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Evaluation of Escape Safety Depending on the Number of Users of Residential Convenience Facilities in the Apartment Complex and the Kind of Elevators

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Abstract

This study wants to provide basic data on effective escape safety plans when residents of apartment complex use residential convenience facilities. The findings of the analysis are as follows. First, when this study applied the actual number of users (No=54) of those facilities, the existence of elevator for escape reduced the escape time by 189.0 seconds. Second, when the number of users was calculated on the standard of the number of people who can be accommodated for performance based design (No=316), the existence of the elevator for escape reduced the escape time by 173.5 seconds. Finally, when the number of users was calculated on the standard of installing fire-fighting facilities (No=122), the existence of the elevator for escape reduced the escape time by 159.2 seconds. As a result, it was found that elevator for escape reduces the escape time from fire. Accordingly, it is necessary to revise the construction law to make it obligatory for residential convenience facilities to be equipped with elevator for escape. Currently, apartment buildings lower than 30 stories have either elevator for passengers or elevator for escape. Thus, in future studies, it is necessary to compare escape times in fire depending on the kinds of elevator, and identify the usefulness of elevator for escape.

Keywords: *Evaluation of Escape Safety, Apartment Complex,Residential Convenience Facilities, Elevator, pathfinder*

1. INTRODUCTION

Residence is the basic unit which makes it possible for humans to be able to live a stable and peaceful life, and the source of activity to soothe physiological and psychological fatigue and recharge energy for life [1].

Recently, improvement of income and living standards, reduction of labor hours, and the following increase of leisure time lead people to demand residential environment which is more pleasant to live, and which can improve quality of life [2].

Various leisure facilities of convenience facilities belonging to apartment housing have made it possible for many people to gather in a limited space, and, with various programs including collective exercise, to do community activities in convenience facilities near their residential areas without moving to far distances.

Recently, as buildings become bigger, higher, denser, and more mixed, it has become urgent to design anti-disaster facilities to secure safety of residents when disasters happen inside the building. In particular, old or handicapped people whose muscle powers are drastically reduced compared with other people have less abilities to cope with emergencies, and have difficulty moving by themselves. Thus, they can be called the

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vulnerable for disasters. Therefore, when a fire takes place in a building, what is the most important is to escape not only healthy common people, but those who cannot move freely to safer places. In order to do that, it is necessary to secure safe escape routes considering the conditions of all kinds of residents [3].

Analyzed the time needed in escaping from a fire in the case of 11-story apartment building where construction-related laws and rules are not applied. They considered 300 seconds after a fire starts in the case where the width of direct stairs is narrowed by obstacles piled on them and some people did not recognize the fire[4].

Investigated and analyzed the situations of installment of details of convenience facilities from the access route (walking road) to apartment buildings to unit houses [5].

Did experiment on flow rate on the bottleneck of escape stairs and compared modeling. Hwang pointed out that, when a fire occurs in a building, confluence of escapees on stairs is a very important element in interpreting escape from the fire. She performed experiments on confluence of escapees on stairs, and applied simulations, and compared the results. Based on such consciousness on problems, she made experiments and compared modeling on flow rates in case of the bottleneck situation [6].

Using the AHP technique, determined priorities of the escape scenarios by making weights of evaluation items and sub-items into indices to establish objective fire and escape scenarios, and compared appropriateness and danger of escape scenarios [7]. To improve safety against fire, examined the situations of safety related with fire-fighting and escape from fire, and analyzed consciousness of residents [8].

As apartment complexes need spaces to support hobby, culture, and leisure activities for residents and activate community consciousness through mutual contacts, people began to pay attention to community facilities installed in apartment complexes. In spite of the fact that community facilities in apartment complexes have emerged as an important element to provide comfortable residential environment, there are not enough researches on the dangers of width of escape stairs, and piled materials on stairs, confluence of people in the stairs, and consciousness of residents. Based on such perceptions on problems, this study aims to provide basic materials on effective programs to escape from disasters including fire by developing escape scenarios when various kinds of people use dense residential convenience facilities in a limited span of time.

2. COMPOSITION OF THE SCENARIO

2.1 Overview of the Structure

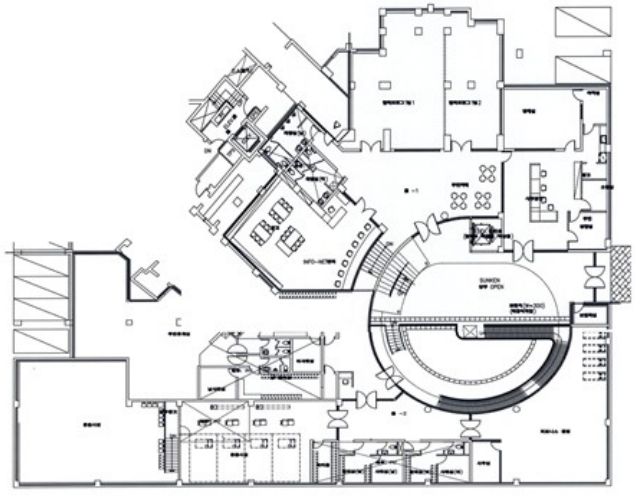

Figure 1. Ground plan of the structure

The target structure is an apartment complex. Assuming that a fire occurred in the residential convenience facilities located on the underground floor as shown in Figure 1. This place is near the underground parking lot, and many people come and go to the administration office of the apartment complex, library, and sports facilities. Sports facilities are located in the second and the first underground floors, and residential convenience facilities are in the first underground floor. Residential convenience facilities are connected horizontally to the underground parking lot. People can safely move to the first floor on the ground through the stairs.

This study analyzed the data considering that the elevator installed in the first underground floor could not be used in emergency. This study analyzed how those in the exercise facilities in the second and the first underground floors could escape to the ground floor.

2.2 The number of Persons to be Accommodated in the Structure

As shown in Table 1, the fitness club in the first underground floor usually accommodate 15~20 persons. Users usually use the facility as groups. Exercise facility B in the first underground floor is table tennis court. There are 4 tables. Users usually use the facility as family units. There is usually 8~10 persons in the facility. The library in the same floor is used by infants accompanied by their protectors and primary school students. There is usually 15~20 persons in the library.

Table 1. The number of persons to be accommodated

Use	Area (m^2)	No of actually using persons		Life safety standard			Fire protection standard		
				m^2/person	No of persons		m^2/person	No of persons	
Indoor tennis court	121.8	4	old: 0	1.4	87	old: 9	4.6	27	old: 3
			adult:3			adult:61			adult:19
			child:1			child:13			child:4
			disabled:0			disabled:4			disabled:1
Table tennis court	155.73	10	old: 1	1.4	112	old: 11	4.6	34	old: 3
			adult:7			adult:78			adult:24
			child:1			child:17			child:5
			disabled:1			disabled:5			disabled:2
Fitness club	34.73	20	old: 2	1.4	97	old: 10	4.6	30	old: 3
			adult:14			adult:67			adult:22
			child:3			child:15			child:5
			disabled:1			disabled:5			disabled:2
Library	91.2	20	old: 2	4.6	20	old: 2	3	31	old: 12
			adult:14			adult:14			adult:22
			child:3			child:3			child51
			disabled:1			disabled:1			disabled:2
Sum	503.46	54	old: 5	-	316	old: 32	-	122	old: 12
			adult:38			adult:220			adult:84
			child:8			child:47			child:19
			disabled:3			disabled:15			disabled:7

The second underground floor is indoor tennis court. It is usually used by 2~4 persons. Thus, in total, this study assumed that 54 persons at maximum use the sports and other facilities in the underground floors. Residential convenience facilities are frequently used as family units, and there are infants and children, old people, and handicapped people. This study assumed that the proportion of users is 70% adults, 25 % children and old people, and 5% handicapped people. The standards of the area per person for fire-fighting purpose are as follows: 4.6 m^2/person for the sports facilities like indoor tennis court, table tennis court, and fitness club; 3 m^2/person for other fire-fighting objects including library.

The floor area of each facility is as follows: 121.8 m^2 for the indoor tennis court; 155.73 m^2 for the table tennis court; 134.73 m^2 for the fitness club; 91.2 m^2 for the library. The number of persons to be accommodated in each facility is as follows: 4 persons for the indoor tennis court; 10 persons for the table tennis court; 20 persons for the fitness club; 20 persons for the library [9].

On the other hand, according to the human safety standards in the performance-based design (PBD), the number of persons to be accommodated in each facility is as follows: 1.4 m^2/person for leisure sports facilities like indoor tennis court, table tennis court, and fitness club. Thus, each facility can accommodate 87 persons, 112 persons, 97 persons, respectively. In total, those 3 facilities can accommodate 296 persons. The library can accommodate 20 persons considering that it allows 4.6 m^2/person.

3. SCENARIO AND VARIABLES

3.1 Scenario

Sports facilities in the first underground floor are indoor tennis court, table tennis court, and fitness club. The number of persons who actually use those facilities is 54, and the number of persons life safety standards are applied for PBD is 316, and the number of persons when fire-fighting facility installment standards are applied depending on the size of specific fire-fighting objects is 122. When compared with the allowed number of persons life safety standards are applied, the actual numbers of persons using indoor tennis court, table tennis court, and fitness club were much small.

Table 2. Composition of scenarios

	No of persons	Kind of elevator	Escape route
Scenario 1	54	Elevator for passengers	Without using the elevator for passengers, people escape to the ground floor using the slope for cars.
Scenario 2	54	Elevator for escape	People escape to the ground floor using the elevator for escape.
Scenario 3	316	Elevator for passengers	Without using the elevator for passengers, people escape to the ground floor using the slope for cars.
Scenario 4	316	Elevator for escape	People escape to the ground floor using the elevator for escape,
Scenario 5	122	Elevator for passengers	Without using the elevator for passengers, people escape to the ground floor using the slope for cars.
Scenario 6	122	Elevator for escape	People escape to the ground floor using the elevator for escape,

Scenario 1 is the situation where 54 persons who actually use those facilities escape using the slope.

Scenario 2 is the simulation where 54 persons use the elevator assuming that the elevator for passengers is replaced by elevator for escape.

Scenario 3 is the simulation where 316 persons allowed when life safety standards are applied for PBD use elevator for passengers.

Scenario 4 is the simulation where 316 persons use the elevator for escape.

Scenario 5 is the simulation where 122 persons applying fire-fighting facility installment standards depending on the size of specific fire-fighting objects use elevator for passengers.

Scenario 6 is the simulation where 122 persons use the elevator for escape.

3.2 Characteristics of the Users of Facilities

As shown in Table 3, users are composed of child, old person, adult, and wheel chair user. The height and the shoulder width of child are the average scores for male and female children from 8 to 13 years old. The height and the shoulder width of adult are the average scores for male and female adults from 30 to 50 years old. Those of the old are the average scores for male and female old people from 60 to 69 years old.

Those who use the pathfinder program were classified into child, adult, and old [10,11] depending on height, and shoulder width among body sizes. Gait speed was inserted by referring to related data. Gait speed for wheel chair users was also inserted by referring to related data.

Table 3. Gait speed and body sizes of users

Composition of users	Gait speed (m/s)	Height (mm)	Shoulder width (mm)
Child	0.77[12]	1,419	307
Old	0.92[13]	1,584	365
Adult	1.19[14]	1,649	376
Wheel chair user	0.71[15]	-	-

4. RESULTS AND DISCUSSION

4.1 Scenario 1

As shown in Figure 2, in scenario 1 where people could not use elevator, the routes people in different facilities to escape from the fire were as follows: those in the indoor tennis court went through table tennis court, and used the slope for cars; those in the table tennis court and fitness club could use the corridor installed in the first underground floor. Those in the library could use the exit for the library, and it took shorter time to escape than others. The time spent for all the people to escape was 348.8 seconds.

Wheel chair users who could not use the stairs had no choice but to use the slope, and took long time to escape.

Figure 2. The time spent for people to escape in Scenario 1

4.2 Scenario 2

As shown in Figure 3, 54 people used the elevator for escape. Those in the indoor tennis court went through the table tennis court, and through the corridor, arrived at the elevator. The distance from the library to the exit was not far. So, those in the library took shorter time to escape than others. In addition, wheel chair users could shorten the time to escape because they could use the elevator for escape. The time spent for all users to escape was 159.8 seconds.

Figure 3. The time spent for people to escape in Scenario 2

4.3 Scenario 3

Scenario 3 assumed that 316 persons were using the underground facilities. They could not use the elevator for passengers. As shown in Figure 4, those in the indoor tennis court passed through the table tennis court, the parking lot, and the slope to escape. Those in the table tennis court and the fitness club went through the corridor. a number of people who needed to escape caused the phenomenon of bottleneck, lengthening the time spent to escape. The time spent to escape for all the users was 778.0 seconds.

Figure 4. The time spent for people to escape in Scenario 3

4.4 Scenario 4

Scenario 4 assumed that 316 persons were using the underground facilities. They could use the elevator for escape. As shown in Figure 5, while they could use the elevator for escape, the situation in which many persons had to escape at the same time caused the bottleneck phenomenon, lengthening the time spent for escape. In total, 604.5 seconds were spent for everybody to escape from the underground.

Figure 5. The time spent for people to escape in Scenario 4

4.5 Scenario 5

Scenario 5 assumed that 122 persons were using the underground facilities. They could not use the elevator for escape. As shown in Figure 6, those in the indoor tennis court passed through the table tennis court, the parking lot, and the slope to escape. Those in the table tennis court and the fitness club went through the corridor. The distance from the library to the ext was not far. So, those in the library took shorter time to escape than others. In total, 405.5 seconds were spent for everybody to escape from the underground.

Figure 6. The time spent for people to escape in Scenario 5

4.6 Scenario 6

Scenario 6 assumed that 122 persons were using the underground facilities. They could use the elevator for escape. In total, 246.3 seconds were spent for everybody to escape from the underground.

Figure 7. The time spent to escape in Scenario 6

4.7 Comparative Aanalysis of Scenarios

As shown in Table 4, Scenario 1 and Scenario 2 assumed that the number of users was 54. It was found that, when the elevator for escape was used, the time spent for escape was shortened by 189.0 seconds. Scenario 3 and Scenario 4 assumed that the number of users was 316 seconds. Using the elevator for escape shortened the time spent by 173.5 seconds. Scenario 5 and Scenario 6 assumed that the number of users was 122 seconds. Using the elevator for escape shortened the time spent by 159.2 seconds.

Table 4. Comparison of scenarios

	NO of users	Time spent to escape	Difference in time spent
Scenario 1	54	348.8	189.0
Scenario 2	54	159.8	
Scenario 3	316	778.0	173.5
Scenario 4	316	604.5	
Scenario 5	122	405.5	159.2
Scenario 6	122	246.3	

As described above, Using the elevator for escape instead of using stairs or slope shortened the time spent for escape on all the scenarios. When the number of users of the underground facilities was the smallest, the

difference of time spent between the case where there was the elevator for escape and the case where there was not was the largest (189.0 seconds). The reason can be found that the width of stairs and the slope was 1.5 m which caused the bottleneck phenomenon lengthening the time spent to escape. In addition, there was only one exit, which worsened the bottleneck phenomenon.

5. CONCLUSION

The aim of this study is to provide basic material on effective and rational escape plans when various kinds of people use residential convenience facilities in apartment complexes. The findings of the analysis are as follows. First, when the times spent to escape were compared between the case where the elevator for escape was installed and the case where it was not installed, in the situation where actual number of users (54) used the underground facilities, the difference was 189.0 seconds.

Next, when the number of users was calculated on the standard of the number of people who can be accommodated for performance-based design, the existence of the elevator for escape reduced the escape time by 173.5 seconds.

Finally, when the number of users was calculated on the standard of installing fire-fighting facilities, the existence of the elevator for escape reduced the escape time by 159.2 seconds.

In summary, it was found that installation of elevator for escape affects the escape from fire to a great degree in residential convenience facilities in apartment complexes. Currently, residential convenience facilities in apartment complexes are not required to install elevator for escape. But, as those facilities are accessible to the mobility handicapped accompanied by their protectors, it is necessary to make it obligatory to install elevator for escape in residential convenience facilities in apartment complexes by revising the construction law.

Based on the above findings, this study suggests the followings. First, it recommends that all residential convenience facilities be equipped with elevator for escape. While the current law requires tall buildings which are 30 stories or over or 120m high or over to install elevator for escape, it is necessary to revise the law to make residential convenience facilities be equipped with elevator for escape, because those facilities are linked with residence [16]. Second, this study suggests that the width of stairs and slope for cars be enlarged to reduce the bottleneck phenomenon. Third, it is necessary to disperse movement routes. It is desirable to design two or more escape routes in different directions to make users of those facilities walk smoothly [17]. As future research projects, it seems necessary to do researches in comparing the time spent in escape from fire in the case where elevator for escape is installed and the case where such an elevator is not installed for apartment buildings with lower than 30 stories. Such researches will be useful to check whether such an elevator is crucial if fire occurs.

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