Journal of Engineering and Applied Sciences 12 (18): 4585-4589, 2017
ISSN: 1816-949X

A Study on Standard of Evacuation Route Selection for Prevention of Flood Damage Focused on Standard of Korea

[1]Lee Ji-Soo and [2]Lee Youn-Ha
[1]Departments of Disaster Prevention and Safety, Gyeongju University, Gyeongju, Korea
[2]School of Architecture, Civil, Environmental and Energy Engineering,
Kyungpook National University, Daegu, South Korea

Abstract: This study was to draw the problems of the evacuation criteria during inundation based on the experiment result considering gradient, age and depth. The results showed that the evacuation criteria currently being enforced was set based on the foreign instances and didn't reflect Korean's pedestrian characteristics. We investigated the factors affecting the evacuation in order to establish the best evacuation plan against inundation and analyzed the degree of effects of each factor with experiment result. Based on this we drawn the problems of current evacuation criteria in Korea, set the 4 different routes having different characteristics and estimated travel time for evacuation of each route. But there's a limit of that other factors except for gradient and depth were not analyzed. We consider the complement and further studies will be needed.

Key words: Flood, evacuation, criteria, inundation depth, gredient, factor

INTRODUCTION

Background and purpose: Korea has intensive rain in summer, it's called "rainy seaso". It lasts about 30 days and covers about 40% of annual rainfall. Moreover, heavy rain accompanied by strong wind for short period of time due to typhoon causes damage of human life and property. Accordingly, the structural or non-structural countermeasures have been established and implemented. Among the measures, shelter and evacuation route are very important for preventing damage of human life.

But the evacuation rules currently being enforced in Korea were prepared based on the foreign case or has obscure criterion. Therefore, this study based on the experiment results is going to draw the problems of the evacuation rules and suggest improvement plan.

MATERIALS AND METHODS

Method and scope of the research: To draw the problems of evacuation rule in Korea, the following studies were conducted:

- Drawing the factor influencing on the evacuation in case of inundation by studying the preceding research
- Analysis of reduction rate of walking speed influenced by each factor (gradient, inundation depth)
- With writing scenario, prediction of evacuation travel time according to the characteristics of evacuation route
- Drawing the problems of evacuation rules in Korea and suggestion of improvement plan (Fig. 1)

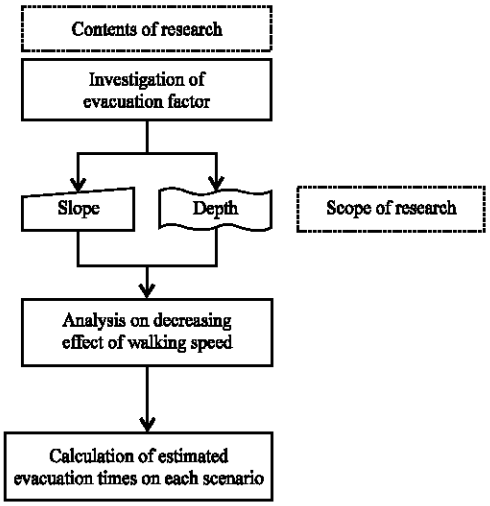

Fig. 1: Flow diagram of this study

The criteria of flood shelter and evacuation route in Korea

Standard of establishment for flooding disaster shelters: In the master plan of preliminary and warning alarm of

Corresponding Author: Lee Ji-Soo, Departments of Disaster Prevention and Safety, Gyeongju University, Gyeongju, Korea

Table 1: Standard of establishment for flooding disaster shelter (NDMI, 2013)

Category/Standard of establishment	Location of establishment
Flooding disaster shelters	
Flood safety area (school, public institution building, etc)	The shortest distance outside the area of flood expectation-designation or equip in 1 km for walking evacuation
Satisfying medical facilities and facilities for long period	Considering the place that be designated from city office or disaster headquarters
Scale of accommodation: about 2000-8000 people	
Special disasters shelters	
Shelters by using for special object of protection (hospital, etc.)	1 or 2 place in each district

Table 2: Standard of establishment for evacuation route

Categorys	Contents
Evacuation distance	<1 km
Evacuation travel time	Within 30 min (by walking)
State of road	Main route width: 10~15 m secondary route width: 8 m
Accessibility to around streets	-
Condition of around buildings	-
Potential risk in evacuation route	Inundation, landslide, collapse of a structure, etc.

disaster, shelter is to operate by distinguishing into general shelters (performing general-purpose evacuation functions) and special shelters (accommodating people requiring a special medical attention).

In Korea, in the case of a tsunami after a disaster (weather Newsflash issued) in accordance with the evacuation plan (E-30, evacuation-30 min) and develop a plan to evacuate within 30 min. In the case of a natural disaster (storm and flood damage, landslides) and establish a plan to evacuate to a safe place before the predicted time of disaster damage occurred in the district designated evacuation carried out in accordance with Pre-Evacuation Plan(P-EP).

According to the "Guidance on disaster mapping standards", evacuation area shall as a rule, designated as a place to escape on foot is available. Preferentially using public facilities, considering the size of the evacuation site or facilities it should be appropriately placed (Table 1).

Standard of establishment for evacuation route: The route for rapid and safe evacuation to shelter by walking in principle should be selected. So, the evacuation route should be the road that has never been inundated or the wide road that has had low inundation depth even though it has been inundated. It also should be considered the points such as potential inundation by flood, steep slope land and danger of landslide in selection of evacuation route (Table 2).

RESULTS AND DISCUSSION

Analysis of factors affecting the evacuation at inundation: The purpose of this study is analyzing the factors affecting the evacuation during inundation and drawing the problems of evacuation criteria currently being enforced in Korea. The study was proceeded based on the experiment results.

Table 3: Evacuation factors in flooding (Lee *et al*., 2014)

Categorys	Contents
Individual factors	Age, gender, degree of disability, experience in flood damage, perception of shelter and evacuation routes
Environmental (physical) factors	Inundation depth, flow velocity, distance, slope of evacuation route
Social factors	Weather information, evacuation alarm, effectiveness of evacuation plan

Table 4: Result of experiment (Youn *et al*., 2016)

Category (cm)	Walking speed (m/sec)	Running speed (m/sec)
0	1.43	3.90
10	1.24	2.58
20	1.07	2.23
30	0.98	1.83
40	0.92	1.47
50	0.85	1.27

The preceding studies show that the factors affecting the evacuation during inundation are pedestrian characteristics according to age, sex and degree of disability, inundation experience, perception of evacuation route and information delivery about inundation depth, flow velocity, distance of evacuation route, gradient, flood and weather. It is classified at Table 3 and 4.

This study was focused on the walking speed with gradient and inundation depth. In case people didn't escape before inundation they have to walk or run in water and their walking or running speed should be lower than usual. In order to measure the walking speed at supposed inundation, walking speed of 30 adults with various inundation depth was measured.

In case of evacuation from a high place to a low place during flood, pedestrian characteristics with gradient and age of refugees should be considered. So, we measured the walking speed with gradient of total 30 people who are classified into the group of 15-29, 30-44 and 45-60 years old. And 4 types of evacuation routes were assumed with an average slope of 0°-15° (Fig. 3 and Table 5).

Analysis of evacuation travel time with route according to evacuation scenario

Setting the scenario with inundation situation: Based on the experiment results of walking speed with gradient and water level, two scenarios for supposed inundation were created in which other factors such as flow velocity and wind speed were not considered. Total evacuation

Table 5: Result of experiment (Lee and Hong, 2009)

Course/Groups	1	2	3	4	5	6	7	8	9	10	AVG
Slope 0°											
1	2.56	2.63	3.06	2.91	2.70	2.11	2.33	2.13	1.81	2.42	2.47
2	2.31	2.09	2.20	2.45	2.08	1.70	2.07	1.99	1.92	1.95	2.08
3	1.74	1.85	1.78	1.84	1.58	1.92	1.90	1.80	1.72	1.85	1.80
Slope 5°											
1	2.65	2.26	2.69	2.70	2.42	1.71	2.31	1.74	1.76	1.79	2.20
2	2.31	2.09	2.20	2.45	2.08	1.70	2.07	1.99	1.92	1.95	2.08
3	1.61	1.55	1.61	1.53	1.39	1.42	1.60	1.54	1.59	1.72	1.55
Slope 10°											
1	2.24	2.03	2.26	2.16	2.20	1.48	2.09	1.38	1.72	1.48	1.90
2	2.01	1.69	1.74	1.91	1.60	1.52	1.80	1.82	1.75	1.72	1.76
3	1.37	1.39	1.26	1.25	1.38	1.49	1.28	1.28	1.49	1.51	1.37
Slope 15°											
1	2.09	2.12	1.92	2.03	2.06	1.36	2.03	1.34	1.39	149.00	1.78
2	1.93	1.46	1.66	1.57	1.50	1.43	1.62	1.60	1.50	1.46	1.57
3	1.32	1.19	1.21	1.39	1.39	1.21	1.27	1.23	1.15	1.26	1.26

Unit: m/sec

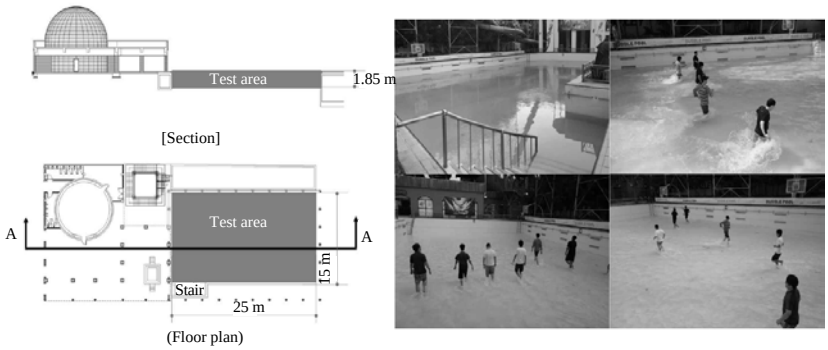

Fig. 2: Experiment of walking speed in water (Lee *et al*., 2016)

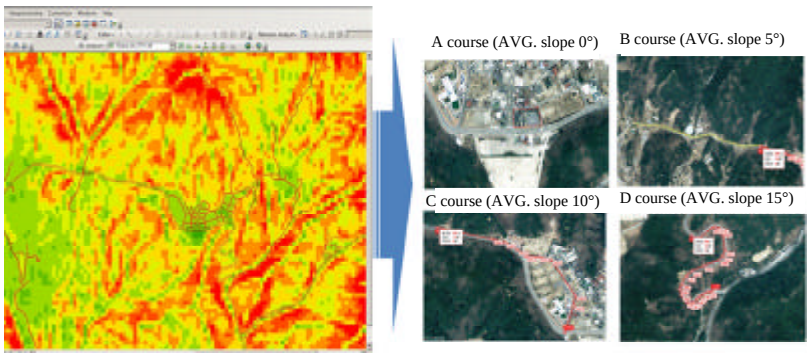

Fig. 3: Experiment of upward walking speed (Lee and Hong, 2009)

distance was the same as 500 m but four different routes having different inundation distance, inundation depth and gradient were supposed.

First evacuation scenario is constituted of the path (A′-A″) which has gradual gradient but through the inundated area and the path (B′-B″) which has steep gradient but no water area (Fig. 4).

Second scenario is constituted of the path (C'-C'') which is long through inundated area but has gradual gradient and shallow water and the path (D'-D'') which is short through inundated area but has steep gradient and deep water (Fig. 5).

Analysis of evacuation travel time with evacuation scenario: The measured result, previously described of walking speed with gradient showed that walking speed decreased by 10% with 5% increase of gradient. And with 10 cm increase of depth, speed decreased by 5-13% from the usual. There's difference in initial measured value of walking speed with gradient and depth so it was

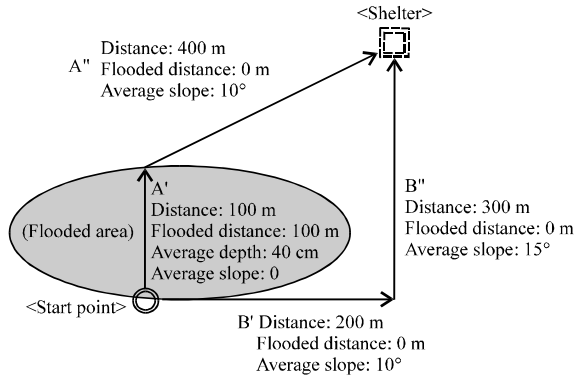

Fig. 4: Concept map of scenario 1

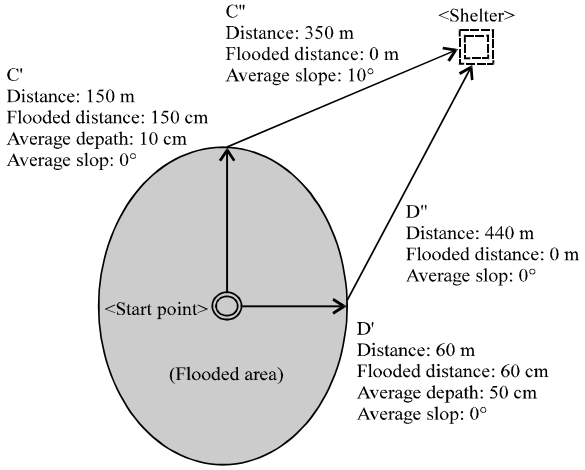

Fig. 5: Concept map of scenario 2

supposed to be the speed of 1.0 m/sec for ordinary adults and 0.5 m/sec for the aged and walking speed decrease rate with each gradient and depth was applied. Based on this point, evacuation travel time with the path of scenario 1 and 2 was estimated and the result are shown in Table 6.

Problems of selection criteria of evacuation route

Problems of evacuation distance and evacuation travel time: The current criteria of selection of evacuation route is shown in Table 2 and the evacuation distance is <1 km. Generally, it is estimated that walking speed of the aged is 0.5 m/sec and that of ordinaryadult is 1 m/sec. If it is set as 0.5 m/sec for the walking speed of the aged, it would be estimated that it would take >30 min for the aged to be evacuated. This value doesn't meet the evacuation travel time (<30 min) one of criteria of evacuation route selection. If the decrease of walking speed with gradient, depth and flow velocity were applied, the walking speed would more decrease and the evacuation travel time would increase.

Table 6: Prediction of evacuation travel time

	Evacuation travel time (second)	
Category	Ordinary adults	Elderly
Scenario 1		
A'-A"	656	1313
B'-B"	679	1357
Scenario 2		
C'-C"	610	1224
D'-D"	591	1178

Table 7: Walking time without resistance (TKT, 2000)

	Min (%)				
Ages	3	5	10	15	Average
Under 39	2	8	47	43	11.61
40~59	2	14	46	38	11.06
60~69	3	15	50	32	10.64
70~79	3	18	52	27	10.24
Over 80	10	35	40	15	8.30

Table 8: Instances of 2011 great East Japan earthquake (Yoon and Koh, 2015)

Category	Average evacuation speed	Evacuate with child or elderly	Average evacuation distance	Average evacuation travel time
Contents	0.64 m/sec	0.52 m/sec	438 m	11.2 min

As shown in Table 6, total distance of each evacuation route is 500 m but it took up to 1357 sec that is about 23 min for the aged to be evacuated. The flow velocity and wind velocity were not applied in this case if these factors applied, the travel time of the aged would be increase. If the current criteria of maximum 1 km was applied, therefore, it would not be estimated for the aged to be evacuated in 30 min. Moreover, it's hard for the aged to walk for a long time which was quantified in the preceding study results in Table 7 and 8. Among the real instances of 2011 great east Japan earthquake, the "Investigation report of the damage caused by tsunami of great east Japan earthquake (the 3rd report)" of "Ministry of land, infrastructure, transport and tourism" in Japan showed that average walking speed was 0.64 m/sec, the average distance to a shelter was 438 m and the average travel time to a shelter was 11.2 min (Yoon and Koh, 2015).

Problems of risk criteriaby considering flow velocity and inundation depth: In Korea currently, the information the analysis result of flood and inundation, flood travel time, inundation duration, flow velocity and risk was organized and utilized for making disaster information map. In case of setting the risk considering the possibility of evacuation, the risk was estimated by the criteria of flow velocity and depth (Table 8).

But the details of Table 9 and 10 are based on the instances of foreign countries so they don't reflect

Table 9: Standard of evacuation possibility by considering flow velocity and inundation depth

Flow velocity	Standard of evacuation possibility (adult)
Under 0.5 m/sec	When inundation depth is below than waist
0.5~1.5 m/sec	When inundation depth is below than knee
Over 1.5 m/sec	Difficulty to a safe evacuation

Table 10: Risk criteria by using flow velocity and inundation depth

Category	1.0≤h	0.5≤h<1.0	h<0.5
1.0≤V	1	2	3
0.5≤V<1.0	2	3	4
V<0.5	3	4	4

Korean pedestrian characteristics. The measurement result of walking speed with depth showed that the average speed at 50 cm depth was 1.27 m/sec slower than normal speed (1.43 m/sec) it was the result of healthy people with age 10-30 sec, so the walking speed would be estimated much slower for the case of the aged and children. It meant that the evacuation speed was influenced by body size in case of low depth but the deeper the depth, the bigger effect the physical capability had on the evacuation speed.

Moreover, if the flow velocity was considered, the walking speed would much decrease. Based on the result of this study, it is considered to be necessary to reset (to be lower) the criteria considering the possibility of evacuation.

CONCLUSION

This study was to draw the problems of the evacuation criteria during inundation based on the experiment result considering gradient, age and depth. The results showed that the evacuation criteria currently being enforced was set based on the foreign instances and didn't reflect Korean's pedestrian characteristics. The following problems were drawn. Considering the pedestrian characteristics of weak people of disaster and walking speed decrease with gradient, flow velocity and depth, it is considered to be hard for rapid evacuation due to being set <1 km of evacuation distance.

According to the criteria, the shelter is to be installed at the location within the distance of taking <30 min by road. So, it is estimated to be difficult for the aged having limit of pedestrian evacuation to be evacuated safely.

For the setting the risk considering the possibility of evacuation, it is considered to be needed to re-set the criteria (flow velocity→downward/depth→downward) in terms of pedestrian characteristics of weak people of disaster and walking speed decrease with gradient, flow velocity and depth. In the scenario of 4 different evacuation routes having different depth or gradient, there's difference of evacuation travel time even in the same distance and there's about 15% difference between maximum travel time and minimum travel time.

We investigated the factors affecting the evacuation in order to establish the best evacuation plan against inundation and analyzed the degree of effects of each factor with experiment result. Based on this we drawn the problems of current evacuation criteria in Korea, set the 4 different routes having different characteristics and estimated travel time for evacuation of each route. But there's a limit of that other factors except for gradient and depth were not analyzed. We consider the complement and further studies will be needed.

ACKNOWLEDGEMENT

This research was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (NRF-2015R1D1A1A01058785).

REFERENCES

Lee, H.K., W.H. Hong and Y.H. Lee, 2016. A study on the evacuation speed changes according to the depth of water. J. Archit. Inst. Korea Plann. Des., 32: 75-82.

Lee, J.S. and W.H. Hong, 2009. Upward evacuation experiment for estimating evacuation speed in water disaster?. Adv. Sci. Technol. Lett., 100: 97-101.

Lee, Y.H., J.S. Lee and W.H. Hong, 2014. An analysis on effect factor of weak person's pedestrian evacuation during urban flooding. Architectural Institute of Korea, Seoul, South Korea.

NDMI., 2013. A study on the revitalization for technology in evacuation and disaster relief. National Disaster Management Institute, New Delhi, India.

TKT., 2000. A study on considering transportation provided transportation abbreviation and facilities maintaennance instructions. The Korea Transport Institute, Jakarta, Indonesia.

Yoon, D. and J. Koh, 2015. Analysis of shelters acceptable range according to evacuation speed during flood disaster by severe rain storm. J. Korean Soc. Hazard Mitigation, 15: 115-123.

Youn, H.L., J.L. Soo and W.H. Hwa, 2016. A study on the possible evacuation distance for the elderly considering the slope in order to prepare for flood disaster. Adv. Sci. Technol. Lett., 124: 103-108.