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EARTHQUAKE DAMAGE of FIRE FIGHTING and LIFE SAFETY SYSTEMS

MASATAKE NAGANOH
Research & Development Institute TAKENAKA Corp., 1-5 Ohtsuka, Inzai-Machi, Inba-Gun, Chiba 270-13 Japan
KOICHI SAKAMOTO and NARUKO TAKANASHI
Institute of Disaster Policy and Information Society, Inc., 402-10-10 Tomisawa-Cho, Nihonbashi, Chuo-Ku, Tokyo 103, Japan

Abstract

Big earthquakes often cause fires. Fire-fighting and security facilities must three-fore be effective during and after earthquakes too. However, fire- fighting and security facilities are often damaged during an earthquake. Authors investigated the damage to fire-fighting facilities during recent earthquakes in Japan and State of California, USA . The damage produced an obstacles to fire-fighting and life security functions, thus generating the secondary damage. There is the possibility that a disaster is magnified by the damage sustained to fire-fighting facilities during an earthquake. Aseismic performance of fire-fighting facilities must be reinforced, and reliability needs to be raised.

Keywords
Earthquake damage; fire-fighting and life security facilities; sprinkler system; fire-alarm system; water supply system

1. Introduction

Various fire-fighting and life security facilities are installed in offices, businesses, institutions and factories. It is important that performance of fire-fighting and life security facilities be maintained because of the various kinds of confusion that occur at the time of a big earthquake. But, such facilities cannot function effectively when fire-fighting and life security facilities receive damage during an earthquake.
Authors investigated the damage to fire-fighting and life security facilities during recent big earthquakes, and the influence by the damage was examined. Authors investigated the damage to fire-fighting and life security facilities in recent big earthquakes in Japan, the 1978 Miyagiken-Oki Earthquake, the 1993 Kushiro-Oki Earthquake, the 1994 Hokkaido-Toho-Oki Earthquake, the 1994 Sanriku-haruka-Oki Earthquake and the 1995 Great Hanshin earthquake. In addition, authors investigated the damage to

such facilities occurred by the 1989 Loma Prieta Earthquake and the 1994 Northridge Earthquake in the State of California. Epicenters of the investigated earthquakes are plotted in figure 1 and 2.
Materials and investigative reports related to earthquake damage to fire-fighting facilities were collected, and an analysis was carried out. Investigative interviews were also carried out to fire-fighting officials and security managers. Authors attached much more importance to the classification and influence of damage than to the amount of damage. In particular, the damage to sprinkler systems was given much attention.
The results of investigative studies are reported.

2. System of fire-fighting and life security facilities and aseismic performance regulations.

The system for fire-fighting facilities consist of (1) fire detection, (2) initial fire extinguishing, (3)alarm and warning, (4) refuge instruction (5) full-scale fire fighting, (6) fire prevention and (7) smoke removal. (Fig. 3)
Water to extinguish a fire and supply of electricity are indispensable so that these systems function.
In Japan, the B building Standard Law and the Fire-fighting Law establish the performance required of these facilities and installation methods as well. However, a definite aseismic performance for fire-fighting facilities is not described. Fire-fighting facilities follow aseismic performance regulations set for general facilities. The regulations for aseismic performance of facilities explain how to fix the foundations of machinery, and describe how to prevent rolling of pipe laying systems as well. The Tokyo Fire Defense Agency has established particular regulations regarding aseismic performance of fire-fighting facilities in high-rise buildings.
The regulation for performance of sprinkler systems in the State of California are established specified mainly in UBC and NFPA13. Generally, the water pipes of sprinkler systems in California e are connected to water-supply pipes directly.

3. Earthquakes and fires

In most cases, some fires break out when a big earthquake occurs.
In Japan, many deaths were caused by fire during the large-scale city fire at the time of the 1923 Kanto Earthquake. In the case of the 1948 Fukui Earthquake, a big fire of scale also occurred, and many persons were burnt to death. After this, a large-scale fire resulting from an earthquake did not occur until the 1995 Great Hanshin Earthquake. At the time of the 1995 Great Hanshin Earthquake, an area of approximately 65 ha was destroyed by fire in Kobe and another city. Water supply pipes were damaged here and there, and a fire spread because water to extinguish fire could not be secured. Some fires occurred after recovery of the power supply. This type of fire is a new phenomenon that attention to should be given to.
A fire occurred in the Marina District of San Francisco during the 1989 Loma-Prieta Earthquake in California too. Fires also occurs in several mobile-home parks and another places at the time of the 1994 Northridge Earthquake.

4. Damage to fire fighting and life security facilities by earthquake.

The damage to fire-fighting and life security facilities at the time of recent earthquakes are described in the following, according to each earthquake.

4.1 Earthquakes in Japan

Figure 4 shows the classification of damage to foe-fighting and life security facilities and the amount in the

case of 3 Earthquake, the 1978 Miyagi-ken-Oki, the 1993 Kushiro-Oki, and the 1994 Hokkaido-Toho-Oki, in Japan.

a) The 1978 Miyagi-ken-Oki Earthquake

The earthquake of magnitude 7.4 that occurred in June 1978 caused various kinds of damage to Sendai City and peripheral region. In particular, damage greatly influenced the function of city institutions, and gas, water service and communication networks. Fire-fighting and life security facilities received much damage. The problems that emergency power-generation of water-cooled systems depended on supply of water were pointed out.

b) The 1993 Kushiro-Oki Earthquake

The earthquake of magnitude 7.9 that occurred off Kushiro City 100km beneath ground level in January 1993 generated damage of buildings and nine fires. This earthquake caused damage to fire-fighting and life security facilities in many buildings. The ratio of to total number of fire-fighting and life security facilities and amount is shown in figure 5 during this earthquake. It is clear that the damage ratio of facility related to a sprinkler is high. In one department store, products got wet due to the leakage of water from damaged sprinkler pipe. This damage caused the department store to close for four days. Damage from water leakage was reported in some supermarket too.

The damage to fire alarms was extensive. When a actually fire occurred, the damage to a fire alarm leads to a delay in initial fire extinguishing activity.

c) The 1994 Hokkaido-Toho-Oki Earthquake

Kushiro-City and the peripheral region again received the damage from a strong earthquake in October 1994 . There was some damage to fire-fighting and life security facility in Kushiro-City and cities and towns. The amount of damage to facilities was less than that caused by the 1993 Kushiro-Oki Earthquake. The damage related to sprinkler stood out, with damage caused by water leakage from sprinkler systems occurring once again.

d) The 1994 Sanriku-Haruka-Oki Earthquake

The earthquake of magnitude 7.9 that occurred to the east off of Aomori Prefecture in December 1994 brought damage Hachinohe City and the peripheral region. The damage occurring to fire-fighting and life security facility systems included sprinkler systems in this instance, too. Damage to sprinkler heads was extensive. In hotels, department stores and game centers, secondary damage due to water leakage from damaged water pipes was reported. In this earthquake, there was one report that a sprinkler system carried out fire extinguishing functions. That sprinkler systems are effective for fires by an earthquake was shown.

The damage to water tanks was comparatively heavy. In facilities other than sprinkler systems, damage was reported for smoke removal duct and smoke diffusion-prevention walls.

e) The 1995 Great-Hanshin Earthquake

The Great Hanshin Earthquake which occurred in January 1995 more than 5500 deaths were reported. This earthquake caused various damage to many institutions.

Fire fighting and life security facilities received various kinds of damage, but the amount was difficult to measure. Some of the major damage to fire-fighting and life security facilities reported follows:

1) Damage to water supply pipe network containing fire hydrants; 2) Damage to sprinkler systems; 3) Movement and toppling of water tanks; 4) Movement and toppling of fire extinguishing facilities; 5)

False operation fire-alarm systems; 6) Disformation of or damage to fire-prevention door and fire walls; 7) Toppling of escape stairways; and 8) Trouble with emergency power-generation systems.

Damage to water supply pipes in many regions made water supply difficult, and greatly fire extinguishing activities. The lack of water to extinguish fires magnified fires. Water pipe systems were damaged, and water was lost from storage tank installed on roofs. Emergency power-generation systems overheated due to loss of coolant supply, and stopped operating.

Damage to indoor water pipes produced secondary damage caused by water leakage.

4.2 Earthquakes in California

In California, sprinkler systems comprised much of the fire-fighting facilities, and information about other facilities was minimal. Generally, in the United States, the water pipes of sprinkler systems are connected directly to outside water-supply pipes. For the this reason, damage to sprinkler pipe systems causes water leakage damage and lack of water to extinguish fire.

a) The 1971 San Fernando Earthquake

The earthquake of magnitude 6.6 that occurred in the northern part of Los Angels city, San Fernando district in February 1971, caused big damage to elevated road and buildings. This earthquake also caused damage to the sprinkler systems of fire-fighting facilities. Because main water-supply pipes were damaged in this earthquake, the large-scale damage cause by water leakage did not happen in buildings.

In California continent, this earthquake resulted in the review of the aseismic performance of such structures as buildings and facilities.

b) The 1989 Loma Prieta earthquake

The Loma Prieta Earthquake that happened in October 1989 caused damage to San Francisco, Oakland and other cities in the bay area.

A fire occurred in the Marina district of San Francisco. High-pressure fire-fighting water-supply pipes built from lessons of the large earthquake disaster in 1906 were damaged. Part of this pipe system was utilized, and seawater was used for fire extinguishing activities.

Damage to sprinkler systems was reported from various kinds of institutions, such as office buildings, industry factories, air terminal and so on.

Much water leakage damage occurred due to damage to sprinkler systems. In a part of the airport terminal, a large quantity of water flowed out. In an office, constituted in five buildings, the damage to pipe system and wiring occurred in part of the expansion joint.

c) The 1994 Northridge Earthquake

The earthquake of magnitude 6.7 that occurred in the northern part of Los Angeles directory under the Northridge district in January 1994 caused the damage to many elevated roads and building structures and resulted in 61 deaths.

Many fires occurred at several mobile-home parks, along Balbola Boulevard and other places. Most fires were caused by gas leakage.

The main water pipe system was damaged, and this damage gave hindrance to fire extinguishing activities.

This earthquake caused damage to many sprinkler systems. The main water pipe damage resulted in lack water for sprinkler systems to distinguish fires, on the other hand, secondary damage by water leakage was reduced.

5. Influence of earthquake damage on fire-fighting and life security systems.

In recent big earthquakes, the damage to fire-fighting and life security systems was extensive. Fires at the time of on earthquake magnifies the earthquake disaster. Therefore, the maintenance and security of functional fire-fighting and life security facility systems are important. In a big disaster, people easily fall into psychological confusion. Accordingly, fire-fighting and life security systems are required to operate automatic. High reliability is required of automatic fire detection systems and automatic sprinkler systems. When a fire occurs, warning systems and evacuation instruction systems become important.

The following examines the major classifications of earthquake damage to fire-fighting and life security facilities.

1) Sprinkler system

Most earthquake damage to sprinkler systems is damage to sprinkler heads and water pipes. The cause of damage to sprinkler head s is collision of head and ceiling. When earthquake response characteristic of sprinkler head and ceiling are different, this collision happens. The location of damage to water pipes is as follows: Where pipes penetrate the wall, Points where several pipes connect and where buildings are joined. One cause of damage may depend on the differences in the dynamic characteristic of pipe systems and wall construction, and, other causes may depend on differences in each dynamic characteristic of the pipe systems or buildings.

The support methods for sprinkler heads and the water pipes need to be improved.

2) Fire detection, fire prevention and evacuation facilities

Fire detection systems are installed on ceilings. Therefore, detection systems will not function when a ceiling falls. Installation methods need to be revised.

Cases in which fire prevention doors were disformed or damaged are reported. In that event, the function of preventing fires from expanding does not work. Furthermore, opening and shutting of the door may become difficult. The toppling of exterior evacuation stairways was reported, and in such cases the selection of evacuation routes reduced.

3) Emergency power generation systems

In a disaster, the role of emergency power-generation systems is important, Some damage to such systems has been reported. One type of damage is movement and toppling from foundations, while another is overheating of the system due to lack of coolant supplied in the water-cooling system. Furthermore, short-circuits happened on switchboards by a leakage of water from water pipes. When emergency power-generation systems are installed, various kinds of consideration are necessary to assure they function in a disaster.

4) Water supply system

Damage to the city water-supply systems made fire extinguishing activities difficult at the time of the 1994 Northridge Earthquake and the 1995 Great Hanshin Earthquake. Aseismic performance of city water - supply system needs to be reinforced, and it is important to secure water supplies for extinguishing fires.

6. Conclusion

Fires after an earthquake magnify the tragedy of the disaster. In the case of a fire, action at the earliest possible stage is important. However, fire-fighting and life security systems receive various kinds of damage during recent earthquakes. Facility installation methods and methods of supporting of pipes and electrical wiring need to be reviewed to minimize earthquake disasters.

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References

1) Investigation Research Report of the 1978 Miyagi-Ken-Oki Earthquake; Architectural Institute of Japan, 1980 (in Japanese).

2) Report of the Damage Related to Fire-fighting Facilities by the 1993 Kushiro-Oki Earthquake; Kushiro Fire Department, 1993 (Data table)

3) Report of the Damage Related to Fire-fighting Facilities by the 1994 Hokkaido-Toho-Oki Earthquake; Kushiro Fire Department, 1994 (Data table)

4) Report of the Damage Related to Fire-fighting Facilities by the 1994 Sanriku-Haruka-Oki Earthquake; Hachinohe Fire Department, 1994 (Data table)

5) Investigation Research Report of the 1995 Great Hanshin Earthquake No. 3 ; Takenaka Corp., 1995 (in Japanese).

6) Investigation Research Report of the 1994 Northridge Earthquake; Tokyo Fire Department 1995 (in Japanese).

7) NFPA 13, Installation of Sprinkler Systems; NFPA , 1994

8) Earthquake Spectra Supplement to Vol. 6, EERI, 1990

9) Northridge Earthquake January, 1994; EERI, 1994

10) Northridge Earthquake January 17; Fire Sprinkler Advisory Board, 1994

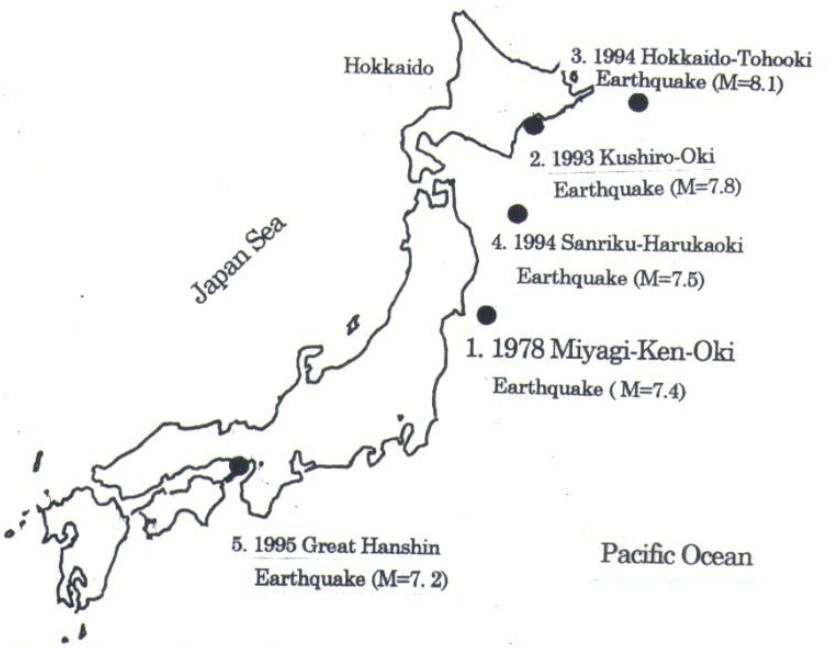


Fig. 1 Distribution of investigated earthquakes in Japan.

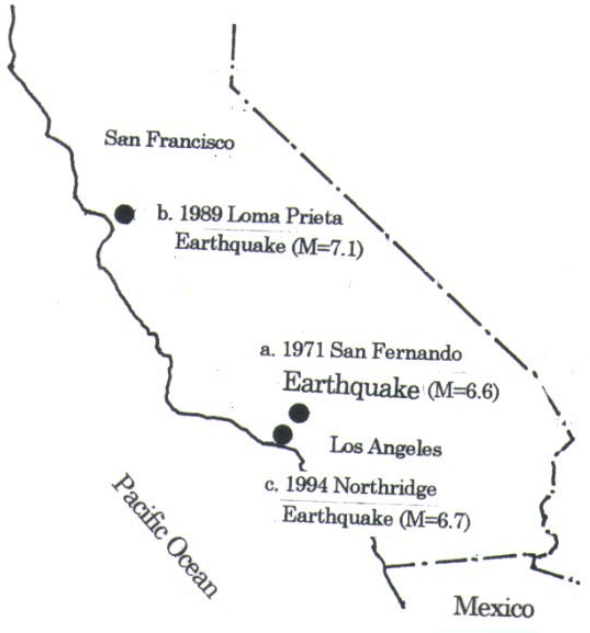


Fig. 2 Distribution of investigated earthquakes in California.

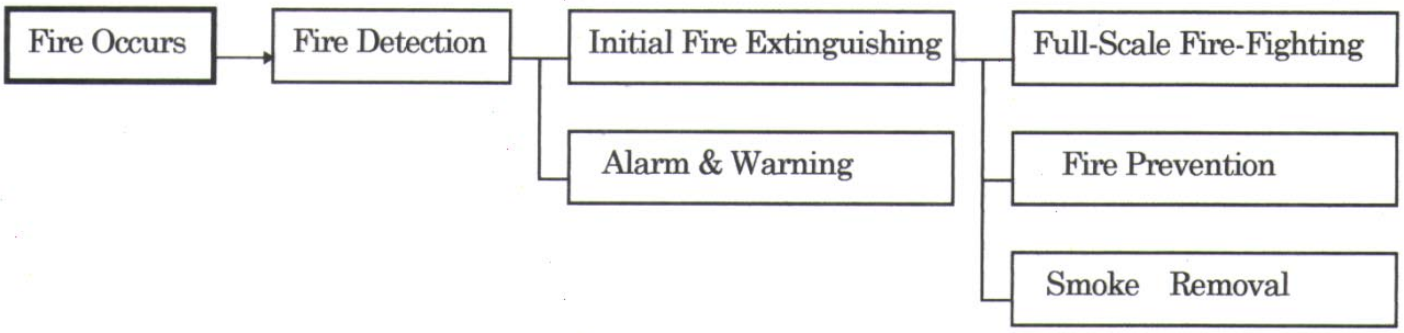


Fig. 3 Systems in a fire-fighting facility.

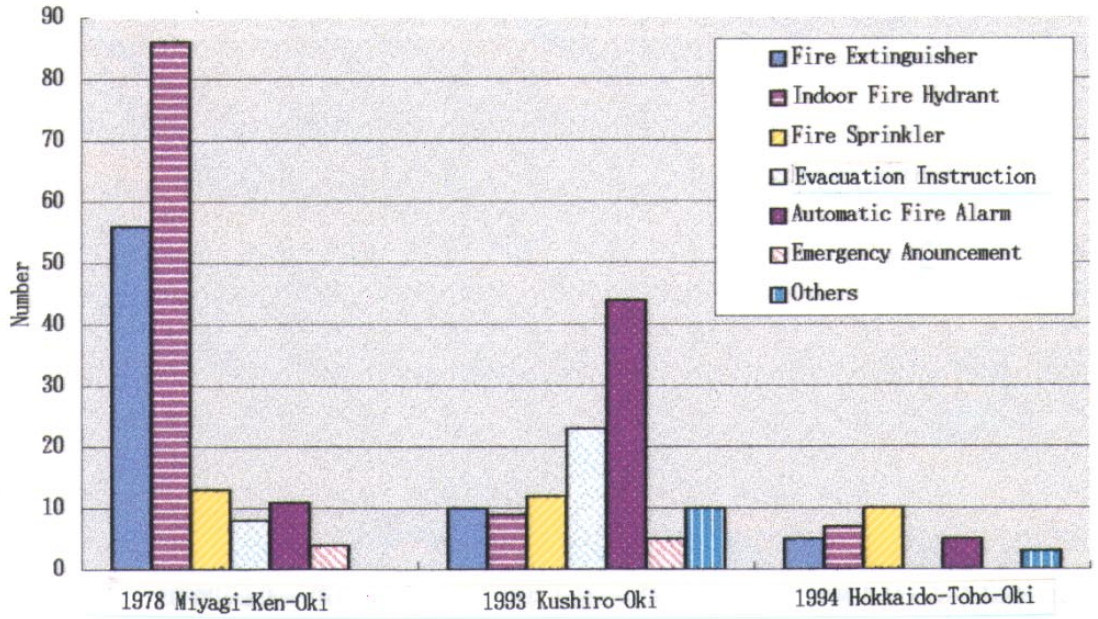


Fig. 4 Classification and number of fire-fighting facilities in three Japanese earthquakes.

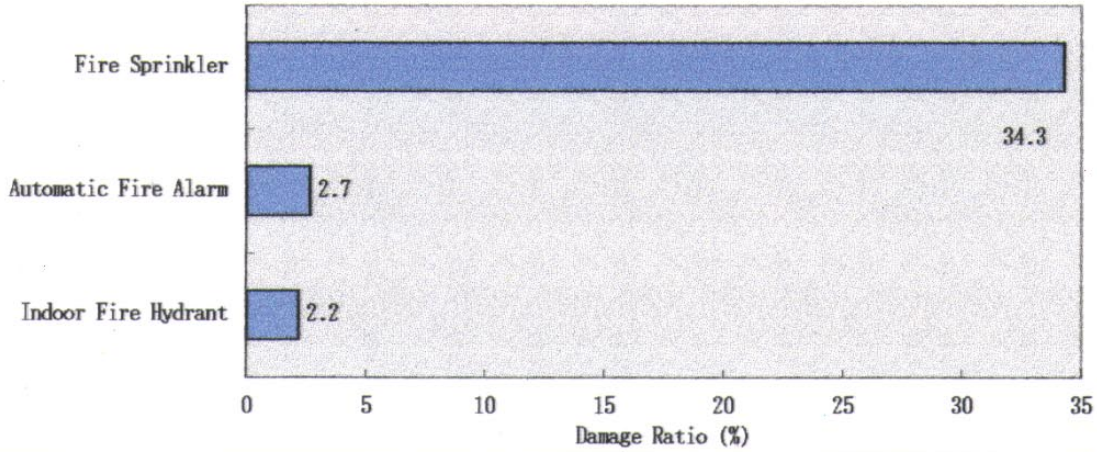
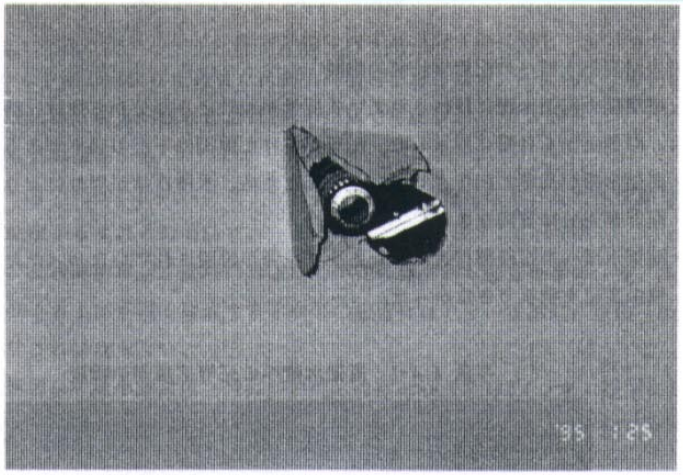
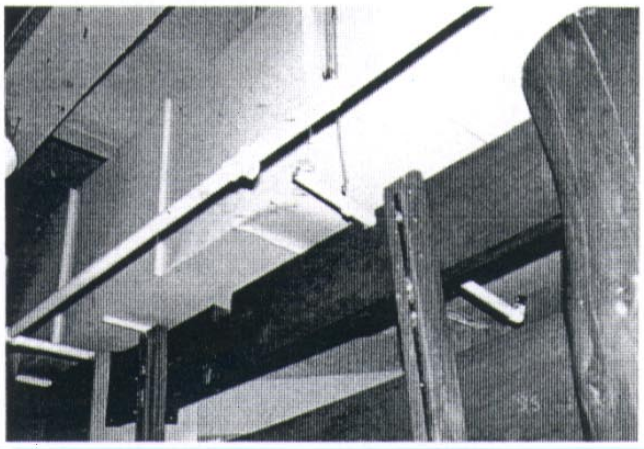


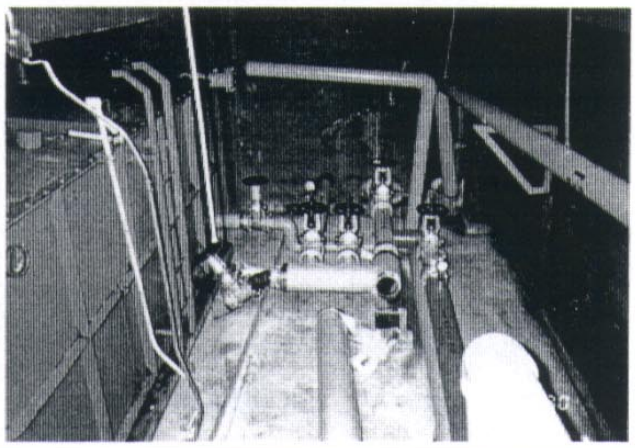
Fig. 5 Damage ratio for fire-fighting facilities in the 1993 Kushiro-Oki Earthquake.



a. Damage to sprinkler head



b. Damage to water pipe.



c. Damage to water storage tank & pipe system

Fig. 6 Examples of earthquake damaged life security facilities.