthquake protection due to no design standards or restrictions in cost. After decades or even hundreds of years of weathering, these buildings often have damage to their structural parts, especially wooden parts, leading to greatly reduced disaster resistance. Thirdly, most traditional residences in China have different forms of courtyard combination, such as Siheyuan in Beijing, Tulou in Fujian, Yikeyin in Yunnan, and Sishui Guitang in South China. Such combined architecture forms increase the possibility of fire spread, and make it more difficult to evacuate in case of geological disasters such as earthquakes and mudslides (see Figure 1).

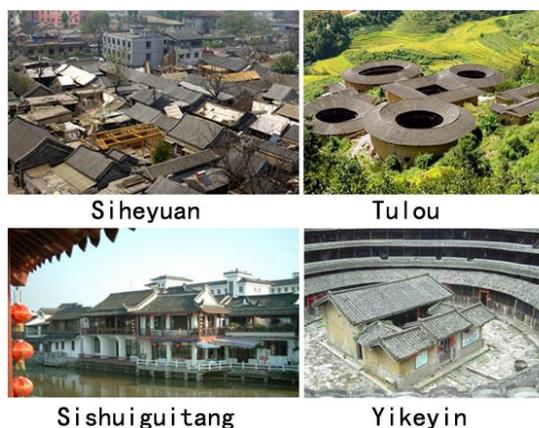


Figure1. Chinese traditional courtyard houses forms (Source: <http://image.baidu.com>).

Conditions of street and surrounding environment

Most historic districts have such problems as small spaces, narrow streets and high building density. In addition, some streets and alleys are not connected with each other. Figure 2 shows an old residence deep in an alley of Tunxi Old Street, where fires have broken out repeatedly. These conditions make it difficult for rescue equipment such as a fire engine to approach, and often result in great loss. In addition, architecture heritage concentrated areas typically have a high density of population and commercial buildings, and often bear too heavy functional burden of residence or tourism due to high population. For example, a fire broke out in a commercial building in Fenghuang Old Town in April 2013, which was a building integrating a restaurant, bar and a hotel. The building was completely burned down, and the cause for the fire has not been discovered.

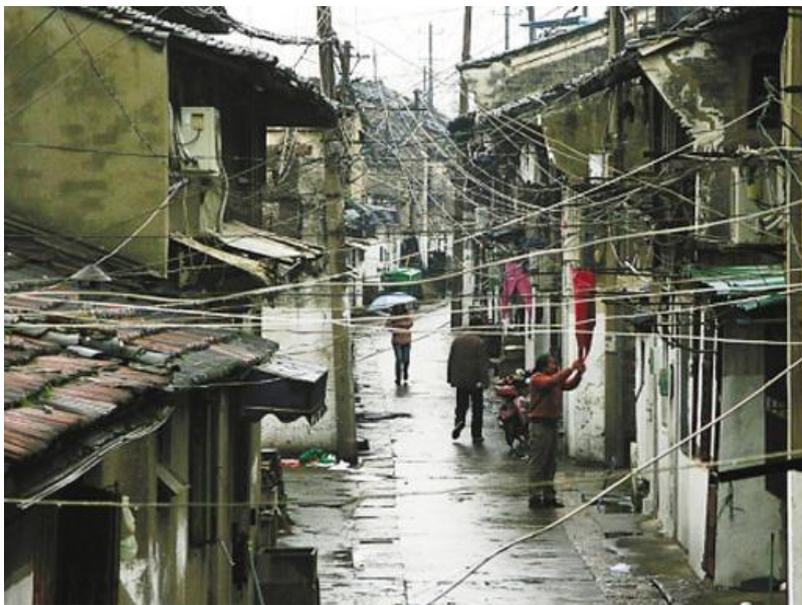


Figure 2. Nantanhe Historic area in Ningbo China. (Source: <http://www.zjww.gov.cn/news/2009-03-12/170045778.shtml>).

Conditions of the infrastructure

Along with the social development in modern times, “old areas” where architecture heritage is concentrated often becomes an underdeveloped area, where infrastructure such as electrical equipment and lightning protection equipment is old, electrical insulation is poor, power wires are old, overloaded and out of order, and water supply and drainage systems cannot meet firefighting needs.

Laws, regulations and management systems

According to incomplete statistics, China has promulgated 13 laws and regulations related to cultural relic protection since 1963, including Provisional Measures for Protection and Management of Cultural Relics, Fire Protection Management Rules for Historical Buildings, Management Measures of State Cultural Relics Bureau for Emergencies, and so on. However, damage caused by unscrupulous developers to relics cannot be restricted simply by means of penalty, and some applicable laws and regulations are not actually implemented. As cultural heritage resources are subject to jurisdiction-based management, local governments often think about economic benefits first when dealing with historical and cultural heritage. In some areas,

little heritage other than those under state-level protection are managed by dedicated persons. Heritage of low protection levels often lack maintenance funds, and are damaged due to natural weathering or improper repairs made by local people.

Command disasters threatening architecture heritage

Common disasters threatening architecture heritage in China mainly include fire, geological disasters and meteorological disasters, among which fire, earthquake, flood, windstorm and lightning have the most serious impact.

Fire is the most common disaster for architecture heritage. As most historical buildings in China are constructed of wood structure and have cluster or group layout, the occurrence of fire in such buildings is frequent, the combustion and spread speed after the break-out of fire is high, and it is difficult to put it out. Geological disasters include landslides, mudslides, surface collapse, land cracks, land subsidence, and the like caused by natural factors or human activities. China is one of the countries with the most serious geological disasters in the world, and such disasters are direct threat against the safety of architecture heritage of poor quality. For example, the Wenchuan Earthquake in 2008 caused different degrees of damage to the surrounding heritage such as the Dujiangyan Irrigation System. Meteorological disasters threatening architecture heritage mainly include rainstorms, floods, tropical hurricanes, windstorm, and lightning (figure 3). In China, historical buildings are more vulnerable to lightning than modern buildings due to their construction, structure and materials.

With respect to space-time distribution of disasters, the region and time features of fire disaster are not obvious, whereas more meteorological disasters occur in coastal areas in some of the seasons. Geological disasters, however, tend to occur in inland areas such as Southwest China and Northwest China. The impacts of human factors in these disasters are more complicated. For example, some serious damage to architecture heritage caused by floods are due to raised surrounding areas arising from urbanization, blockage of drainage system, changed elevation of district, or other human factors.



Figure3. Distribution of major meteorological disasters in China (Source: Comprehensive Volume of Chinese Meteorological Disaster Records).

ANALYSIS ON THE IMPACT OF MAJOR DISASTERS AND THE EVALUATION FACTORS

Fire: Analysis on fire disaster of architecture heritage and the related risk evaluation factors is helpful to reasonably describe and judge the possibility and hazard severity of fire disaster in the operation and development of architecture heritage. This can guide people in setting scientific protection strategies under current conditions, and to minimize the possibility of and loss from fire (Fitzgerald, 1993).

On the cause: Among 210 fire disasters of architecture heritage that have occurred in last 30 years, causes for 117 cases have been identified, which included natural factors, environmental factors, human factors and electrical factors. Of these, 62 cases were caused by human factors, 41 cases were caused by electrical factors, 10 cases were caused by natural factors, and 4 cases were caused by environmental factors (see Figure 04).

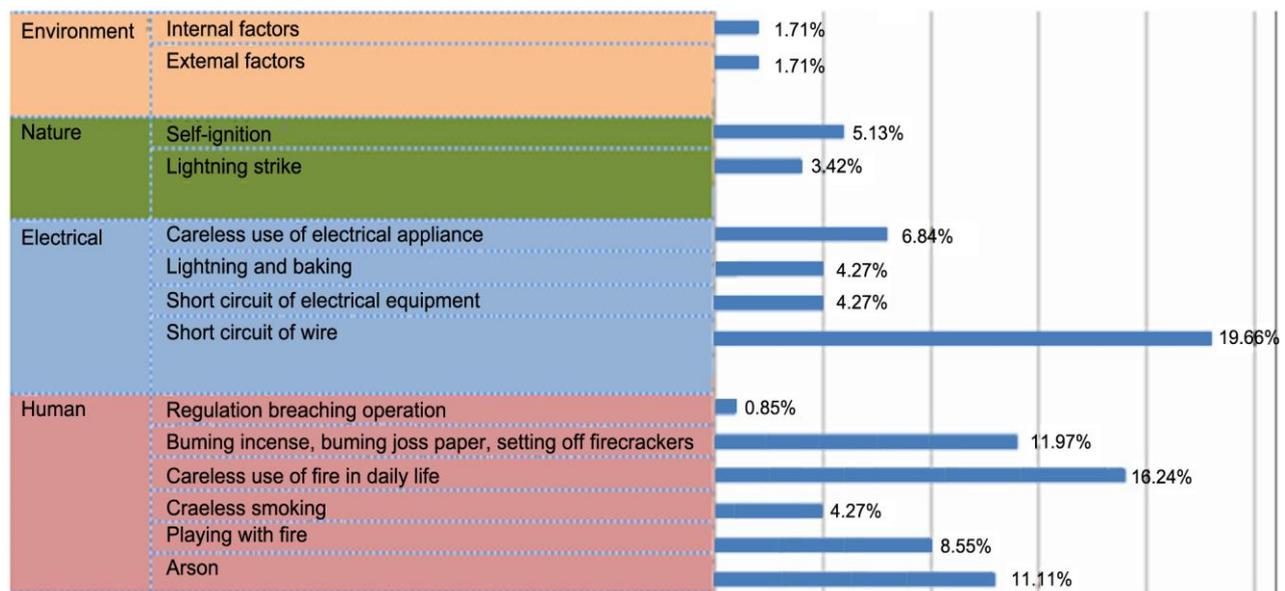


Figure 4. Cause for fire (Source: Authors).

On the loss: In the above-mentioned 210 fire disasters, losses included physical heritage loss, personal injury or death, and direct economic loss. In terms of building type, fire in memorial buildings and public buildings often caused greater losses than those in residential buildings. In terms of time distribution, fires which occurred at night often caused greater loss due to no timely discovery and extinguishing.

Risk evaluation factors: Risk evaluation of fires mainly consists of qualitative evaluation and half-quantitative evaluation. A fuzzy comprehensive evaluation method is used to combine the certain laws and the uncertain influencing factors. Then data and subjective evaluation of the evaluator are combined to get convincing conclusions. Risk of fire disaster in architecture heritage covers fire possibility and hazard severity, and risk evaluation for such disaster also covers these two aspects.

As discussed above, the occurrence and hazard of fire in architecture heritage is mainly related to three factors: human; object; and environment. Thus, fire risk evaluation also covers these three aspects. The human factors involves twelve aspects: condition of burning incense; condition of burning light/candles; condition of burning paper money; behaviour of tourists; behaviour of occupiers; behaviour of residents; illegal behaviour; fire protection education;

firefighting organization; fire drills; and firefighting guarding. Object factors involves nine aspects: interior condition of the building; use of electrical appliances; condition of wires; condition of lightning protection device; condition of firefighting equipment; water for firefighting; firefighting channels; and the condition of building itself. Environment factors involve four aspects: external condition; internal condition; geographical environment condition; and traffic and topographic condition. The evaluation results are obtained based on evaluation of these aspects.

Earthquakes

Based on the damage severity of historical buildings in an earthquake, the earthquake hazard is divided into four levels: turbulence; damage; destruction; and collapse. Turbulence refers to the condition where pillar bottoms of historical buildings experience small sideways movement; small cracks or peeling occurs on walls; some girder or pillar nodes become loose; girder frame, tile surfaces and other positions are intact, and the structure requires only minor repair. Damage refers to the condition where weak parts of the building itself is damaged; pillar bottoms experience sideways movement; obvious cracks occur on walls, and some walls collapse; some girders or pillar nodes become loose; room surfaces and decoration are damaged; local repairs are required. Destruction refers to the condition where pillar bottoms of the historical building experience sideways movement; walls have obvious cracks or collapse; some girders or pillar nodes are seriously damaged; girders tilt; room surfaces and decoration are damaged; large areas of tiles peel off; the main structure is seriously damaged; major repairs are required. Collapse refers to the condition where most walls of the building fall; girders tilt obviously or fall; most of the tiles peel off; and the building cannot be recovered through repair.

Characteristics of damage caused by earthquakes

Based on study of damage to architecture heritage caused by earthquakes, it can be found that the following damage is very common(see Figure 5-8): 1) In buildings of rock structure: wall crack, tilt, peeling, foundation settlement, step rupture, and even collapse; 2) In buildings of rock-wood structure: rupture or disconnection of wood structure, wall tilt, serious distortion of building structure, roof tile side slide, tile falling, and so on; 3) In grottos: crack of rock body, water penetration, mountain collapse, and so on; 4) In buildings of brick-rock structure: tilt, rupture or collapse of the main body, 5) Foundation destruction: pillar bottom sideways movement, pillar tilt, loose node connection, fitment rupture, girder tilt, tile falling, and so on; 6) In soil relics, secondary hazards such as slide and mudslide (Cultural Heritage Planning and Research Center of Sichuan Cultural Relics and Archaeology Research Institute, 2008).



Figure 5. Xiaoyao Building - located in Guangyuan City, Sichuan Province; wood structure (Source: <http://image.baidu.com>).



Figure 6. Fazang Temple - located in Pengzhou City, Sichuan Province; wood structure (Source: <http://image.baidu.com>).



Figure 7. Qinyan Building - located in Dujiangyan City; wood structure (Source: <http://image.baidu.com>).



Figure 8. Lingbao Seminary - located in Pengzhou City; brick-wood structure (Source: <http://image.baidu.com>).

Causes for damage

The first factor is location. Damage severity upon historic buildings positively correlates with earthquake magnitude and distance from the epicenter. The second factor is the geological environment. In two historical buildings in the same seismic belt and with similar distance from the epicenter, one of them may be easily subjected to secondary disaster due to poor geological conditions. The third factor is building materials. Historical buildings of wood structure have better earthquake resistance than buildings of brick, rock or earth structure. The fourth factor is building form. Building layout, structure, connection with ground, foundation form, windows in the walls and structure type have different impacts on architectural stability. The fifth factor is the age of building. From comparisons of damage conditions of architecture heritages in several violent

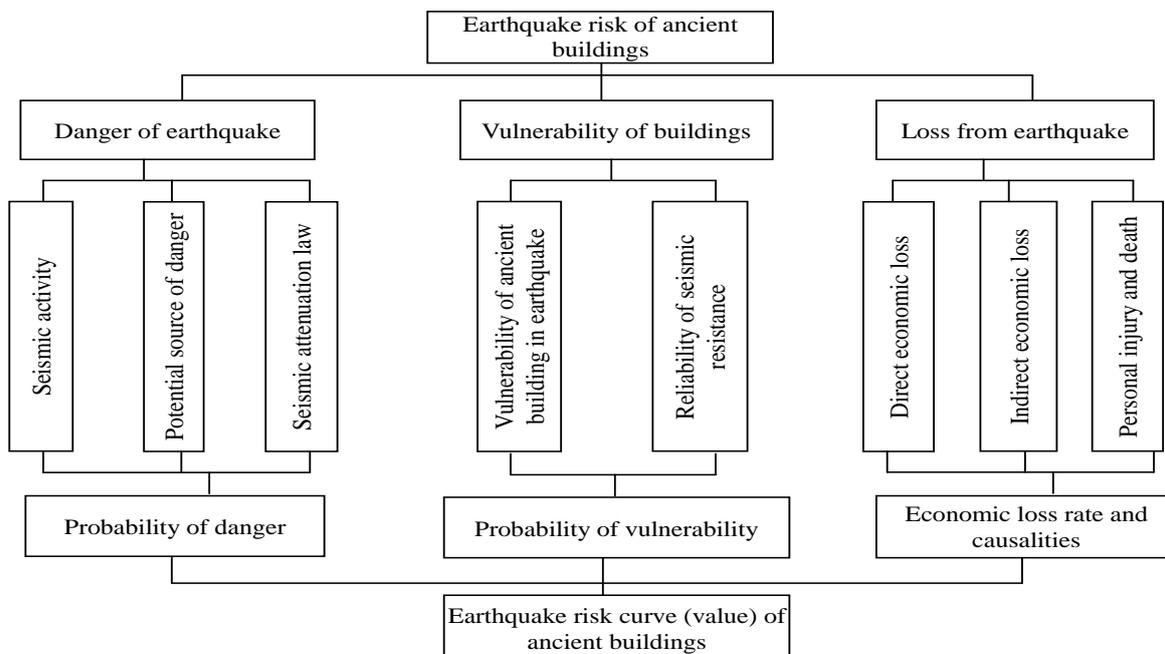


Figure 9. Composition of earthquake disaster risk of ancient building (Source: drawn by the authors).

earthquakes, newer buildings and reconstructed buildings tend to experience more serious damage than those with a long history. The last factor is daily maintenance, for example, properly maintained wood-structure historical buildings can resist an earthquake with an intensity grade of 9 (Li, 2006).

Risk evaluation factors

Earthquake risk evaluation factors for architecture heritage mainly involves analysis of the disaster causing risk, study on vulnerability, and an evaluation of disaster loss. Analysis of disaster causing risk refers to the analysis on earthquake danger, aiming to determine the possibility or cycle of earthquakes in the area where the historical building is located. Study on vulnerability aims to evaluate the earthquake resistance of the historical building based on the structural features and value of the building as well as the earthquake resistance mechanism of the building itself and the interior parts. Evaluation of disaster loss refers to the evaluation of the potential times of earthquakes in the area in a given period as well as the potential loss that may be caused to the historical building. The first two factors focus on probability of earthquake hazards, while the third factor focuses on consequences of the earthquake hazard (Liu, 2010). (see Figure 9).

Meteorological Disaster

Damage of flood disaster and related risk evaluation factors

Loss caused by flood disaster is determined by three factors, respectively: the vulnerability of the affected objects; density of the affected objects; and disaster strength. Flood disaster risk analysis mainly includes two parts: analysis of the danger of flood hazard; and analysis on the vulnerability of the affected objects. Analysis on the danger mainly covers the disaster causing environment and the disaster incurring factors, and then the probability function of flood distribution in the given area is analysed (Wei,1997).

Damage of windstorm disaster and related risk evaluation factors

Damage caused by wind storms are related to such factors as building location, wind strength, architectural layout, building form, tightness of component connection, and collapse of surrounding objects. Risk analysis of windstorm covers the danger of windstorm, vulnerability of structure, and loss from the disaster. Danger of windstorm involves the type, grade and probability of the potential windstorm disaster in given period in given place. The vulnerability of structure involves the resistance of historical buildings against wind load and loss from the disaster involves the calculation and analysis of the total physical loss caused by the windstorm disaster (Chang, 2003).

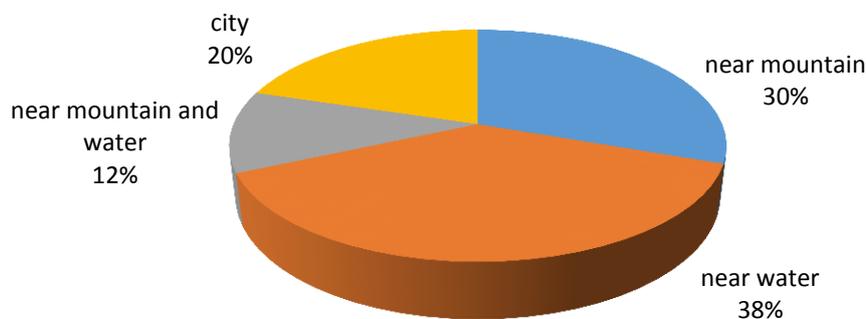


Figure10. Geographical distribution of historic buildings damaged by lightning (Source: Authors).

Damage of lightning disaster and related risk evaluation factors

The location, shape, structure and equipment of historical buildings may impact on the likelihood of the occurrence of lightning disaster. For practical reasons, traditionally in China, people often chose hillsides or mountain bottoms to locate their buildings and these were often surrounded by water. These factors also make historical buildings vulnerable to lightning disaster. Among the 80 lightning strike accidents mentioned in Analysis on Lightning Disaster Features of Historical Buildings, 80% of the buildings struck were beside mountains, water, or both (see Figure 10). In addition, the structure and shape of architecture heritage also has an impact on the parts damaged by lightning. Protruding parts on the roof are highly vulnerable to lightning in historical buildings (see Figure 11). In addition, buildings with metal decorated parts are particularly vulnerable to lightning. Among the buildings struck by lightning, 30% were struck on a protruding part of their fabric and significantly, most architecture heritage does not meet modern safety standards (Tong, 2007).



Figure11: Vulnerable positions of architectural heritage to lightning (Source: Authors).

In Analysis on Lightning Disaster Features of Historical Buildings, there are five lightning risk evaluation factors: significance of building; expected annual times of strike; architecture structure; interior environment change; and lightning strike history. The respective weights of these five factors in lightning strikes are 20%, 25%, 15%, 25%, and 15% (State Technical Supervision Bureau, 2000).

DISASTER PREVENTION AND REDUCTION STRATEGIES FOR ARCHITECTURE HERITAGE

For the purpose of long existence and the sustainable development of architecture heritage, it is necessary to set suitable and proper disaster prevention and reduction strategies, and to improve the comprehensive safety of architecture heritage. Such strategies should be centered on prevention, with a combination of disaster prevention, defence and relief.

Disaster prevention

Disaster prevention includes disaster investigation, early warning, safety risk evaluation, and comprehensive safety planning. Disaster investigation refers to the regular inspection of architecture heritage to eliminate potentially hidden fire risks, and to prevent dangerous behaviour such as illegal fire use, power use, and gas use. With respect to geological disaster and meteorological disaster, the investigation is mainly performed using GPS, GIS and 3S technologies, in combination with a ground disaster sorting method, aimed to measure and test the potential influence of local geological conditions and weather conditions on a disaster (Yin & Zhu, 2001; Yang, 2012).

Disaster early warning systems include two parts: an automatic fire warning system and an earthquake early warning system. These systems should be used on the premises of having no negative impact on the conditions of the historical buildings, and be consistent with the related management measures (Liu & Zhao, 2009). Technical monitoring and human supervision should be strengthened for architecture heritage in flood seasons and dry seasons based on the time distribution of disasters. Early warning and monitoring of significant natural disasters mainly involves effective forecasting of various disasters using modern information technology as well as existing hydrological, meteorological and geological resources. For the evaluation of fire disaster in architecture heritage, the factors that may cause a fire should be selected and a value assigned to judge the probability. Significant geological disaster and meteorological disaster is often forecasted by collecting and analysing the features and records of historical disasters, and then analysing the danger degrees and distribution of disasters in different areas (Zhou, et al., 2001). Comprehensive safety planning includes improving existing disaster prevention plans; strengthening cross-plan combination; improving the connection with other plans, repair methods and various laws and regulations. It also includes the implementation of comprehensive safety standards in combination with repair design requirements; paying special attention to the historical geological disasters and meteorological disasters; classifying the disasters, and bringing forward disaster prevention standards based on the classification for the future recovery of the buildings after disasters and reconstruction at other sites if necessary.

Disaster Defense

Disaster defence includes structure reinforcing, material treatment, and equipment updating and environment improvement for architecture heritages.

For example, the historical buildings mentioned in the Protection Plan for Wugongci Temple in Haikou City prepared by the author, many buildings in the Wugongci building group have safety issues such as weathered or broken tiles, corrosion of wooden pieces, distortion of structural components, and the instability of the overall structure (Xia & Zhang, 2013). It is planned to gradually investigate and repair the roof, tiles, wooden pieces, pillars, walls, and exterior surfaces using proper technical means on the premise of relic protection, so as to recover the good performance of the main structure of the building (Zhang, et al., 2011).

With respect to material treatment, it is planned to perform fire protection and water proofing treatment for the building materials of the architecture heritage through painting, immersion, and other techniques (Shen, 2006). The wooden pieces will be painted with fire resistant liquid to improve the fire protection capacity while keep the original style of the building. Fireproof materials will also be used to seal the seams of wooden pieces and joints of components and buildings for better fire prevention and control (Kang, 2008). Corrosion resistant and moisture resistant materials will also be painted or applied to exposed and embedded wooden pieces, and insect-killing agent will be injected into holes in the wooden pieces.

With respect to equipment, portable fire extinguishers and firefighting buckets will be provided in rooms where it is inconvenient to install spraying and hydrant devices. Adding

lightning protection devices properly in the form of ancient style pillars or ornaments will not affect the overall appearance of the architecture heritage (Yang, et al., 2010; Gong, 2008).

With respect improvement of surrounding environment, a separating belt will be arranged using greenbelts, squares, water and streets around the heritage to prevent the spread of disaster. Alternatively, firewalls may also be built to block fire spread. The functional layout of the architecture heritage will also be adjusted, and the interior danger sources and buildings vulnerable to fire such as retail stores, restaurants, bars and temples will be strictly controlled. Disaster prevention performance of channels will be optimized, and proper infrastructures will be arranged based on the scale of the architecture heritage.

Emergent Disaster Relief

Disaster relief facilities

Construction of disaster relieving facilities is mainly for non-natural disasters such as fire. A small fire engine will be located based on the width of the road around the architecture heritage, or fire motorcycles will be used for firefighting. An un-manned fire engine and fire air plane together with a GIS system will be used to extinguish fires in the architecture heritage (Li & Li, 2003). A high pressure hydrant water supply system will also be arranged within the architecture heritage and automatic spraying devices and fire extinguishers will be configured.

Emergency management

Based on the administrative divisions in China, there is likely to be a prevention system consisting of three levels, respectively, city level, county/district level and town/street level. This will involve a complete command system for the central commanding and by-level disposal. Such a system may have an early response, disposal command, emergency disposal command, and on-site command section. Regional disaster prevention and a reduction information platform may be formulated for information exchange among governments and departments (Zhang, 2010). A GIS system may also be used to collect, manage and dispose of disaster information. The decision making level of the commanding department will be improved so that effective and timely decisions can then be made.

CONCLUSION

Study on the disasters of architecture heritage involves many subjects such as geology, meteorology, firefighting, land resource, administration, city planning, and so on. In this paper, the status quo of the protection of various architecture heritage as well as the related conditions of disasters are collected and analysed. In addition, the impacts of various disasters on such heritages are discussed, and the features of architectural heritage that make it vulnerable, the disasters that can be prevented by human interference, and the disasters that cannot be controlled but can be minimized in loss are summarized. Finally, it comes to two main conclusions: one is the risk evaluation factor system of major disasters influencing architecture heritage (see Table 1), the other is disaster prevention and reduction strategies are brought forward in four aspects: prevention, defence, relief and guarantee mechanism (see Table2).

The paper is written from the view of an urban planner, and the discussion in this paper covers various disasters of architecture heritage. As such, the analysis in this paper is at a broad or preliminary level in terms of the comprehensive safety of architecture heritage. The further research objectives is to establishing a complete evaluation system of disaster risk and damage in detail for each disaster including purposes, contents and numerical indexes based on the methodology we have achieved and a more detailed and comprehensive disasters data collection. According to the evaluation results, we can put forward specific improvement requirements for historical architectural heritage, strengthen their resilience practically, promote the comprehensive level of safety, and ensure the long-term survival of historical buildings.

Table1. Risk evaluation factors of major disasters influencing historical architecture heritage
(Source: Author, 2015).

Disaster types	Objective	Factors
FIRE	Human activities	Condition of burning incense; condition of burning light/candle; condition of burning paper money; behavior of tourists; behavior of occupiers; behavior of residents; illegal behavior; fire protection education; firefighting organization; fire drill; and firefighting guarding.
	Object space control	Interior condition of the building; use of electrical appliances; condition of wires; condition of lightning protection device; condition of firefighting equipment; water for firefighting; firefighting channels; the condition of the building.
EARTHQUAKE	Degree of risk	Seismic activity, potential source of danger, seismic attenuation law
	Possibility of damage	Structure and material of architectural heritage, reliability of seismic resistance, significance of heritage
FLOOD	Degree of risk	Disaster causing environment, the probability of flood distribution in the given area
	Possibility of damage	The structural vulnerability of building; density of the building; disaster strength
WINDSTORM	Degree of risk	Type, frequency and level of windstorm
	Possibility of damage	Building location, wind strength, architectural layout, building form, tightness of component connection, collapse of surrounding objects.
LIGHTNING	Degree of risk	Expected annual times of strike (25%), lightning strike history (15%)
	Possibility of damage	Significance of heritage (20%), architecture structure (15%), interior environment change (25%)

Table2. Disaster prevention and reduction strategies list for architectural heritage (Source: Author, 2015).

Objective	Strategy	Factor
PREVENTION BEFORE DISASTER	Disaster prevention	Disaster investigation, early warning, safety risk evaluation, comprehensive safety planning.
DISASTER RESISTING	Disaster defense	Structure reinforcing, material treatment, equipment updating, environment improvement for architectural heritages.
DISASTER RESCUE	Emergent disaster relief	disaster relief facilities, emergency management

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