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BEHAVIOR OF LIGHTING SYSTEM IN THE HANSIN-AWAJI EARTHQUAKE DISASTER

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SUMMARY

In this paper, surveys of questionnaire concerning the lighting conditions during the earthquake, that of damage of lighting equipment, and examination of installation standards and so on of the disaster prevention lighting were made to the victims of the Great Hanshin-Awaji Earthquake in order to clarify the evacuation action in a large-scale disaster and the functions of the lighting equipment necessary for rescue operations. As a result, the following problems and improvement schemes were pointed out.

1.A considerable number of victims stayed for about an hour after the earthquake to wait for the dawn before taking actions. Therefore emergency power supplies should be installed to the lighting equipment such as street lights and other outdoor lights and lights of general residential houses which are exempted from the duty of installation of the emergency power supply in the current disaster prevention standards.

2.Even the victims relieved by the light immediately after the earthquake complained sleeplessness caused by the light in the night after time passed and aftershocks subsided. In such a manner, people having contrary feelings toward the lighting were housed in the same space to increase mental and physical stresses.

3.In commercial buildings and so on with small damages to the building, the disaster prevention lighting equipment such as emergency lights and leading lights functioned sufficiently. However, almost no people needed evacuation and lights. Lighting was insured for 30 minutes, legal lighting time for evacuation from a fire, but the duration of power outage of the commercial power supply was longer than the period. Therefore the capability necessary for evacuation from an earthquake and installation of a control system are necessary.

INTRODUCTION

The Hyogo-ken Nanbu Earthquake which occurred at 5:46 January 17, 1995 brought about 6,400 death toll. At the same time, 2.6 million houses in the Hanshin District and Awaji Island were stripped of lights(Kansai Electric Power,1995). Because it was near dawn and power stations and power transmission facilities were not damaged, houses in a power outage were reduced to about one third in almost two hours from the occurrence of the earthquake, and the daylight was obtained soon, so that no evacuation panic was caused by the darkness.
If a massive earthquake hits in the midnight or before the closing time in winter and a power outage occurs in a wide area for an extended time, the fear of darkness is beyond our imagination. It is common sense during a large earthquake to get out of the car and evacuate on foot. However, it will be almost impossible to urge people to abandon the space, information, air conditioning and lighting provided in one's own car to evacuate in the darkness where the sense of direction is lost. One of the major features of the present earthquake is that a large number of victims were obliged to live in the refuge for a half year or longer. Lights in both the daytime and nighttime at the emergency refuge initially alleviated the fear of aftershocks but the lights of the gymnasium

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which are not the lighting equipment for the living space gradually caused mental and physiological effects such as irritation and sleeplessness.
The functions and capability of the lighting equipment necessary for a large-scale disaster are examined herein, based on these features of the earthquake.

EVALUATION OF LIGHTING EQUIPMENT BY VICTIMS OF EARTHQUAKE

Outline of Survey

Three types of questionnaire surveys were conducted. First, a visit survey was conducted to the residents of makeshift temporal houses, the whole or half of whose original houses were supposed to be destroyed, in July, 1995 for items concerning the lighting equipment at the time of earthquake occurrence, during evacuation, at the refuge site and at the temporal house (effective respondents: 533). Second, a similar visit survey was conducted in November, 1995 to the residents of apartment houses with minor building damage (effective respondents: 170). Third, a postal survey was conducted in September, 1995 to the residents of detached houses sampled randomly in intensity scales (total distribution: 2,000, effective respondents: 524).

Fear of Darkness Immediately After Earthquake

We rely on visual recognition for nearly 85% of information obtained from the environment. If the light is lost, we feel trouble in the judgement of the surrounding circumstances and decision of the next action. The light source for acquisition of visual information is indispensable in an emergency and disaster. On the other hand, in the urban and suburban areas, we are in the light pollution and we hardly experience darkness in daily life. Therefore urban dwellers live daily life without feeling the fear of darkness.

The Hanshin-Awaji Earthquake was the first wide-area outage experienced by dwellers of metropolises since World War II. According to Figure 1, almost all the victims of the earthquake reported a blackout of street lights at or near their own houses occurring simultaneously upon the earthquake. However, 12% of the respondents living in the Hanshin District do not have the memory of the state of street lights; they suffered supposedly from a violent shock.

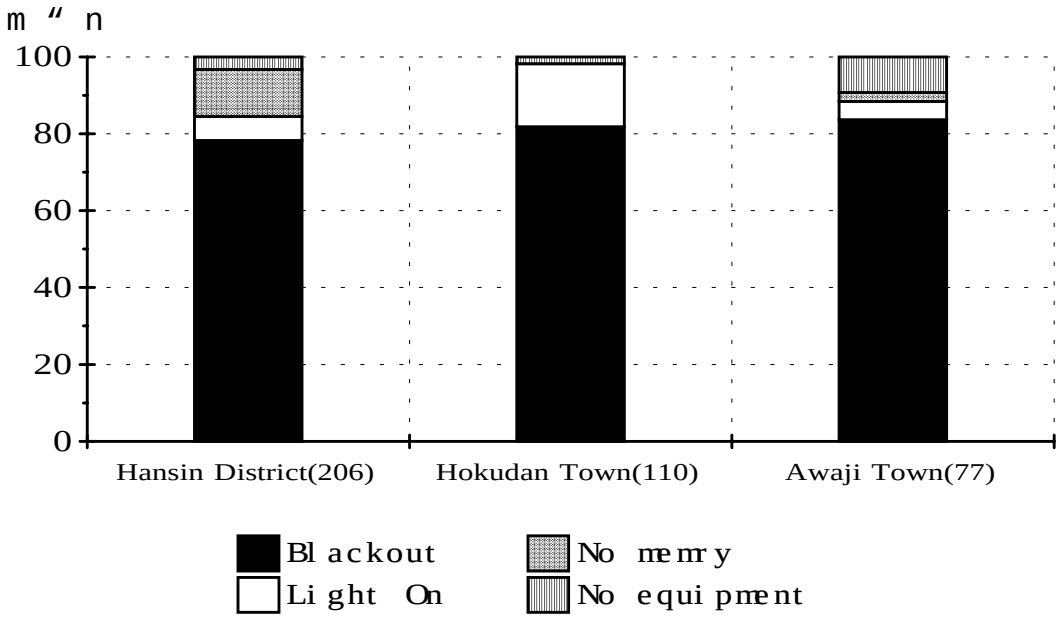


Figure 1: Blackout of street light at the time of earthquake

As shown in Figure 2, the largest part of respondents who evacuated immediately told that "I lost myself and did not think anything," but many respondents told that "It was dark and I was scared", "I wanted for daybreak," or "The light of the refuge site calmed my nerve." Thus, evaluation of the light for mental calmness is recognized as

well as fears of the darkness.

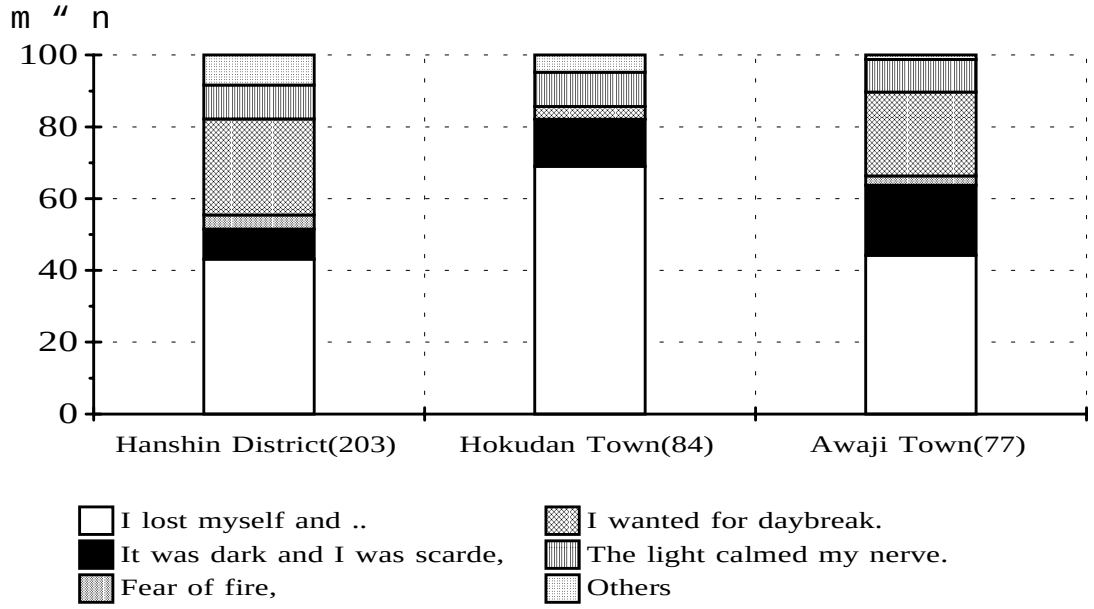
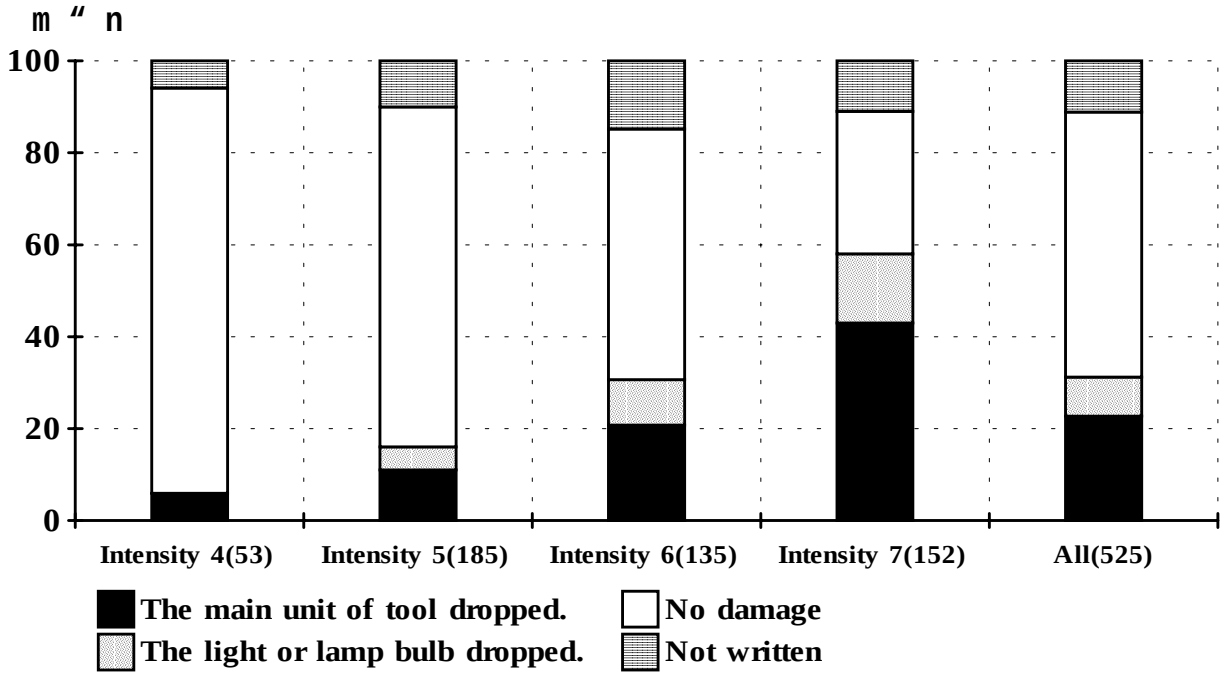


Figure 2: State of mind during evacuation

Most of the people used a flashlight as a light during evacuation. However, some dwellers of high-rise buildings reported the leading light at the stairs while there was a blackout at their rooms and in the vicinity. The disaster prevention light functioned effectively. The disaster prevention lighting equipment at general residential houses currently exempted from the duty of installation and emergency lighting of street lights during power outage should be examined again from the view of disaster prevention.

Figure 3: State of damage of pendant type lighting tool (survey to detached houses)



On the other hand, the pendant type lighting tool indicates a main unit dropping ratio of 20% at seismic intensity 6 and 42% at intensity 7 as shown in Figure 3, increasing the damage in proportion to the intensity of the earthquake. While other hanging type lighting tools show similar damage, equipment on or buried in the wall shows smaller damage. Most of the damaged lighting tools in commercial buildings were the hanging type, too.

Amount of Lights Rather Than Quality of Lighting in Emergency Evacuation

Most of the victims of the earthquake evacuated in the nearby school, public hall or other facilities. In Awaji Town, about 10% evacuated to nearby plowland. As shown in Figure 4, because of fast recovery from power outage, lights were recovered in most refuges on the first night after the earthquake. Among the lighting control states in refuges such as the gymnasium, "light-on in the day and night time" or "reduction of light at bedtime" was more popular than "light-off at bedtime" at any refuges. Concerning this state, respondents who "slept well due to the light" prevailed over those who "could not sleep well due to the light," reflecting the strong fear against aftershocks. The light helped recover the calmness anyway. To put the emergency evacuation state to about 72 hours, the feeling of being safe brought about by the light takes precedence over fine control of the light. Generally speaking, lighting equipment in most public buildings is designed to be suitable for their functions, such as that in a gymnasium designed to help the function of the
gymnasium, while the lighting function as a residential space is not considered; the light during power outage is sufficient for the function of the emergency refuge site. However, this is only for emergency refuge; as the time passes, mixture of "those who cannot sleep well in the light" and "those who cannot sleep well in the darkness" causes stresses and other new problems.

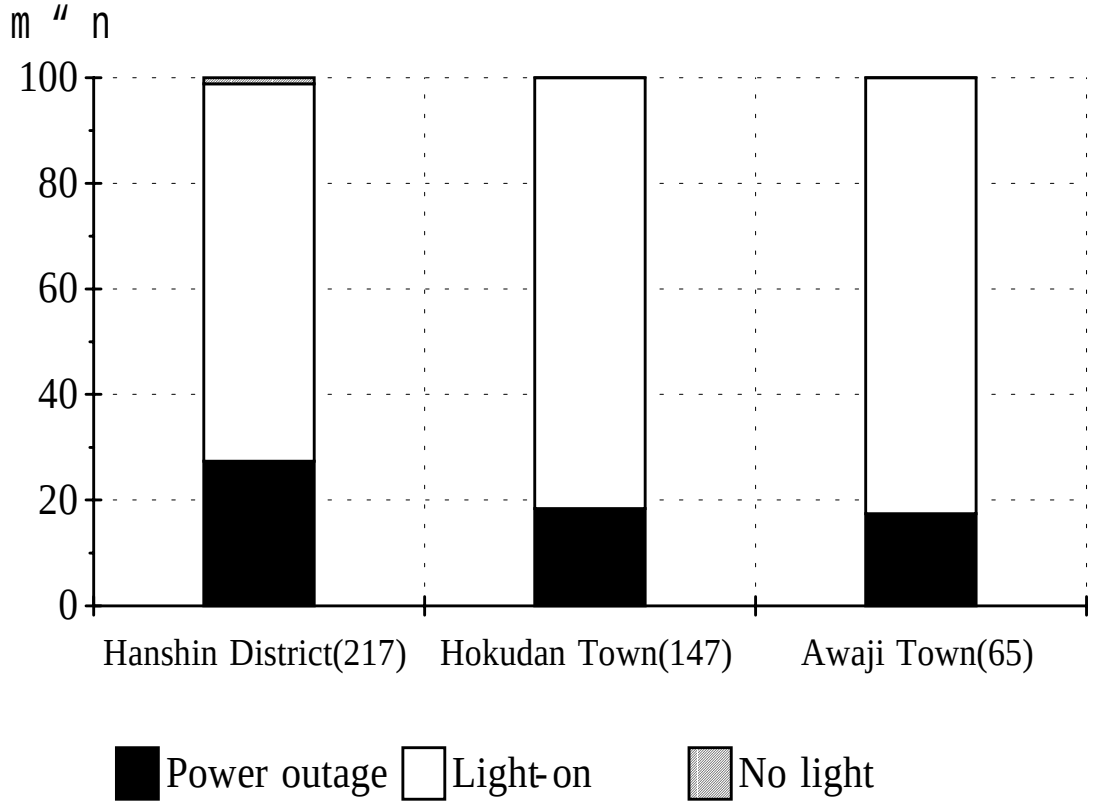
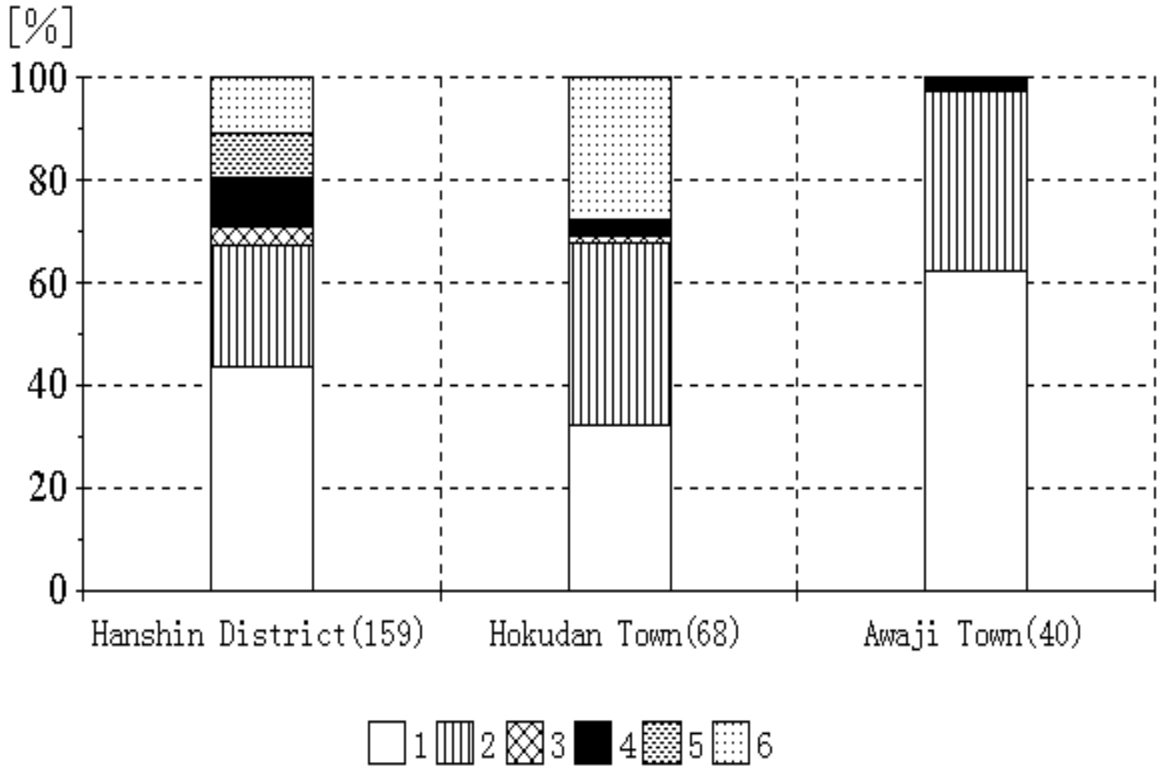


Figure 4: Power outage at refuge site (night of occurrence of earthquake)

From Lights in Amount to Quality Lighting for Restoration of Daily Life

Some people lived as long as more than a half year in the emergency refuge. It is well known that the natural light resets the body clock to maintain the circadian rhythm. Life under the artificial light which features insufficient on-off control without delicate changes and a far low luminance and few changes when compared with the day light causes sleeplessness and disorder in the physiological functions if it continues for a long time. Especially the situation was serious for the elders stripped of outgoing chances and ambition. If the life at the refuge is extended for unavoidable reasons, a well paced life pattern becomes necessary. A regular life, going out for an appropriate outdoor walk and other stimulation from the sociological environment, stimulation from the daylight, and appropriate lighting control are required. Though some residents of the temporal house reported

that he/she "could not sleep because of uneasiness if the light is turned off," most residents were returning to the state where he/she could not sleep in the light." No complaint about the lighting at the bedtime is observed in persons who lived in class rooms where the lighting control was easy, but those housed in a large space such as gymnasiums issued many complaints. As the time passed, the qualitative aspect of the lighting rather than the quantitative aspect was sought.



1:Felt safe because of the light. 2:Could not sleep because it was too brilliant.
3:Slept better in the dark. 4:Could not sleep due to darkness.
5:Could not sleep without relations to the light. 6:Slept well without problems.

Figure 5: Evaluation to lighting at refuge

PROBLEMS OF DISASTER PREVENTION LIGHTING EQUIPMENT

The disaster prevention lighting tools (leading light, emergency lighting tool) regulated in the Fire Fighting Law and Building Standard Law aim at the light provided for unspecified multiple people so that they can evacuate quickly and safely upon a fire. For this reason the light must be of at least 1 lx and it must continue to turn on for more than 20 or 30 minutes. However, a blackout of not only the building itself but in a whole area is not considered as well as the situation where the form of the routine evacuation path is changed abruptly. This can be easily understood from the fact that the scope of duty of installation excludes the living part of residential houses, where quick evacuation of a limited number of people who are familiar with the site is expected, and paths and corridors exposed directly to the atmosphere effectively for daylighting reasons. Further, it is only an exceptional number of local governmental bodies having experienced major tsunami disasters, such as Taro Town and Kainan Town, that installed street lights equipped with an emergency power supply (including solar system) for assurance and support of the safety of the evacuation path to the emergency refuge site. If a power outage occurs in a wide area at night due to an earthquake in a metropolis such as Tokyo and Osaka now, it is foreseen that there is a blackout at outdoor evacuation paths and refuge sites to hamper smooth evacuation actions.

There are the following problems in the current standards of emergency lighting, awaiting improvements.

1) Upon a wide-area power outage at night, the daylight or nearby lights are not expected.
2) Furniture and things move and topple down to block the regular paths, making it difficult to evacuate in a short time.
3) Some users of buildings or attendants in rooms cannot evacuate by their own.
4) After emergency batteries are discharged, refuge sites may not operate properly until the commercial power supply is restored even if the building is not damaged.

FUNCTION OF OUTDOOR LIGHTS IN DISASTER

The effect of the outdoor lights in conventional time includes assurance of traffic safety at night, crime prevention, and formation of street vitality and bustle and the urban night landscape. On the other hand, functions such as recognition of the state, prompt evacuation and rescue, assurance of evacuation paths and leading, conception of stabilization and feeling of safety of the victim, and maintenance of order are needed in an emergency. As described previously, outdoor lights provided with disaster prevention functions are not fully prepared. Problems are summarized in the following points.

1) There are no lighting installation standards concerning refuge site and evacuation paths.
2) There are no lighting standards of illuminance and uniformity ratio of illuminance considering evacuation and rescue in a disaster as well as the mental state of victims.
3) The seismic standard of lighting tools and light posts is not fully prepared.
4) There is no spare battery for the commercial power supply to be used at power outage.

Generally speaking, refuge sites for disasters are designated by local governments. Even for local residents, evacuation with feeble persons such as elders, infants and the injured at night through roads with scattered matter and falling buildings requires a higher visibility than that needed for crime prevention. Further, in the metropolitan areas, there are usually lots of temporal visitors and passers as well as local residents, and a visibility is necessary in a relatively wide area to guide these evacuees who are geographically strangers. To achieve the purpose, light emitting guide plates and maps showing refuge sites (parks, squares, schools, etc.) as well as lighting of the evacuation path are indispensable. To achieve the purpose, the following items are necessary.

1) Lighting installation standards and illuminance standards considering disaster prevention and crime prevention should be established.
2) The seismic characteristics of street lights and other outdoor lighting tools and light posts should be improved.
3) Lit guide maps and nighttime land marks should be installed.
4) Refuge sites and public facilities should be lit in an emergency for easy recognition.
5) A solar cell system should be introduced to street lights and park lights.
6) Solar cell and other types of emergency power supply should be installed to the gate lights and garden lights of general residential houses to make them function as complementary street lights.

In order to examine the lighting standard in the disaster prevention phase, the relationship between the brightness of the road surface and the visibility of obstacles on the road was sought. As shown in Figure 6, 0.1 to 0.3 lx was suitable for average road surface illuminance. When the interval between adjacent street lights is taken into consideration, about ten-fold brightness is necessary(Tanabe ,1997). This value is known to be nearly the same as the current recommended illuminance for pedestrian paths.

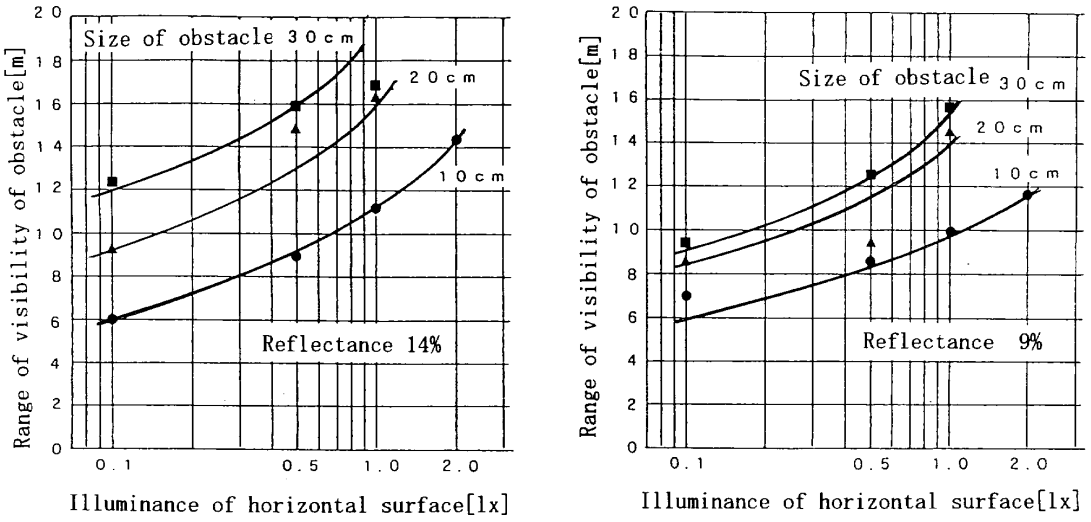


Figure 6: Relationship between illuminance of range of visibility of obstacle

CONCLUSION

In the Great Hanshin-Awaji Earthquake, no evacuation panic occurred in spite of a power outage in a wide area for a long time. This was not because emergency lights and other types of disaster prevention lighting were fully prepared and lights were assured at evacuation paths, but because the earthquake was shortly before the dawn and the sky became bright in a relatively short time. Because actual street lights and residential house lighting equipment are not equipped with an emergency power supply, an evacuation panic would occur due to the darkness and the death toll would be far larger than that of the present earthquake if the earthquake occurred at another time. The regulations for the specification of emergency lighting equipment are determined to support evacuation from a fire of the corresponding building. Consequently, installation standards and equipment capabilities must be improved to make the equipment support evacuation in earthquakes and other disasters and achieve the function for refuge sites.

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