# Review of studies on urban post earthquake fires

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Abstract:Earthquake secondary fire is the most likely to occur, the most devastating earthquake secondary disaster. After analyzing the characteristics of the secondary fires after fire, spreading and post-earthquake fire fighting, three key topics of research on secondary fires in earthquake are put forward: fire after fire, spread of fire and fire suppression after earthquakes. In response to these three topics, a comprehensive introduction and in-depth comments on the relevant research at home and abroad. Through the comments, the shortcomings, difficulties, key points and train of thought in the research of secondary fire in earthquake are put forward for further research.

An earthquake is a sudden and destructive natural disaster. A strong earthquake often causes the building to collapse, the facilities to be damaged, the traffic jam, the burst of the dam burst, and even casualties in seconds or minutes, giving life to people Property and national economic construction caused huge losses. The earthquake not only directly caused tremendous damage, but also induced a variety of secondary disasters, such as fires, floods, landslides, tsunamis and so on. Among them, the earthquake secondary fire is the most likely to occur, but also the most dangerous. According to many earthquakes at home and abroad [5-8], most destructive earthquakes can cause fires, and the losses caused by earthquake-induced fires sometimes exceed those directly caused by earthquakes [22]. For example, on April 18, 1906, an earthquake of magnitude 8.3 occurred in San Francisco, USA. As the chimney collapsed, the stove fell and other reasons, the city at the same time more than 50 fire. At that time, the fire brigade was destroyed, alarm and communication system failure plus road traps, housing collapse, traffic congestion, water pipe breaks, water cut off, fire is difficult to fight, and even the fire burned for three days and nights, burned 521 streets,
Of 28,188 houses, 400 were killed and the loss amounted to 400 million U.S. dollars. According to statistics, the losses caused by the earthquake and fire were three times greater than the direct losses caused by the earthquake. As another example, on Sunday, September 1, 1923, at noon, an earthquake of magnitude 7.9 occurred in the Kanto region of Japan. The earthquake was just at the peak of people's use of fire and led directly to a large number of fire incidents. At that time, Yokohama City, 60 km from the epicenter of the earthquake, one-fifth of the city's houses collapsed and more than 200 flashed at the same time. Four-fifths of the city's houses were destroyed by fire. In addition, Tokyo city 90 km from the epicenter, due to the earthquake after the failure to power, turn off the gas valve and other reasons, the city at the same time fire 136. According to statistics, the area destroyed by fire in Tokyo is about 3 830 hm2, 70% of the total number of houses destroyed by fire were destroyed (450,000 households) and more than 56,000 people were burnt to death. As another example, at 5.46 am on January 17, 1995, a devastating earthquake struck the Kansai Earthquake in Japan. This is the Hanshin Earthquake. The earthquake caused the loss, in addition to housing collapse caused a large number of casualties, the most serious earthquake fire. Earthquake caused gas pipeline rupture resulting in gas leaks, a case of fire immediately caused a raging fire. At the same time, the earthquake also caused water and electricity to be cut off. Even when the firetruck arrived, there was no water and no one could only watch the fire raging and the large houses burned to ashes. It is reported that for various reasons.

More than 200 fires were caused, and hundreds of thousands of m2 of houses were burned down in Kobe alone. More than 500 people died on the scene of the fire.
The data of the secondary fires of the above three major earthquakes show that the secondary fire in earthquakes is extremely dangerous and the losses caused by them are extremely serious. Earthquake is one of the most serious natural disasters people face in our country. The secondary earthquake fire naturally becomes the focus of people's disaster prevention. As far as China's actual situation is concerned, most large and medium-sized cities in China have a long history, high population density, heavy construction, complicated pipelines and more facilities for electricity supply. Therefore, it is highly probable that an earthquake and fire will occur. Especially after the founding of the People's Republic of China, some emerging cities relying on industrial bases have many shortcomings and hidden dangers in earthquake disaster prevention and reduction. In particular, they rarely consider the earthquake resistance and fire safety requirements when planning city mastering and how to improve their ability to defend against disasters , Making these cities particularly vulnerable to earthquakes and secondary fires. Therefore, it is necessary to understand the characteristics of earthquake-induced secondary fires and accurately forecast the occurrence, spread and destruction of secondary fires so as to rationally arrange and plan the layout of urban construction, the placement of dangerous and flammable products, the distribution of fire fighting rescue forces, Fire prevention measures, etc., to enhance the city's ability to fight against and withstand earthquakes secondary fires has a very important meaning.

1. Earthquake secondary fire characteristics
   Earthquake secondary fire refers to the fire caused directly or indirectly by the earthquake [15]. It is a series of disasters caused by the destruction of the ground caused by the earthquake, the urban construction and the lifeline system. Although the secondary fires of earthquakes cause serious human losses like ordinary civil fires, there is a great difference between them. The secondary fires of earthquake have their own significant characteristics.
   1. 1 earthquake fire characteristics
   (1) many fire at the same time. After the earthquake, there will be many simultaneous fires in the city, and the fire has spread throughout the affected areas of the city.
   For example, in Los Angeles in the 1994 Northridge earthquake in the United States, only 15 fires occurred in just half an hour after the earthquake [28]. In the 1995 Kobe earthquake in Japan, 53 fires occurred within 15 minutes after the earthquake in Kobe area [2 , 28].
   (2) The cause of the fire is complex and diverse. There are many causes of fire due to earthquakes. There are mainly gas, liquefied petroleum gas and natural gas leaks caused by pipe rupture; household appliances fall, fall and destroy resulting in overflow of fire; household inflammables encounter open flames and cause fire; wires Short circuit, open circuit ignition ignitable combustible materials; flammable and explosive leaks, in case of fire or vibration, impact friction caused by fire; industrial electrical fire caused by fire. In addition, the earthquake was also affected by a combination of many factors, including time, human and meteorological factors.
   (3) after the earthquake one after another fire; some time after the earthquake (1-3 days), the city will continue to have a fire event. After the earthquake, the fires started to catch up with the recovery of the post-disaster facilities (especially the recovery of the power

system) [28]. The aftershocks continued to be closely related to the generation of new sources of fire during the fire spread [35].

1.2 fire spread characteristics

(1) The complex and diverse modes of spread; the post-quake fire is often spread uncontrollably (firepower greatly weakened) over a large area and spread

There are significant differences in the way with the daily fire, mainly the direct flame spread, the spread of thermal radiation, the spread of flue gas plumes and the spread of fire spread over long distances [2].

(2) The particularity of fuel; the building will be the main fuel for the secondary fire in the earthquake. The internal structure of the building, the fire load, the structure type, the fireproof performance, the height difference and spacing between the buildings all determine the speed of fire spread [ 2 ] . In addition, the damage characteristics of buildings after the earthquake also affect the overall flammability of the building structure [18].

(3) Meteorological conditions affect the spread of fire; meteorological conditions (temperature, humidity, wind speed and direction) are important factors that affect the fire spread after the earthquake. Among them, the wind is the most critical meteorological elements, the wind direction to control the direction of the spread of fire, the wind speed determines the speed of fire head spread.

1.3 fire fighting characteristics

(1) Fire protection system was destroyed; After the earthquake, various fire protection systems (including automatic sprinkler system

Equipment, smoke detectors, automatic alarm systems, firewalls and fire doors, etc.) have been damaged to varying degrees, losing their due functions and contributing to the spread of flames and fumes [9]. In addition, a strong vibration will make the building a larger offset between the layers, resulting in the wall slits, fire doors and elevator doors twisted, air conditioning, heating and heating pipe rupture, which makes the indoor flame and hot flue gas is easy to penetrate Through these seams for interlayer spread [9]. In addition, built construction of the external walls of the window no doubt for the fire broke open between the buildings opened the portal.

(2) Lifeline systems are destroyed; earthquakes often cause traffic congestion, interruption of communications and earthquakes in underground pipelines. These lifeline systems

The destruction after the earthquake was largely related to the expansion and spread of secondary fires. Seismic leaks in underground gas lines increased the risk of fire; after the earthquake, the interruption of communication and loading delayed the alarm time of the fire; the traffic jam delayed the arrival of the fire brigade after the earthquake; the rupture of the water distribution network and the city after the earthquake Fire hydrant destruction led to a serious shortage of fire water supply. All these adverse conditions have greatly contributed to the spread of the fire.

(3) The firepower decreased significantly; After the earthquake, the city's firepower appeared "overloaded" in the context of a large-scale disaster [35], which could not meet the needs of disaster-stricken areas. First of all, the earthquake has a sudden nature. When an earthquake occurs, the firefighters can not fully work, resulting in a decrease in the number of firefighters who put into disaster relief after the earthquake. In addition, the fire brigade after the earthquake not only to assume the task of fighting the earthquake

fire suppression, but also for rescue work after the earthquake [7], personnel and equipment investment once again reduced. Furthermore, there are many fire incidents in the city after the earthquake and the fire distribution in the city is extremely uneven. This forces the limited firepower to disperse and deal with a large number of fires [35], radically weakening the firepower.

(4) The special element of fire resistance; the great weakening of the firepower after the earthquake has led to the fact that the firepower can not be extinguished and the fire field effectively controlled [35]. At this time, other elements in the city will act as a fire-retardant device. Large open spaces in the city, extensive roads and railroads, fire-proof buildings and fire walls were cast in flat and three-dimensional fire stop bands [28], preventing the spread of the fire. For example, in the fire resistance elements of the Hanshin earthquake, roads and railroads account for 40% of the total, vacant land accounts for 23%, fireproof buildings and firewalls account for 23%, while firepower and volunteer teams only account for 14%. [28]

2 earthquake secondary fire research

So far, the research on earthquake secondary fires at home and abroad is still in its infancy and the research methods are relatively weak. Foreign research carried out earlier, especially Japan and the United States. The Japanese study defines the concept of seismic fire risk, constructs an empirical model of fire spread, establishes an earthquake fire prediction system, and develops a series of disaster prevention and mitigation measures. The United States applied many aspects of earthquake fire prediction and prevention High-tech, but also achieved greater success. In China, relevant departments carried out a series of special studies on earthquake fires, but they are far from meeting the needs of the times. In particular, the domestic research mainly focuses on the formulation of secondary fire control measures and post-disaster emergency plans. It should be said that the formulation of such measures is very beneficial to mitigate the impact of earthquake secondary fires. However, we also noticed that research on countermeasure is also increasingly in urgent need of hard science support. Only in a more scientific and accurate prediction of the occurrence rate of secondary fires in the earthquake, the development and spread of secondary fires, the control of floodplains and the assessment of loss after a disaster, can secondary fires and even emergency measures be formulated more accurately and in more detail Purpose [14].

As mentioned above, the secondary fires in earthquakes have many complicated characteristics, all of which make it more difficult to study secondary fires caused by earthquakes. So far, there have been three domestic and international analysis and research topics on secondary fires in earthquakes, ie, analysis of fire from earthquakes, modeling of fire spread and analysis of fire suppression after earthquakes.

2.1 Earthquake Fire Analysis

The research contents of the earthquake fire include the analysis of the causes and influencing factors of the earthquake fire, the investigation of the relationship between the fire of the earthquake and the fire factor, the earthquake

Fire number and earthquake fire distribution forecast. 2.1.1 Earthquake Causes and Influencing Factors (1) Earthquake Action

Earthquake is the root cause of fire after earthquake. Strong earthquakes will cause violent ground vibration, causing all kinds of potential fire sources in the city to cause fires due to overturning, falling and destruction. The following trends can be obtained

from historical statistics. For any particular earthquake-affected area, the more dangerous the fire, the greater the danger of post-quake fire if the other fires are the same.

(2) a variety of potential sources of ignition

Some potential sources of ignition in the city under the earthquake caused by fire is the direct cause of the fire. These potential sources of ignition include daily-use coal stoves Or gas stoves, gas pipelines and liquefied gas irrigation, residential supply, substation equipment, wiring and residential indoor appliances, lighting and wiring [7], chemical plants, chemical warehouses, laboratories, chemical products in the laboratory , Flammable, explosive materials, chimney, etc. [8]. Specifically, when an earthquake occurs, a coal stove or a gas stove is being used. Staff panic "escape" and have no time to extinguish it. As a result, the stove vibrates upside down or is smashed by other crashes. Around the combustible items and cause a fire; gas pipeline rupture, liquefied gas valve damage or tip over caused a large number of gas leaks, encountered fire will also trigger a fire; residential area for the transformer substation equipment, wiring and residential indoor Household appliances, lighting fixtures and wiring are short-circuited with the destruction of buildings, and are prone to fire after the power is restored. Chemical products in chemical plants, chemical warehouses, laboratories and laboratories are easily removed from pipelines and containers in case of strong earthquakes Or outflow, occur spontaneous combustion or friction with each other on fire; flammable, explosive materials in the earthquake friction and collision with each other and fire.

(3) the degree of damage to the building

The destruction of buildings is the indirect cause of the fire after the earthquake. Buildings under the action of the earthquake, some collapsed or have a larger displacement deformation, resulting in

Gas pipeline cracking, liquefied petroleum gas valve wrecked and leaked a large number of gas, in the event of open flame or high temperature will trigger a fire, or even an explosion. In addition, the completely collapsed buildings covered by gas leaks due to rubble, not easily noticeable, in the event of a source of fire (for example, power recovery after the earthquake so that short-circuit wires stimulate the spark) immediately triggered a fire.

(4) the time factor

Time is a key factor that affects the fire in an earthquake and is related to the number of earthquakes. Time factors associated with an earthquake fire include hair

Earthquake season and earthquake time [5, 36]. In different seasons, residents often use electrical equipment at different frequencies, especially in winter, with the general increase of electrical equipment used by urban residents for heating, which greatly increases the potential sources of fire in the cities [36]. Seismogenic time refers to the specific time of day when an earthquake occurs. For example, the time of occurrence of an earthquake is at mealtime for urban residents, and the rate of fire after the earthquake is greater than that of an earthquake occurring during late-night residents' rest [36].

(5) Human factors

Human factors are easily overlooked factors in the earthquake fire. People in the earthquake fire played two opposite roles, namely, negative effects and plot

Very effective. Negative effect is that when earthquake occurs, people panic "escape", too late to stoves, gas stoves and electricity equipment off, eventually leading to a fire

[8]. The positive effect was that after the earthquake, unhunts found the source of the fire and promptly took measures to put them out so that the tiny fire would not cause a large area of fire [8].

(6) Meteorological factors

Meteorological factors are also important factors that affect the fire in an earthquake. In sunny days, the weather is dry, hot and the windy weather is cloudy, rainy, humid, cold and windless

The weather, the risk of fire is much greater [19].

2. 1. 3 comments

It is learned from the study of the earthquake fire model that some progress has been made in the study of the earthquake fire model at home and abroad,

The methods and methods of earthquake fire model research are still in a quite immature stage. The regression analysis model needs a large amount of historical statistics as the basis for the model construction. However, due to the large time span of earthquake fires and the lack of attention paid by the countries to the earthquake fires, detailed statistics can not be conducted after the earthquake, resulting in the statistical data of earthquake fires Serious deficiencies, which makes the regression model has defects in applicability, the existing model can only be applied to a specific period and a specific area. The construction of the event tree model depends on many event parameters. The probability of occurrence of these event parameters needs to be obtained through a large number of experiments, which increases the difficulty of model construction. The probability model proposed by our country scholars is lack of verification of actual earthquake fire data, so the model is doubtful in reliability. These problems and deficiencies will all become the focus of our research work in the future.

In addition, there are several topics related to the earthquake that deserve further study.

(1) Investigate the relationship between earthquake fire rate and various fire factors; until now, the modeling of earthquake fire rate has been limited to the construction of fire rate The mathematical relationship between individual fire factors. However, in fact, the earthquake fire is the result of a combination of many causes and factors after the earthquake. Therefore, how to construct the relationship between seismic fire rate and multiple fire factors is the key and difficult point in modeling the current fire rate. The key to solve this problem is to collect, organize and count a large amount of seismic fire data.

(2) Pay special attention to post-earthquake chemical fires and oilfield fires. According to statistics, fires caused by chemical products are more or less likely to occur in the recent earthquake fire events. Such fires are found mainly in universities, pharmacies and chemical plants and other places [29]. In addition, another special type of fire, the field fire, has also become a type of fire with a high seismic fire outbreak in recent years. Due to the fact that such fires have the characteristics of being hard to extinguish with high burning intensity, they often result in huge economic losses and damage to the surrounding environment. Therefore, in the future earthquake fire research, we should pay special attention to these two special types of fires and correctly evaluate their risk of fire after the earthquake.

(3) An analysis of the rate of extinction of fires by urban residents after a quake; after an earthquake, an uninjured urban resident who can detect a source of fire in time and take effective measures to fight the blaze will, in the very great case, not trigger Large fire. It

can be seen that the fire extinguishing rate of urban residents has a great impact on the rate of earthquake fire, and the influencing factor should be considered in the model of earthquake fire.

(4) Study on time pattern of earthquake fire; time is an important factor that affects the fire of earthquake. The difference of seismogenic season and seismogenic time often brings about different amount of fire after earthquake. In addition, some fire events will occur one after another after the earthquake, ie, the earthquake fire has a certain distribution pattern on the time series after the earthquake. The influence of two kinds of time factors on the earthquake fire deserves our in-depth study and discussion.

(5) Research on the pattern of spatial distribution of earthquake fire; From the perspective of space, the distribution of earthquake fire location also has certain rules. It can be seen from the data of historical earthquake fires that the fire points after the earthquake are often concentrated in areas with large earthquake intensity, serious destruction of building structure, concentration of flammable structures and large population density. This kind of evaluation of the spatial distribution characteristics of fire spots is very beneficial for determining the dangerous area of urban fires and should be further studied and explored in future work.

2.2 Modeling the spread of fire

The spread of secondary earthquakes in urban earthquakes is a large-scale spread of fire. There were many fire incidents, communications and supply in the cities after the earthquake

Water and other life-line systems have been destroyed to a certain extent, firepower greatly weakened and other adverse conditions led to the fire may be a large-scale spread in the city, a catastrophic urban mass fire. On the one hand, there is a great difference between the spread of an urban mega-fire and the daily civil fire and has its salient features. On the other hand, the spreading process and physical mechanism of urban mega-fires are quite complicated, and there are a lot of uncertainties in them. All of these have brought great difficulty to the research on the spread of the city's extra-large fire and the spread of the secondary fire in the earthquake. Up to now, the physical and chemical processes involved in the spread of urban fires have yet to be further studied and understood, and the ability to simulate the spread of extra-large fires needs to be further improved [38].

2. 2. 1 Characteristics of the fire scene of the secondary fire in the earthquake

The huge fire scene in the city caused by the earthquake has the following characteristics:

(1) The fire is fiercely burned on a large scale and develops and spreads at a high speed. The ways of spreading are complicated and diversified.

(2) Various types of fires may occur simultaneously on the fire site, such as houses, factories, warehouses and oilfield fires;

(3) Under the earthquake, urban water supply, power supply, communications, transportation, medical aid and logistics support have all been destroyed to some extent, and even war

The non-combat downsizing of forces has made the situation on the fire more complicated.

(4) fire complex, large radius of combat, the fire fighting power into the combustion area is not easy to break into the interior, personnel rescue, fire fighting, material evacuation and protection

Fire treatment and other work will be affected accordingly to promote disaster expansion.

2.2.2 Earthquake secondary fires spread

There are four main types of earthquakes in secondary fires [2, 38]: (1) direct flame contact;

(2) heat radiation (radiation);

(3) Thermal plumes of thermal flue gas;

(4) long-distance firebrands (fire brands).

The actual fire spread is the result of the combined effects of the various approaches described above. The contribution of various modes to the spread of fire depends to a great extent

Environmental wind speed. In the case of strong winds, methods (3) and (4) have a significant impact on the spread of fire. On the contrary, in the case of small wind speed, the method (1) has a significant impact on the spread of the fire because the flame is usually high.

## 3 summary and outlook

Earthquake secondary fire has caused huge losses of life and property to many cities and is a devastating city disaster. Although modern cities are striving to improve building structure technology, fire safety standards and city fire resistance, this greatly reduces the probability of a city fire. However, we are also well aware that modern cities are still vulnerable to secondary fires in the wake of the earthquake. In order to combat and prevent secondary fires caused by urban earthquakes, experts and scholars at home and abroad have conducted various studies and obtained some achievements. But on the other hand, we are also aware of the lack of research. Earthquake secondary fire is a complex process involving a large number of systems engineering and a large number of uncertainties in the chain of disasters, so far its research has not been able to solve all the problems. These problems provide us with the opportunities and challenges of the study so that we can understand the phenomenon and mechanism of the earthquake fire more minutely and evaluate and predict the occurrence and spread of the earthquake fire more accurately so as to promote the urban fight against and resist the earthquake fundamentally Comprehensive ability of fire.

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