A STUDY ON SAFE EVACUATION FROM INUNDATED UNDERGROUND MALL BY A MULTI-AGENT MODEL

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1. Introduction

In the urban area of Japan, underground spaces, such as underground mall, subway stations, have been developed to effectively utilize the limited land. However, in recent years, due to climate change, the number of heavy rainfalls has increased, and underground spaces are prone to inundations caused by pluvial flood. Therefore, it is important to perform quick and safe evacuation in the event of a disaster. In this study, it was investigated how to improve the evacuation success rate in an underground mall in the urban area, assuming the possibility of underground flooding caused by pluvial flooding caused by short-term torrential rainfall. The study area is a large-scale underground mall in the Umeda area in Osaka, Japan. Figure 1 shows the location of Umeda. This area is very vulnerable to water-related disasters because of its low ground level and rivers and seas on all sides. Figure 2 shows the mesh data and analysis range of the underground shopping mall.

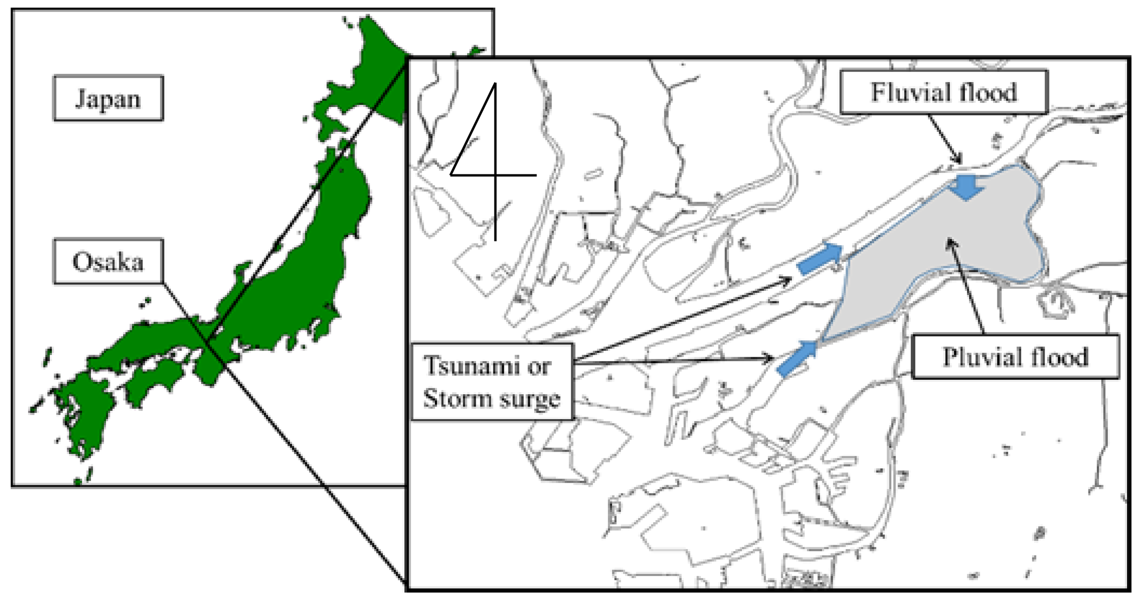

Fig.1 Umeda area, Osaka, Japan

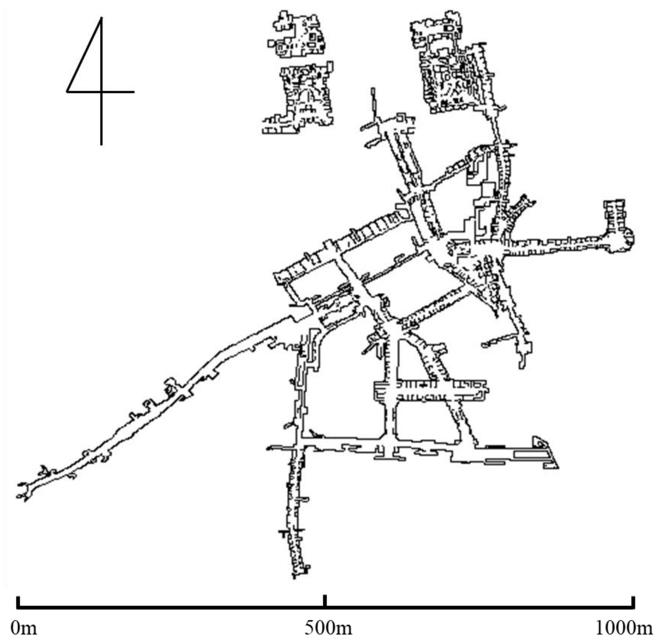

Fig.2 Study area (Umeda underground mall)

2. Model

a) Pluvial Flood Model

The inundation calculation was performed using InfoWorks CS that can analyze ground inundation considering the sewer road network. The rainfall data are those created using three rainfalls of 60mm/hr, 120mm/hr and 180mm/hr. The rainfall of 120 mm/hr and 180mm/hr are twice and three times as large as the reference rainfall of 60 mm/hr, the design rainfall in Osaka City (Kho et al., 2018). Figure 3 shows hyetographs of these rainfalls. These data are centralized with a time interval of 5 minutes and a rainfall duration of 2 hours.

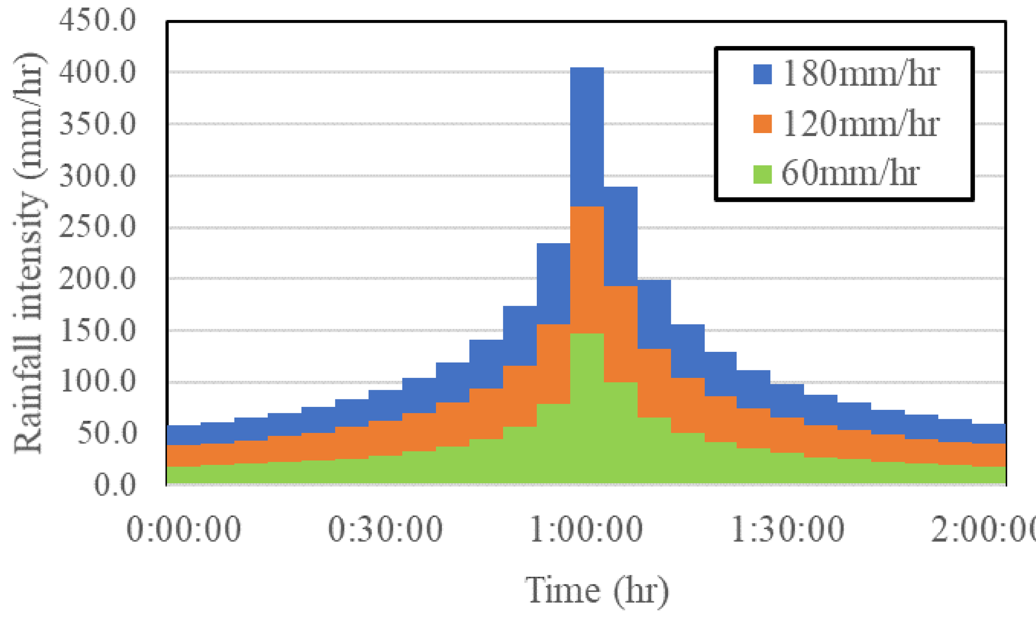

Fig.3 Rainfall hyetograph (three types) (Kho et al., 2018)

b) Evacuation Model: Multi-Agent Model

The evacuation simulation model was built by a multi-agent simulation platform "artisoc 4.2" developed by Kozo Keikaku Engineering Incorporated. Figure 4 shows a flowchart of evacuation behavior. The study area is a one-dimensional network model composed of nodes and links, and widths are set for passages. Evacuees were set to adapt to changes such as speed reduction due to congestion, and movement to a link with more people when there were multiple destinations. Evacuation was simulated with six patterns of 10,000, 12000, 14000, 16000, 18000, and 20000 visitors. The simulation was performed 10 times for each pattern. All agents started to evacuation when rain started, and the time which everyone finish to evacuate was measured. After that, the average evacuation time for each pattern were calculated.

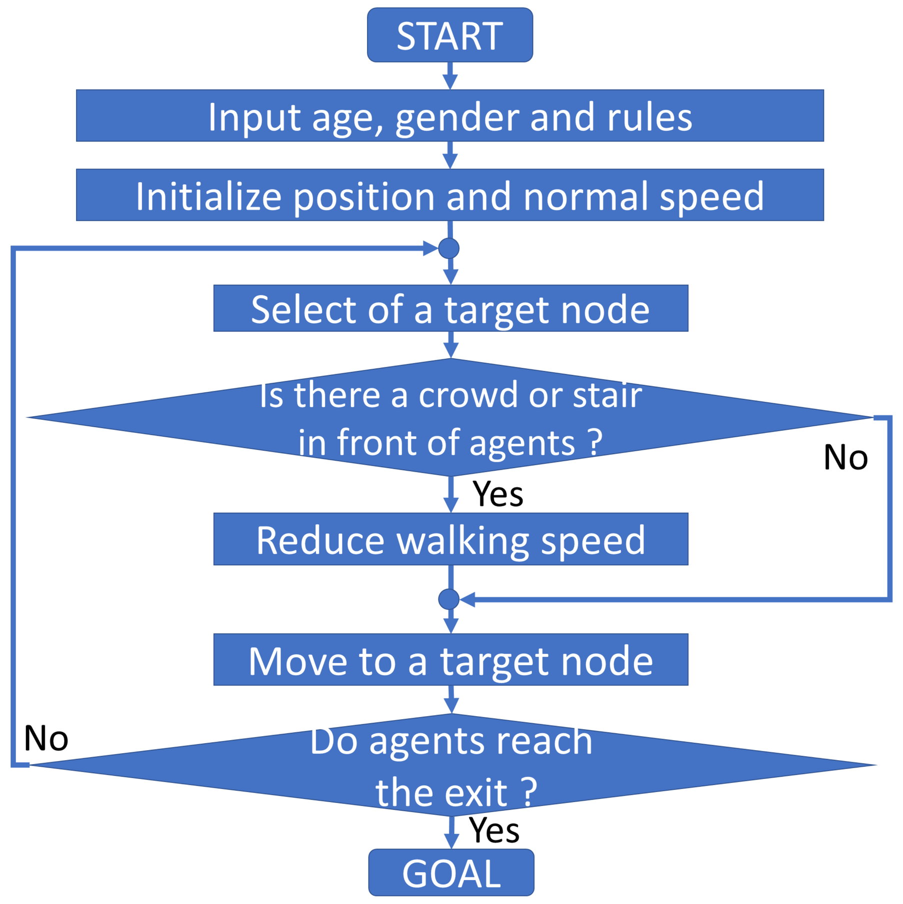

Fig.4 The flowchart of the evacuation behavior

3. Results

From the inundation results, the safe evacuation time starting from the start of rainfall is calculated. The safe evacuation completion time is obtained by using a criteria based on the specific force per unit width for elderly female whose evacuation is difficult at the earliest time (Asai et al., 2010). Figure 5 shows the change over time in the proportion of the area that can be evacuated. In this study, the safety evacuation time is the time when the ratio of the safe evacuation area falls below 100%.

Figure 6 shows the results of the evacuation behavior simulation. The evacuation completion time increases as the number increases from 10,000 to 20,000. In this study, it was considered that the evacuation time increased because people settled at a specific exit because the following action was set in order to consider the synchronicity at the time of disaster. It would be possible to shorten the evacuation time if it could be set so that the route could be changed in the event of a guide or congestion.

Figure 7 shows a comparison between the average of evacuation time and the critical lines of the safe evacuation time. In the case of 60 mm/hr, all patterns can be evacuated with almost no problem, but in the case of 120 mm/hr and 180 mm/hr, as the number of people increases the evacuation margin time decreases. In addition, even if you evacuate to the ground, it is conceivable that evacuation will be difficult on the way to the evacuation sites. In other words, it is dangerous to evacuate to the exit to the ground. It is important for people to evacuate to the building connected in the underground shopping mall and evacuate to the upper floor in order to improve the evacuation success rate.

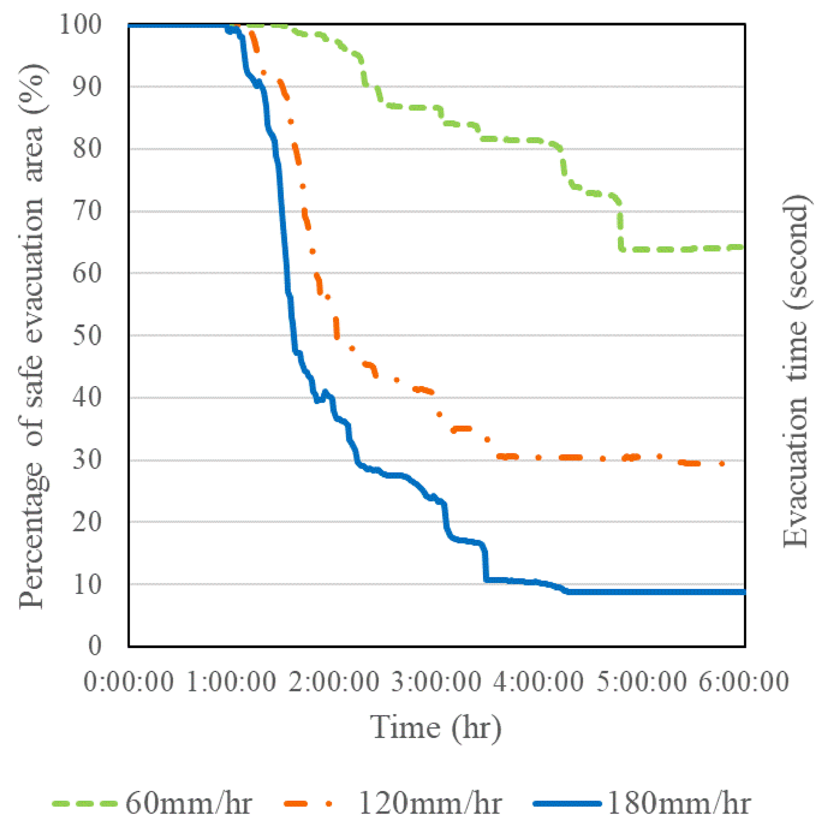

Fig.5 The time variation of safe evacuation area (elderly female)

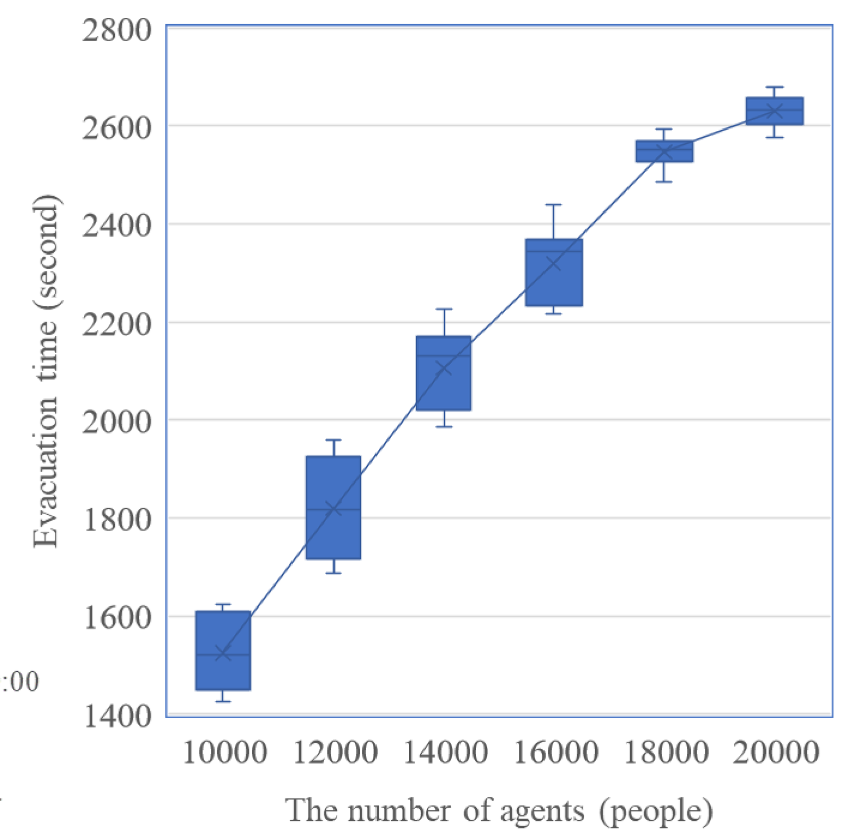

Fig.6 The box-plot of evacuation time (10 times for 6 patterns)

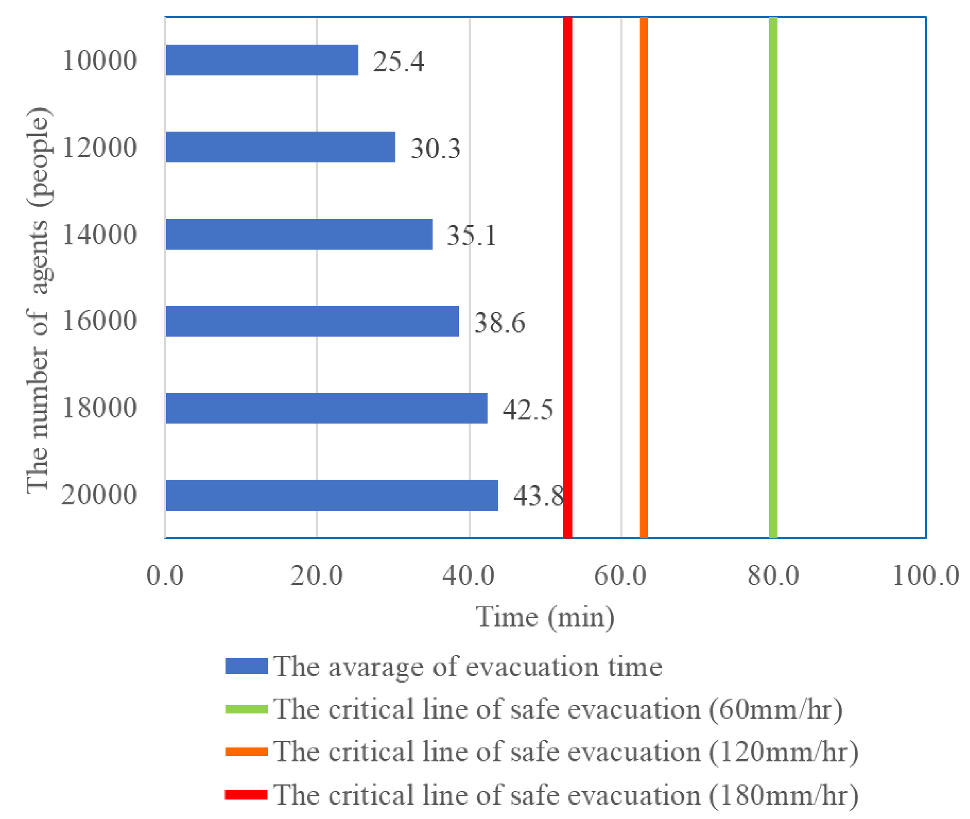

Fig.7 The evacuation time and critical lines of safe evacuation

4. Conclusion

It has been shown that the evacuation time decreases as the rainfall increases and the number of evacuees increases. It has also been shown that evacuation methods of getting out to the ground and going to evacuation shelters were not an effective means to safely evacuate all evacuees if the floods become severe. In the future, it will be possible to consider more specific evacuation success rates by considering when entering connected buildings and adding some guidance systems.

References

- Kho et al. (2018). Evacuation from inundated underground shopping mall under extreme weather condition, Proceedings of Symposium on Underground Space, JSCE, Vol.23, pp.103-108. (in Japanese)
- Asai et al. (2010): SAFETY ANALYSIS OF EVACUATION ROUTES CONSIDERING ELDERLY PERSONS DURING UNDERGROUND FLOODING, Journal of Hydroscience and Hydraulic Engineering, Vol.28, No.2 November, 15-21.