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Evacuation performance of individuals in different visibility conditions

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ABSTRACT

Accurate data on evacuation activities are required under visually handicapped conditions to increase the certainty of the fire performance-based designs and evacuation calculation models. This study was to analyze human behavior characteristics and evacuation performance change through the experiments under evacuation environment where smoke influences visibility. The evacuation experiment was conducted in four different visibility conditions at underground facilities with 125 subjects. The individual evacuation activities of the subjects regarding the evacuation time, movement speed, way-finding and the evacuation routes were recorded and studied. Difference in visibility condition caused changes in evacuee's movement speed and travel distance. The change in visibility condition by indoor ordinary lights caused significant change only in movement speed on flat floors. However, the change in visibility by smoke caused significant change in travel distance as well as movement speed. These changes in evacuation performance were different, depending on the spatial characteristic.

1. Introduction

In the setting up of a building fire evacuation model as part of a performance-based design to pre-calculate the evacuation time needed for existing buildings, a virtual ignition point is selected for potential points with the greatest possibility of being an ignition point or a point from which a fire could cause the greatest damage. In the case of a fire where occupants are able to arrive at a safe exit and evacuation staircase, architectural design and predicting the evacuation time do not become a problem. But when a fire occurs at a point that can cause the greatest damage, occupants may have to move past the ignition floor with a high possibility to move against fire and smoke [1].

For large complex buildings, including skyscrapers and underground transportation facilities, the buildings will have large room capacities and long and complex pedestrian passages. Also, the entrances and exits of these buildings are divided or dispersed much more than in smaller or normal buildings. Due to the conditions of these large complex buildings and the fact that occupants do not use the nearest emergency exit in every case [2], some delay in the evacuation time may occur. Especially for the case of fire in underground transportation facilities such as subway stations, the moving direction of smoke is identical to the evacuation direction and evacuee often has to traverse in order to cross the floor and reach the exit staircases [3]. Due to these facts, it is likely that occupants could suffer risks when coming across such smoke related obstacles during evacuations.

Among the many uncertainties in an evacuation, evacuation behaviors under smoke filled stressful conditions are one of the difficulties in the evaluation of a fire performance-based evacuation design and in predicting the evacuation time of the evacuees. The uncertainties of the actual evacuation also cause a reliability issue on the evacuation simulations where an agent's movement is optimized. Accordingly, to increase the certainty of the fire performance-based designs and evacuation calculation models, accurate data on evacuation activities are required under visually handicapped conditions. Despite the extensive literature on quantifying human movement, few research projects have incorporated the differences of human physical abilities under these handicapped conditions into their studies. Jeon and Hong [1] and Kobes et al. [4] recently studied on occupant's movement when the visibility is decreased through the evacuation experiment. In the previous studies regarding evacuation, it has been suggested that the movement speed of the occupants varies according to the occupant's density [5], travel types [6,7], travel conditions [8,9], place types [10] and occupant characteristics [7,11]. Studies on the movement speed on staircase were conducted by Li [12] and Yeo and He [13], study by Shi et al. [14] offered the account of collected

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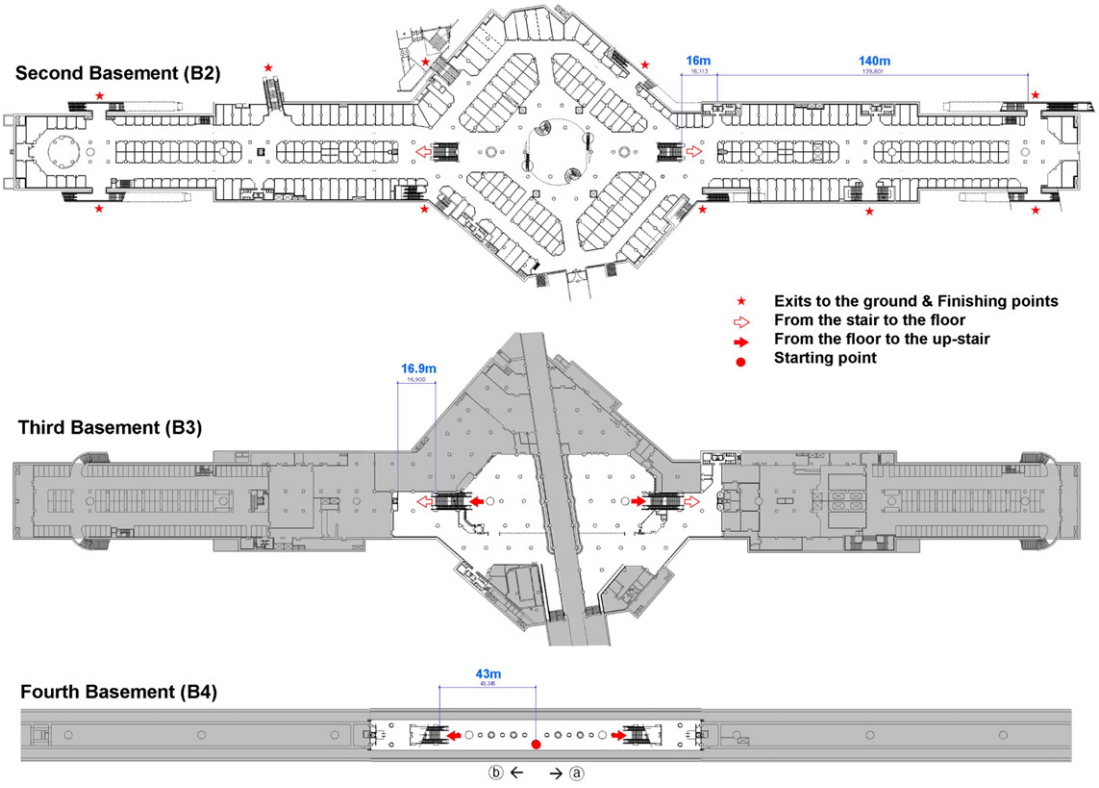

Fig. 1. Layout of Banwoldang underground facility.

data from the previous researches regarding the evacuation behavior and movement speed. While the many studies on the occupant's evacuation have been dominated by a focus on the movement speed, as noted above, the movement distance remains underresearched.

This study will discuss the characteristics and changes of evacuee's behavior under visually handicapped conditions due to smoke during the experimental study. The evacuation experiment was performed in underground complex transportation facilities. The individual evacuation activities of the 125 subjects were recorded and analyzed. The differences regarding the evacuation time, movement speed, evacuation routes and travel distance were studied with different visibility conditions. In addition, evacuee's subjective responses and acknowledgement of a guidance signs were partly addressed on the paper.

2. Evacuation experiment

2.1. Overview

An evacuation experiment was performed for three days in an underground transportation facility which featured four underground floors at different levels. All experiments were conducted from 0:00 to 05:30 without any subway activity. The test subjects were recruited from the people who have previous knowledge on this experiment. The subjects were selected with respect to sex, age, and physical conditions. After the experiment the subjects were asked to answer a survey on their evacuation experience.

The subjects start from the start point in Fig. 1 on the lowest 4th 2nd basement and evacuate to the exit on the ground level one at a time. To prevent people's behavior from being affected by others, subjects were started one by one at the start point. For each subject, a single recorder was given to each subject to record time and the passage they took. The subjects who spent over 30 min were forced to quit the experiment. In this case, only record up to the 30 min was analyzed.

2.2. Experiment facility

The experiment facility, Banwoldang underground facility, was located at the center of Daegu city in South Korea. This facility is a complex transportation building mainly used by the subway station. The Banwoldang facility is composed of subway station, an underground shopping mall and an underground passage and

Table 1
Conditions of evacuation experiment and visibility.

Experiment index	Environmental condition regarding evacuee's vision	Lighting	Transmissivity of the eye-patch	Smoke extinction coefficient [m^{-1}]	Visibility	Evacuation direction on B4[b]
Scenario 1	Normal	On	–	–	>20 m	a
Scenario 2	Light-out[a]	Off	–	–	>20 m	a
Scenario 3	Slight hindrance	Off	27%	0.13–0.26	5–10 m	a
Scenario 4	Heavy hindrance	Off	16%	0.26–0.60	3–7 m	b

[a] The emergency lighting system including the evacuation guidance and guidance signs was still operating in case of a light-out.
[b] The starting directions of the each evacuation on fourth basement are listed in Fig. 1.