한국화재소방학회, 제23권 제4호, 2009년
[논 문]

J. of Korean Institute of Fire Sci. & Eng.
Vol. 23, No. 4, 2009

대규모 위락시설의 피난안전성능 평가에 관한 연구

A Study on Safety Assessment of the Evacuation at the Large-scale Amusement Facilities

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(2009. 7. 23. 접수/2009. 8. 7. 채택)

요 약

성능위주의 설계가 법제화 되면서 화재 및 피난에 대한 연구가 활발히 진행 중이다. 성능위주설계는 인명의 안전성을 증대 시키는 방향으로 발전되어야 한다. 또한, 성능위주의 설계는 소방분야뿐만 아니라 건축법령에서 정하고 있는 피난에 관한 규정을 포함하여 검토되어야 한다. 본 논문은 성능위주의 설계 시 참고가 될 자료로 제시하기위해 다중이용시설인 광주광역시의 OO나이트클럽을 하나의 모델로 삼아 피난시간을 예측하였다. 이를 위해 우리나라와 외국의 피난에 관련된 규정과 연구논문들을 검토하고, 현장을 방문하여 자료를 수집하였다. 그리고 수집된 자료들을 피난프로그램인 Simulex의 입력 자료로 사용하여 피난시간을 측정하였다. 이 연구의 검토과정 및 결과에서 몇 가지 문제시되는 사항을 발견할 수 있었다.

ABSTRACT

As the Performance Based Fire Protection Design is legislated, studies on a fire and evacuation are actively in progress. The Performance Based Fire Protection Design should be developed toward enlarging the Life safety. In addition, the Performance Based Fire Protection Design shall not merely review the aspects of fire fighting but it shall also include regulations pertaining to evacuation stipulated in laws and regulations for buildings. This study performed an evacuation time prediction based on OO Night Club, one of the multiplex use facilities located in Gwang-ju Metropolitan City in order to suggest as a referential data for the Performance Based Fire Protection Design implementation. To do this, I investigated domestic and foreign regulations and research papers related to evacuation and went to visit the actual site and collected materials. The collected data was then used as ones to input in Simulex, an evacuation program to measure evacuation time. The collected data was then used as data to input in Simulex, an evacuation program to measure evacuation time. Through this particular research and results, the study was able to suggest a few concerning areas.

Key words : Performance based fire protection design, Simulex, Multiplex use facility, Walking characteristics, Evacuation

1. Introduction

1.1 Background and Purpose of Study

As an economy gets developed more and is more stable, a requirement to safety gets bigger. It is a good example that even advanced countries spend much money on the protection of life and safety of people. However, characteristic of modern social building shows an aspect of Manhattanization, scale-up and sophistication. This tendency comes to have a difficulty in security of safety for indoor residents from a fire comparing to existing buildings, as persons to hold indoors get increased from wider indoor space comparing to existing ones and many electromagnetic devices are used from automation for user's convenience. According to this, when recently

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Table 1. Main Fires of Amusement Liquor Stores (Nightclub)[2] (Unit: person)

Date of Incident	Nation	City	Damage of Life
Feb, 22, 2003	U.S.	Rhode Island	Death: 98, Injured: 150
Dec, 30, 2004	Argentina	Buenos Aires	Death: 174
Feb, 17, 2007	U.S.	Chicago	Death: 20
Apr, 19, 2008	Equador	Quito	Death: 15, Injured: 35
Aug, 24, 2008	S. Korea	Seoul	Death: 3 (Fire Fighter)
Oct, 11, 2008	China	Shenzhen	Death 43, Injured 88

constructing new large-scale building, a building project to consider has been carried out an evacuation circulation from a design stage but due to a limit of architectural design and administration, a substantial investigation for evacuation safety cannot be made now. Therefore, it is difficult to accurately reflect characteristics of occupants and the number of residents who reside really according to usage of building. So, an establishment of evacuation plan which divides minutely characteristic of building and is proper to evacuation property of occupants is an indispensable requisite. Preparing for this situation, it is appointed in 2009 that it is possible to make a design based on performance in Item 2, Article 11, 「Construction for Fire Facility Act (No. 7660, Law, revision, Aug, 04, 2005)」 among laws related fire.[1] Facility to have density of residence and much damage from fire for building is an amusement facility. Character is of these facilities is that a density of residence is high and movement of behavior for residents may be low comparing to normal persons. A nightclub among amusement facilities is high in density of residence and holds a possibility for many life damages. Actually main example for fire of nightclub is shown like Table 1.

I think that it is important to investigate a prediction time for evacuation, present a method to increase safety for evacuation and prepare for a method to decrease damage of life by coming true more improved evacuation in danger like a fire with a nightclub among amusement facilities to hold danger of large-scale life damage like this.

1.2 Trend of R & D (Research and Development)

Prior to executing a performance based design, an experiment for a situation of fires and evacuations to develop and supply a program and use a program already developed in private sector. Particularly, materials of the U.S and Japan which already have executed a performance based design are used much and then in Korea a supply for data possible to use is required. Existing study papers related to them are shown in Table 2.

1.3 Scope and Method of Research

If, in a nightclub* among liquor stores which is leisure and entertainment facility, due to high density of population per area and characteristic of occupants, in firing, security for evacuation and smooth command is not made, it can connect to many damages of life. So, a measurement for this is required. Even, in the nightclub, seeing characteristic of occupants, as most people are drunk, their walking speed is slow comparing to them of buildings with other common usage and their behaviors may be restricted sometimes. Accordingly, an education about safety measurement for occupants to prepare for a fire and dangerous situation to employees is necessary and regular inspection is required. Thus, as modeled after OO nightclub now operating, this paper compares theoretical number of occupants with real number of occupants, investigates an evacuation time of occupants, checks out an evacuation safety and reduces an evacuation time, it would find a method to increase safety of occupants.

The method for research is that after comparing Korean evacuation regulations with U.S, this research investigated evacuation regulations related to buildings of other countries, confirmed standard of life safety in advanced countries which have made performance

* It comes under an operation of amusement liquor store, Item D, Article 7~8, Enforcement Decree of the Food Sanitation Act.

Table 2. Domestic Studies Related to Evacuation[3-10]

Researcher	Topics for Research	Contents of Research
Mi Kyoung Kim, and others (2001)	Regulation of evacuation design in Japan	A method for evacuation verification to first introduce in Japan is described and compared of contents in U.S.
Sun Wook Kwon (2001)	Study about evacuation plan according to evacuation time by ages	Modeled after 4 schools and 1 building, it is studied about influence of evacuation time according to human body index, calculating an evacuation time.
Jae Sung Park and others (2002)	Comparative study of standards between nations about evacuation safety of building	It compares evacuation regulations in U.S, Japan, England and Korea and proposes improvements of evacuation regulation in Korea.
Jae Sung Park (2004)	Study about evacuation prediction model considering evacuation behavior in firing an building	It studies human evacuation behavior in firing building and an influence which human behavior has on evacuation time in evacuating.
Woon Hyoung Kim, and others (2004)	Analysis of time which model, Simulex starts to evacuate	It recognizes that a difference of time to take evacuation occurs according to change of evacuation initiation time with examples of open space, theater and large-scale store using an evacuation simulation.
Sung Yeop Rho, and others (2005)	Study about assessment for performance of evacuation safety of multiplex	Modeled after two multiplex, it investigates a quantitative evacuation time in Japan and the one of Simulex program and proposes their problems.
Dae Hee Kim, and others (2007)	Study tendency related to evacuation of building and study about its characteristic	It introduces and compares study tendency related to evacuation of building in U.S., Japan and Korea and proposes problems of Korean Building Act.
Eun Kyoung Hwang, and others (2007)	Study about setting an improvement direction of laws through analysis of problems between evacuation regulations of building	It deduces problems to be found as Korean laws related to evacuation is divided into Building Act and fire-fighting act and proposes an improvement direction.
Moo Hun Jeong, and others (2008)	Assessment of an evacuation safety through evacuation training and simulation at school building	Assuming a fire situation at a rest room in OO high school in Cheongju, using a fire simulation, it analyzes fire characteristics, carries out real evacuation training and compares it with materials to use an evacuation simulation.

based design about contents to influence an evacuation behaviors as items to be considered in evacuating, and criteria related to human behaviors in evacuating, and, selecting one model, with Simulex program, it measured theoretical evacuation time of occupants and real one but considering property of usage, real evacuation time of occupants was measured by maximum of occupants. Besides, investigating an effect of improving an evacuation time by change of building structure and change of an evacuation direction, this paper would propose the most effective method in improvement of evacuation.

2. Characteristic of Evacuation Model

2.1 Positional Characteristic

Use of an object to use in investigating evacuation performance is a leisure and amusement facility on division of building and a nightclub among amusement liquor stores which is a facility for crowd use business regulated in fire laws. Positional characteristic and rough contents of building are like Table 3.

2.2 Present Situation of Installation of Fire Facility

Present situation of installing fire facilities is like

Table 3. Positional Characteristic and Rough Contents of Building

Position of Object	Located in a commercial district of Gwangju Metropolitan City and within 1km radius from 119 safety center.
Summary of Floors	It is corresponded to first and second floors above ground for 4 stories above ground and one below.
Area of Business Place	Total: 2,323m^2, First Floor: 1,558m^2, Second Floor: 765m^2
No. of Evacuation Stairs (Direct Stairs)	Two (main stair: width of stair 280cm, assistant stair: width of stair 130cm)

Table 4. Present Situation of Installing Fire Facility

Fire Facility	Present Situation of Installation
Suppression System	Fire Extinguisher, Indoor Hydrant, Sprinkler, Carbon Dioxide Fire Extinguisher
Alarm System	Emergency Broadcasting Facility, Automatic Fire Detection Facility
Evacuation Facility	Exit Light, Emergency Lighting
Fire Fighting Facility	Smoke Control System
Water for Fire-fighting Facility	Water for Fire-fighting Facility of Water Supply

Table 5. Present Situation of One-day Occupants of OO Nightclub

Day / Month of Standard	Mon	Tue	Wed	Thu	Fri	Sat	Sun	No. of Employees
August	500	1,200	1,400	1,600	1,800	2,000	2,100	40
December	700	1,400	1,700	2,000	2,200	2,500	2,800	60

Table 4. As fire facilities are applied by the permission date of objects for fire-fighting and the starting date of business, there is more or less different part from current laws related to fire-fighting like Sight Alarm.

2.3 Present Situation of Number of Occupants

The number of occupants was written with an average value by a business situation from 2004 to 2007 and the standard was December in which customers are the most and August in which customers are the fewest. Their contents are like Table 5.

As shown in Table 5, it is known that the number of occupants is different by days and it is investigated that as the rate of male and female for customers is 40% of male and 60% of female, females are a bit more.

2.4 Characteristic of Evacuation of Occupants

Age range of occupants were most from late 20's to middle 40's and it is known that as over 60% of occupants were drunk, their walking speed, movement by evacuation is low comparing to general people. Due to danger of an accident on characteristic of use, as a situation of emergency cannot be revived, an accurate measurement was difficult, and according to a condition to have watched people go out the nightclub during two hours from 10p.m. to 12p.m. on Sunday, late September, a case to get out an exit and in no time go down evacuation floor was rare and because of chatting between company or small physical contact, normal walking speed was to hard to measure, but for them, people within a range of normal walking was 150 persons for male and 170 persons for female, a walking speed including pathway and stairs was shown as 0.3~0.8m/sec(average 0.6m/sec) for male and female was 0.3~0.7m/sec(average 0.55m/sec) and was shown that there was little difference comparing to male. This result is shown as the one to have much difference comparing to "Free walking speed by age and sex of Korean",[11] studied by Sang Deok Han and a walking speed, 1.4m/sec for pathway and 0.7m/sec for stairs, research materials of Fruin,[12] but considering about 80% of evacuation traffic line of object was carried

out by stairs, it is shown that a walking speed by characteristic of occupants was reduced by about 20% comparing to people of normal state.

3. Investigation and Analysis of Evacuation Model

3.1 Theoretical Evacuation Time of Occupants

In calculating theoretical evacuation of previously described model, some prerequisites to consider are like follows:

First, objects for evacuation are distributed evenly indoor prior to evacuation.

Second, evacuation is initiated unanimously.

Third, evacuee evacuates through decided evacuation pathway.

Forth, a walking speed of evacuee is regular and to pass and to come back toward reverse direction are none.

Fifth, crowd is regulated by width like an exit.

Sixth, in case of diverse exits, if there is no special use, they evacuate to a near exit.

And, a quantitative evaluation of this living room by "New guideline for design of protecting disaster in building"[13] is like Table 6.

In the living room's permitted evacuation time, average height of floor of first floor is over 6m and $3\sqrt{A}$ is made. Like this, if calculating by a method of 'New guideline for design of protecting disaster in building" of Japan, it is confirmed that there is a problem in a method for evacuation evaluation. With Korean present laws not to have regulations of evacuation facility by the number of persons to be admitted, in living rooms for use to be high in density of population like amusement facility or assembly facility, by the above formula, a probability to occur problems is high. This object is also an average 1.59m^2/person and higher density about 6 times comparing to a library. Hence, despite use of the above standard as reference, performance based design is not carried out yet in Korea, and when considering that as ten years has passed since this object was planned and sprinkler and smoke control facility among fire facilities are installed, control of smoke is possible for regular time (over 20minutes), it is judged that the above calculated 290seconds (4minutes and 40seconds) are very fine time, for this object, reflecting given field circumstances, an evacuation time of this building will be investigated making it an aim to finish an evacuation time first within 20minutes (1,200sec) and then I would find out an improvement method and propose it.

3.2 Analysis of Result for Evacuation Model

Based on the result to predict a real evacuation time and predict an evacuation time according to an improvement for evacuation requisites, arrangement of 5-times experimental materials is like Table 7.

In Table 7, it is known how a homing instinct, a form

Table 6. Investigation Items for Evacuation from Living Room

Item for Calculation	Second Story	First Story
Area of Living Room	765m^2	1,558m^2
No. of Objects for Evacuation	300persons	1,260persons
Sum of Width of Living Room's Door	1.2 + 1.0 = 2.2m	1.9 + 1.0 = 2.9m
Sum of Width of Evacuation Door	1.2 + 1.0 = 2.2m	1.9 + 1.0 = 2.9m
Time to pass an Exit, T11(sec)	$T11 = \frac{300}{1.5 \times 2.2} = 90.91$sec	$T11 = \frac{1,260}{1.5 \times 2.9} = 289.66$sec
Indoor Walking Time, T12(sec)	$T12 = \frac{35 + 17}{0.7} = 74.29$sec	$T12 = \frac{44 + 22}{0.7} = 94.29$sec
Living Room's Evacuation Time, T1(sec)	T1 = 90.91sec	T1 = 289.66sec
Living Room's Permitted Evacuation Time, γT1(sec)	$\gamma T1c = 2\sqrt{765} = 55.32$sec	$\gamma T1 = 3\sqrt{1558} = 118.41$sec
Evaluation	Due to T1 ≥ γT1, incongruent	Due to T1 ≥ γT1, incongruent

Table 7. Comparison of Evacuation Time

Division		First	Second	Third	Forth	Fifth
Condition		Application of homing instinct	Decentralization of evacuation route (reflecting width of stairs), Control of some parts for indoor stairs	Decentralization of evacuation route (reflecting evacuation time), Complete control for indoor stairs	Decentralization of evacuation route, Complete control for indoor stairs, complement of inside of building	Decentralization of evacuation route, Control of some parts for indoor stairs, Additional installation of evacuation route
Total occupants 1,460 persons		Main Stairs: 1,320 persons Assistant Stairs: 140 persons	Main Stairs: 870 persons Assistant Stairs: 590 persons	Main Stairs: 760 persons Assistant Stairs: 700 persons	Main Stairs: 760 persons Assistant Stairs: 700 persons	Main Stairs: 540 persons Assistant Stairs: 500 persons New Stairs: 420 persons
No. of Occupants	1 minutes	1,421 persons	1,428 persons	1,428 persons	1,421 persons	1,397 persons
	2 minutes	1,323 persons	1,326 persons	1,330 persons	1,320 persons	1,260 persons
	3 minutes	1,257 persons	1,229 persons	1,227 persons	1,229 persons	1,115 persons
	4 minutes	1,205 persons	1,128 persons	1,122 persons	1,126 persons	971 persons
	5 minutes	1,152 persons	1,023 persons	1,019 persons	1,023 persons	835 persons
	6 minutes	1,100 persons	934 persons	912 persons	924 persons	696 persons
	7 minutes	1,054 persons	845 persons	815 persons	822 persons	543 persons
	8 minutes	1,003 persons	754 persons	717 persons	719 persons	412 persons
	9 minutes	949 persons	654 persons	621 persons	625 persons	272 persons
	10 minutes	905 persons	563 persons	527 persons	526 persons	139 persons
	11 minutes	845 persons	466 persons	433 persons	432 persons	33 persons
	12 minutes	799 persons	375 persons	340 persons	338 persons	0 person
	13 minutes	746 persons	279 persons	242 persons	256 persons	0 person
	14 minutes	692 persons	207 persons	156 persons	147 persons	0 person
	15 minutes	644 persons	155 persons	54 persons	41 persons	0 person
	16 minutes	594 persons	103 persons	0 person	0 person	0 person
	17 minutes	536 persons	57 persons	0 person	0 person	0 person
	18 minutes	461 persons	6 persons	0 person	0 person	0 person
	19 minutes	411 persons	0 person	0 person	0 person	0 person
	20 minutes	361 persons	0 person	0 person	0 person	0 person
Time required for Evacuation		27minutes 25seconds	18minutes 15seconds	15minutes 56seconds	15minutes 25seconds	11minutes 45seconds

in which we behave daily works unfavorably in evacuating on a fire or danger. According to result of materials, on applying a homing instinct in evacuation, it is known that as many as 361persons cannot finish their evacuation within 20minutes. However, as this 20-minute, setting an input value of program as response time is set as 1second, is not nearly given a time lag of response and does not consider obstacle factor of evacuation movement by thermal and non-thermal phenomenon to occur in firing, if considering that an evacuation time of 20minutes is more one than in real fire, it is thought that damages of life from failure of evacuation will increase much more. The summary of contents of Table 7 is like follows:

3.2.1 In Applying Evacuation Behavior in Common State

As mentioned previously, a homing instinct, a propensity to go back where he came and a daily circulation directivity which he would go where he has gone in normal times can occur much damage in evacuation behaviors. As shown in Table 7, the number of people who did not finish an evacuation within 20minutes is 361 persons, and it is shown that it reaches about 25% of all occupants. To relieve this human psychological tendency and do smooth evacuation, through repetitively carrying out an education and training for the people to know well internal affairs like person concerned or employees in normal times, and make them own ability to control occupants, in occurring a danger, safe evacuation of occupants should be improved.

3.2.2 Control of Occupants (Decentralization of Evacuation People Considering Width of Evacuation Route)

As relieving homing instinct and daily circulation directivity and imagining a control by an education for employees, an evacuation is designed. At this time, because width of evacuation route of direct stairs is different, it is decentralized into 60% for people to evacuate by means of wide stairs (280cm) of evacuation route, and 40% for people to evacuate by means of narrow stairs (130cm) of evacuation route. Total evacuation time from this is 18minutes and 15seconds, reduced effect of evacuation time of as much as 9minutes and 10seconds comparing to an evacuation by instinct occurred and as evacuation of all occupants was possible within 19minutes, it is known that performance of evacuation safety elevated. However, considering recognizing time of a fire and a response time lag of occupants, it is necessary for a method to reduce an evacuation time more.

3.2.3 Control of Occupants (Decentralization of Evacuation People Considering Evacuation Time)

By decentralization of evacuation people, performance of evacuation is improved, but because a difference of time to finish evacuation at exit of it is big, to improve this, people, according to evacuation time, are decentralized. Accordingly, with evacuation people 56% in main stairs and 48% in assistant stairs, a program was implemented, an effect of improvement for evacuation time from this was added 2minutes and 19seconds, and as total evacuation time was 15minutes and 56seconds, it is confirmed that evacuation safety is considerably improved. In addition, it is important to confirm an improvement effect by change of inner structure of building and find an effective improvement method.

3.2.4 Control of Occupants and Improvement of Indoor Evacuation

It is confirmed that an evacuation effect to decentralize evacuation people considering evacuation time, and additionally it is confirmed of an effect of evacuation improvement by measurement for enlargement of width of pathway in assistant stairs of first floor which density was high in evacuation and an improvement of evacuation circulation in second floor but an effect of improvement is only 31 seconds and a difference of evacuation people by passing a time per minute is nearly few. Considering width of pathway by the number of persons to be admitted, a standard of the U.S., the Great Britain and Japan, inner structure was improved as possible but it is shown that in this experiment its effect is little. That, on walking characteristic of occupants, walking speed is late might be shown as this result. During implementing the program, a time for congestion in assistant stairs was much, but consequently it is confirmed that evacuation time of final evacuee was longer in main stairs. Of course, in a situation which a life is urgent, 31seconds can be enormous time. But, after seeking more effective measurement, it should be determined whether to adopt this condition. Hence, for the next, it is thought to be important to investigate that an enlargement of evacuation stairs influences into evacuation.

3.2.5 Additional Installation of Evacuation Pathway and Evacuation Exit

In the U.S and the Great Britain, considering that the number of evacuation route by the number of persons to be admitted is regulated (in the U.S, 4 routes for over 1,000persons and in the Great Britain, 4 routes for below 2,000persons),[14-16] in a side of stage, a place which does not reach a standard of those countries but a density of occupants is high and is located at opposite

direction to existing evacuation routes, an evacuation pathway and evacuation exit are additionally installed and occupants possible to use each evacuation exit are decentralized again. Hereupon, with evacuation people 540persons (37%) in main stairs, 500persons (34%) in assistant stairs and 420persons (29%) in new installed evacuation stairs, the program was implemented and its results are shown that as total evacuation time was 11minutes and 45seconds, a considerable effect was made. Of course, as 20minutes presented as a time possible for evacuation are a time to consider a condition of field, it cannot be known whether to use it as a time possible for evacuation in real fire. However, for the CFAST, a fire program, it is said to be difficult to apply it in large-scale room over 1,000m^3.[17] It is thought because credibility to temperature and characteristic of smoke gets low due to diverse variations in large room. I, the researcher, also, as result value to use CFAST to this object is impossible to apply, excluded materials in this part. It cannot deny that credibility to a fire simulation and a process of fire diffusion also are much different from a situation to occur real fire. Besides, between evacuation time by evacuation simulation and evacuation time in real fire condition, a difference may be exist as well. But, something obvious is that at the result of five times implementation, a difference of evacuation happened and also it is confirmed that such difference is also big. In addition, operation parts including control by evacuation education has tremendously big effect in improving evacuation time rather than in facility side like building structure. It cannot emphasize that an education for danger like fire-fighting and evacuation is directly connected to relief of life, too much.

4. Conclusion

In the middle of process of 'Study about evaluation for evacuation safety of large-scale amusement facility' studied as a beginning of damages of precious lives from a fire in a nightclub sometimes ago, I come to know that Korean evacuation regulations have some problems comparing to foreign regulations.

First, in Korea, contents related to evacuation are mainly regulated in acts related to building and in act related to fire-fighting, mainly contents associated with fire facility are regulated. Due to this, acts related to evacuation regulated in acts related to building and contents regulated in acts related to fire-fighting are very different and by operating these acts each department, mutual association is insufficient.

Second, a standard to install evacuation exit, evacuation pathway and evacuation stairs which are evacuation routes regulated in the Building Act is not a standard of the number of occupants proper to characteristics of usage but is set only as a standard of usage, area and floor. Due to this, even though, in case of nightclub or purpose of assembly which the number of occupants is many and its density is high, evacuation pathway is installed legally by acts related to building, serious congestion occurs comparatively in evacuation exit, pathway and stairs. Hence, if evacuation route installed legally in the Building Act in Korea is investigated with quantitative evaluation method used in Japan, it cannot help be incongruent.

For measurement to this, first, unified code to evacuation regulations is required. If making evacuation regulations code through widespread participation of departments related to building and fire-fighting and their employees and gathering opinions, even in amendment and complement, as cooperation between departments is required, I think that it is naturally developed as a construction of cooperative system.

Second, preparing for regulations of evacuation facility reflecting the number of persons to be admitted, in evacuation, by excluding factors of reducing walking speed by population density, an effect to reduce evacuation time should be given.

Also, at the result of investigation of evacuation time by means of the Simulex program, an evacuation program, I confirmed that an important matter in evacuation factors exists.

First, homing instinct and imitation instinct, daily behaviors, may raise enormous damage in evacuation. A merry-making place like nightclub, for convenience of management, has much induced customers into main entrance. Due to this, in evacuation, crowding phenomenon of occupants occur in entrance mainly used among various entrances, behavior to recklessly follow preceding persons without rational judgment, accelerates the phenomenon which evacuation people crowded much more and the second occurrence of damage from this may exist.

Second, it is an importance of evacuation education. To relieve homing instinct and imitation instinct suggested previously and enlarge safe evacuation of occupants, it should do like follows: workers like employees, through repetitive educations, are given strong control power and by developing an evacuation scenario for occupants in firing and making them learn it, it can be applied for situations like a fire.

Third, it is a security of sufficient evacuation routes. Comparing, through several experiments, improvement effect like width of evacuation route with additional installation of evacuation route, when installing evacuation routes additionally, I confirmed that an improvement effect of evacuation time is big. As mentioned previously, if, although a merry-making place usually uses main entrance, several assistant evacuation routes to consider circulation are installed and on occurring a danger like evacuation, can be used, an effect of evacuation can be much bigger.

Forth, it is a limit of the number of persons to use evacuation route. When the number of occupants is many comparing to area like nightclub, it is required for sufficient security of evacuation route. When the number of occupants is many like this, if, such as the U.S and the Great Britain, the number of evacuation route by the number of occupants is set up and the number of persons to use one evacuation route is limited, it is possible for decentralized evacuation and an improvement effect of evacuation will exist.

Like this, I predicted evacuation time by program and proposed an improvement direction. While studying, I considered a use of fire simulation but I excluded it as distortion to a fire occurs when I used a fire program in large-scale room of object. If much more researches to fire programs in large-scale room are carried out and materials are secured, it is my desire that deep research for fire and evacuation in large-scale room by means of fire program is actively progressed.

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