Risk Analysis of Secondary Disaster of Earthquake

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SUMMARY:
Secondary disasters often occur following the destructive earthquake, such as flood, fire, explosion and diffuse of poison gas, etc. The secondary disasters not only extend the earthquake losses in further, but also bring great difficulty to emergency rescue. The risk of earthquake secondary disaster is determined by the probability of occurrence, coverage area and the distribution of population and property in this area. In this paper, considering the characteristic of secondary disaster, the preliminary assessment models of occurrence probability are given. And the influence area of typical earthquake secondary disasters is calculated. Finally, casualties and property losses will be calculated further based on GIS. It is benefit to the disaster prevention and emergency decision.

Keywords: risk analysis, secondary disaster, destructive earthquake

1. INSTRUCTIONS

The earthquake secondary disasters generally mean a series of disasters caused by the damaged structures or components in the strong shaking. Such as fire, flood, tsunamis, landslides, poison leakages, explosions and so on. Sometimes, the casualties and economic losses caused by them maybe larger than that by earthquake. As an example, in June 16, 1964, Japan Niigata M7.4 earthquake occurred, due to strong shaking, the oil tank burst out flames, and then causes the adjacent tanks and refinery explosion. The fire had burned for whole two weeks. Niigata refinery had been ruin throughout, more than 80 oil tanks were damaged, 500 people were killed, and 75% of the gas pipelines and 11 transformer substations were damaged.

In recent years, the sources of secondary disaster are increasing quickly, especially in the energy supply system, and it’s a serious threat to the surrounding people and property. So it is urgent and necessary to study on risk evolution of secondary disaster of earthquake.

2. PROBABILITY OF OCCURRENCE

2.1. Disaster Chain Principle

As the former disaster, earthquake provides the necessary conditions for the occurrence of the next disaster, and the latter would aggravate existing disaster. In this process, we are aware that these disasters do not occur at the same time, and they generally follow in order. The necessary conditions created by the former disaster, as “chain”, arrange and connect the disasters by the time order. The role of the “chain” is very important, as long as the “chain” has been cut off or controlled properly and timely, the formation and development of disaster will be prevented. In fact, the disaster chain is very complex. As an example, sketch of a complete chain in petrochemical industry system is given, see Fig. 2.1.

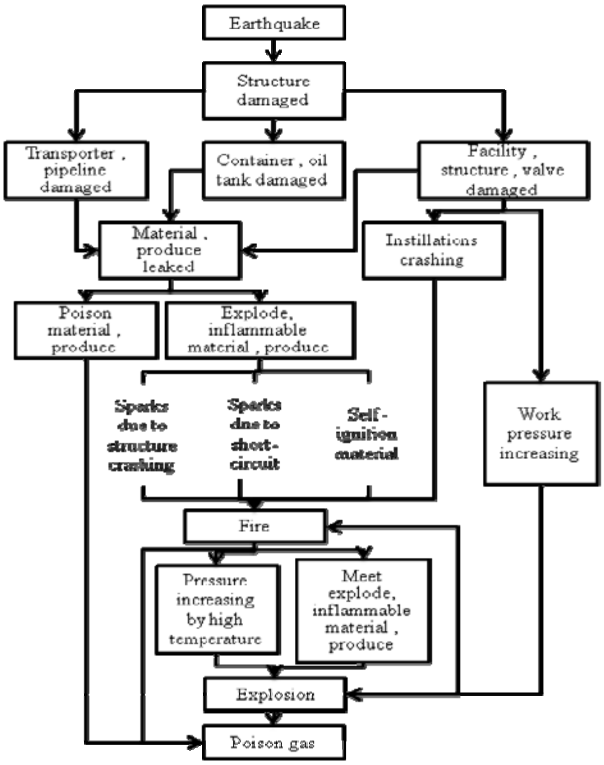

Figure 2.1. Sketch of earthquake disaster chain in petrochemical industry system

Although the equipments and structures in petrochemical industry system are very different comparing each other, but in general we can divide them into three categories by the function, transportation equipments, storage devices and production equipments. Under the earthquake action, seismic response and failure types of these devices are different, and can form different chains.

2.2. Probability Model

For the disaster chain of earthquake & fire in petrochemical industry system, the sketch of disaster chain is shown in the Fig. 2.2.

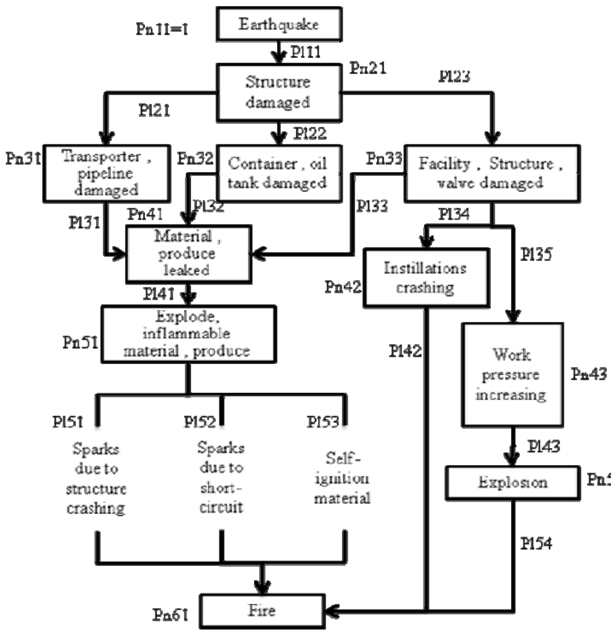

Figure 2.2. Earthquake & fire links in disaster chain of petrochemical industry system

In this disaster chain, the events are looked as nodes and the conditions are looked as links. Using the exiting safety evaluation methods, such as the event tree analysis method, the probability of the links can be calculated. Here, assume the values given in Tab. 2.1. And then the probability of the nodes will be calculated by the Eqn. 2.1.

Table 2.1. The assumed probability of the link Pl_{ij}

j \ i	1	2	3	4	5
1	0.500	-	-	-	-
2	0.700	0.500	0.300	-	-
3	0.800	0.800	0.600	0.200	0.200
4	0.700	0.600	0.700	-	-
5	0.200	0.200	0.100	0.800	-

$$Pn_{i+1} = 1 - \prod_{j=1}^{n} (1 - Pl_{ij_i} \times Pn_{ij}) \tag{2.1}$$

Where, Pn is the probability of node; Pl is the probability of link; i is the i stage of chain j is the j link in the i stage of chain and n is the link number in the i stage. The results are showed in Tab. 2.2.

Table 2.2. The probability of the nodes Pn_{ij} calculated *by Eqn. 2.1*

j \ i	1	2	3	4	5
1	1.000	-	-	-	-
2	0.200	-	-	-	-
3	0.350	0.250	0.150	-	-
4	0.480	0.030	0.030	-	-
5	0.336	0.021	-	-	-
6	0.190	-	-	-	-

Compared with the probability of links in the i stage, the Max one will be looked as the main condition in the i stage, and compared with the probability of nodes in the i stage, the Max one will be looked as the main event in the i stage. In order to reduce the probability of secondary disasters occur, the measures would be carried out directly against these events.

3. INFLUENCE AREA

3.1 Numerical Simulation

Considering the characteristics of different secondary disasters, the numerical simulation of typical earthquake secondary disasters are used to assessment the influence area. Based on the common mathematical analysis models of related fields involved in the secondary disasters, the work of numerical simulation of typical earthquake secondary disasters, such as fire, explosion and diffuse of poison gas are carried out. In the results, the coverage and dynamic process of earthquake secondary disasters are given and displayed quantitatively and intuitively by different dangerous level. Finally, the preliminary estimates of the casualties and economic loss are calculated.

3.2 Numerical Models

For different secondary disaster, the mathematical analysis models are different, as an example, the numerical models of explosion are discussed in bellow. Shock wave and heat radiation produced by explosions will bring casualties and destructions of buildings. For the numerical simulation of secondary explosions, the law of shock wave's harm and destroy has been often used at present. Some models of dangerous areas of casualties and distribution areas of destructive buildings after explosion are provided.

3.2.1 Casualties models
The descriptions of the casualties' zones are listed in Tab. 3.1.

Table 3.1. Descriptions of the casualties' zones

Area	Description
Dead zone	Area's radius is the distance where the probability of causing the lung to bleed and die by the shock wave function is 0.5.
Severe wound zone	Area's radius is the distance where the probability of causing the eardrum to break by the shock wave function is 0.5.
Slight wound zone	Area's radius is the distance where the probability of causing the eardrum to break by the shock wave function is 0.01.

There are three levels of influence zones, named as dead zone, severe wound zone and slight wound zone, which are determined by Eqn. 3.1 and Eqn. 3.2.

$$R_{0.5} = 13.6\left(E/4520000 \right)^{0.37} \tag{3.1}$$

Where, $R_{0.5}$ is the radius of the dead zone, E is the total energy of explosion sources.

$$\begin{aligned} P &= 0.137(Z)^{-3} + 0.119(Z)^{-2} + 0.269(Z)^{-1} - 0.019 \\ Z &= R\Big/\left(E/P_0 \right)^{1/3} \\ P &= \Delta P/P_0 \end{aligned} \tag{3.2}$$

where： R is the radius of severe wound zone, $\Delta P = 44000$ is the overpressure of shack wave.

For slight wound zone, use Eqn. 3.2 with $\Delta P = 17000$.

3.2.2 Building damaged models
For the influence area of building damaged, same equation is used as Eqn. 3.2 with different critical value ΔP . And descriptions of building damaged level with the critical value ΔP are shown in Tab. 3.2.

Table 3.2. Descriptions of building damaged level with the critical value ΔP

Level	Critical value of ΔP	Description of the building function states
1	70000	All buildings have been destroyed.
2	40000	50%~70% of the appearances of brick buildings are damaged. There is danger under part of the wall.
3	20000	The buildings can't be used again.
4	15000	The buildings are destroyed by a certain level, and the timber structures of partition walls should be strengthened.
5	6000	After maintained simple and easily, the buildings can be used to live in.
6	5000	The buildings are intact basically.

4. CASUALTIES AND BUILDING LOSS

For the casualty's assessment, the Eqn. 4.1 is used with assume that all persons in above areas would be dead, severe wound or slight wound.

$$N = \rho\pi R^2 \tag{4.1}$$

where： R is the radius of different area, ρ that is the density of population distribution.

For the loss assessment of building damaged, the Eqn. 4.2.

$$P_l = \sum_{i=1}^{6} \lambda_i P_c A_i \tag{4.2}$$

where： P_l is the loss of building damaged, λ_i is the ratio of building loss to prime cost in different damaged area i, P_c is the average cost of buildings, A_i is the total construction area of buildings in area i.

5. EXAMPLE BASED ON GIS

As an example, assume the explosion source total has energy with 10 t TNT. Based on GIS, the coverage of casualties and building damaged are shown in Fig. 5.1 and Fig. 5.2.

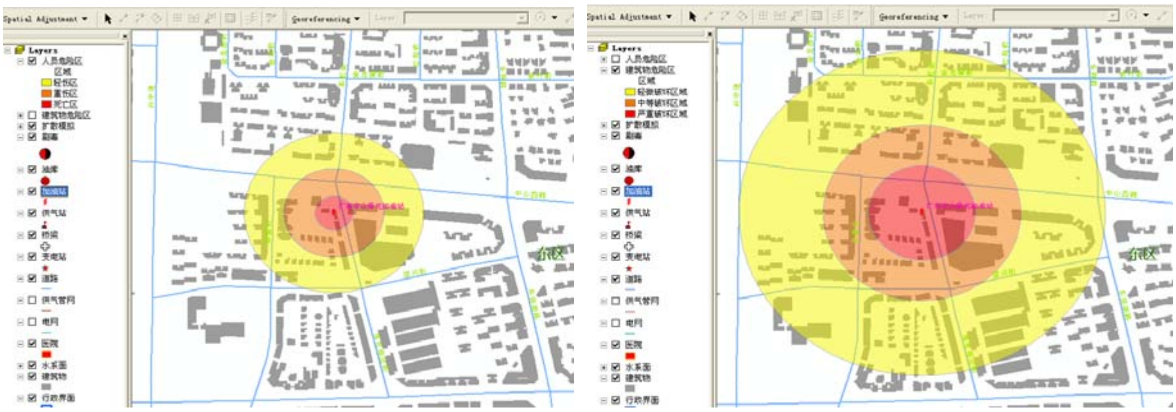

Figure 5.1. Coverage of casualties (left) and coverage of building damaged (right) after explosion

For assessment of building damaged, three levels are used with level 1, 2 and 4 in Tab.3.2. Final, the results of casualties and building loss are calculated. In Fig. 5.2, the results include the number of casualties, construction area and losses of buildings damaged in different areas.

Figure 5.2. Results of casualties and building loss

6. CONCLUSIONS

According to the lack of related data, in the further study, it is difficult to quantize the parameters of the method. And comparing with the actual earthquake damage, statistical analysis and empirical estimate will be carried out to correct method further.

In this paper, disaster chain principle has been used. And the formation process of earthquake disaster chain has been analyzed. As an example, a sketch of complete disaster chain based on the petrochemical industry system has been given. Based on the disaster chain principle, a probability analysis method of earthquake secondary disaster occurrence has been established. The influence zones are calculated for typical earthquake secondary disasters. Finally, casualties and property losses are calculated further based on GIS.

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