International Comparison of Fire Safety Provisions for Means of Escape

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ABSTRACT

In this study, the provisions for means of escape in the regulations of several countries are investigated. The provisions for the number, the arrangement and the capacity of means of escape are compared among countries. Then the concept and the engineering basis of these provisions are discussed for developing performance based standards.

KEYWORDS: means of egress, life safety, performance based codes

INTRODUCTION

Many provisions for means of escape are prescribed in building laws and regulations in each country. Most of these provisions are basically in the form of prescriptive standards. They were established by means of empirical judgements, not always solidly based on any engineering or scientific basis. When the provisions for fire safety in the building regulations were changed from time to time, particularly when large fires claiming many deaths or large property losses occurred, they were made more and more restrictive.

The prescriptive standards are convenient for planning typical or conventional buildings, because they do not require much professional skill for designers. However, these standards sometimes don't accept new and various building plans. For example, maximum travel distance may not be exceeded even by one centimeter, even if this violation is considered trivial for life safety. The prescriptive standards make no allowance for any violations, because the performance attained by the prescriptive standards is not defined clearly.

Instead of the specifications, it is necessary to develop scientific and engineering based standards for fire safety of building [1]. Once performance based standards have been established, various building plans will be made possible. For developing performance based standards for means of escape, firstly it is necessary to define what the performance requirements for means of escape are.

In this study, we investigate extensively the fire safety provisions for means of escape in existing regulations of several industrialized countries. Considering fire statistics, the level of life safety is fairly high in the countries, because the fire safety provisions have been performed effectively. In comparing the provisions, our attention is focused on the concept and the bases of the provisions for means of escape. The ultimate purpose of this study is to establish performance based standards for means of escape in fire.

RESEARCH METHOD

The laws, codes and regulations concerning fire safety in several countries were collected. The list of the regulations studied is given in references [2-10]. Many requirements are involved in fire safety regulations, such as detection, suppression and fire resistance of escape routes. In this study, the provisions that substantially influence planning of a building are mainly investigated. They are considered to be the number, the arrangement and the capacity of the means of escape. Although smoke control systems and sprinkler systems have great effect on life safety in case of a fire, it is thought that provisions for means of escape in fire are most important for planning of a building.

NUMBER OF MEANS OF ESCAPE

In every country the minimum number of means of escape required from any point of a building is in principle two, except for a small room or building. In Australia, not less than two exits are required if the building has more than six stories or the effective height of more than 25 meters. In Japan, not less than two exits are required if buildings having more than five stories, or buildings having five or less stories have the habitable room area of more than 200 sq. meters. In other countries, the minimum number of means of escape from a room or story is given according to the number of occupants. Two or more means of escape are required if a room or story has more than 50 occupants. (See Table 1.)

The purpose of this rule is considered to be that even if one of the means of escape is blocked by smoke, heat, flame etc., the other one can still be used [7]. However, this goal is not attained simply by providing two means of escape. Means of escape are usually composed of two parts. The first part consists of unprotected area from fire, such as a habitable room, and protected area for short time, such as a corridor. The other part is completely protected area such as a staircase and a corridor with smoke barriers. If a fire starts in a room, an exit door cannot be used for escaping from the fire room. If corridors connected with the fire room are logged with smoke, they cannot be used for escaping from rooms in the fire floor. So, it is not sufficient to provide two means of escape only. The arrangement of means of escape is also very important.

For means of escape from any point to a protected area to be used regardless the location of fire origin, one ideal solution is that two means of escape are independent from each other, and they have no common part. However, the complete independence of the paths is too restrictive for planning. It is not practical that each door in every room is connected with a different corridor. So, common part of two means of escape must be allowed to some extent. The means of escape from this common part has only one direction actually.

For a building with a limited height and for a room with a limited area, a single means of escape is usually allowable, because it is physically impossible or economically difficult to require two stairs for every building, and two doorways for every room. When a fire occurs in a small room or a low-rise building, the occupant will become aware of the danger within short time, and will be able to escape quickly. If a fire blocks the only means of escape, nobody will be able to escape. So, it is considered that we have accepted the risk that a small number of persons cannot escape under a certain condition. Every means of escape has the risk to be blocked by fire. This kind of risk, in other words, the availability of means of escape from any point in a building in fire, is one measure of life safety level. Single means

TABLE 1 Minimum Number of Means of Escape

	Australia	France	Japan	U.K.	U.S.
General	2 exits for story a) >6 stories b) >25 m height	for story or part of story · ~ 50 Ps. 1 · ~100 Ps. 2 or 1 + sub-exits · ~500 Ps. 2 · 501 Ps.~ +1 per 500 Ps. over 500	2 exits for story a) >5th floor b) on 3-5th floor room area > 200 sq.m c) on 2nd floor room area > 400 sq.m	for story or part of story · ~ 50 Ps. 1 · ~ 500 Ps. 2 · ~ 1000 Ps. 3 · ~ 2000 Ps. 4 · ~ 4000 Ps. 5 · ~ 7000 Ps. 6 · ~11000 Ps. 7 · ~16000 Ps. 8 · 16000 Ps.~ +1 per 5000 Ps. over 16000	for story or part of story · ~ 50 Ps. 1 · ~ 500 Ps. 2 · ~1000 Ps. 3 · 1001 Ps.~ 4

Ps.: persons

TABLE 2 Arrangement of Means of Escape

	Australia	France	Japan	U.K.	U.S.
Maximum Travel Distance	General 40 m Assembly (good) 60 m Hospital (ward) 30 m	General 40 m from unprotected stairs 30 m	General · ~14th floor 50 m · 15th~ floor 40 m Shop · ~14th floor 30 m · 15th~ floor 20 m *good material +10 m	<1>/<2> Assembly, School 15 m/ 32 m Hospital 9 m/ 18 m Hotel bedroom 9 m/ 18 m elsewhere 18 m/ 35 m Apartment within room 9 m unit door 7.5 m/ 30 m Shop, Office 18 m/ 45 m <1>:1 direction only <2>:2 direction	General 60m (76m) Assembly, School 45m (60m) Hospital (60m) Hotel, Apartment in room 23m (38m) unit door 30m (60m) Shop 30m (60m) Office 60m (91m)
Common Path of Travel	General 20 m Hospital(ward) 12 m Hotel, Apartment from room door 6m	General 30 m	1/2 of maximum travel distance		Assembly 6.1m School 23m Hotel, Apartment out room 10.7m (15m) Shop, Office 23m (30m)
Dead-end Corridor		from room door 10 m	10 m		Assembly 6.1m School 6.1m Hospital (9.1m) Hotel 10.7m (15m) Shop, Office 6.1m (15m)
Distance between Exits	General 9~60 m Hospital, Hotel, Apartment 9~45 m	Apartment 10~28 m	N.R.	N.R.	a) ≧1/2 D b) sprinkler & ≧1/3 D D:diagonal space distance

Ps.: persons, ():with sprinkler

of escape must be allowable based on the concept of this risk.

In the building codes of France, the United Kingdom and the United States, the number of means of escape is increased according to number of persons to be served. Then, three or more number of means of escape are required for large population. In the U.S., the maximum number of means of escape is four for more than 1,000 occupants. In France and the U.K., the maximum number of means of escape is not limited. Roughly, one means of escape is required for every 500 persons when the number of occupants is less than 2,000 persons.

This rule is considered to prepare redundant means of escape, in case a means of escape is blocked by a fire. When the capacities of means of escape are equal, the more the number of means of escape, the higher the level of life safety, because it is able to minimize the loss of the capacity of means of escape which is blocked by effect of a fire.

This rule also means to avoid overcrowding of occupants at an exit. The capacity of means of escape is required based on the number of occupants as described later. Because the maximum capacity of one means of escape is not limited, a large number of persons may gather at one exit. In the past, many tragedies have occurred in such overcrowding conditions. So, it is necessary to limit the maximum number of persons for one exit. The problem is what number of persons is adequate for crowd safety and what the engineering basis of 500 or certain number of persons is.

ARRANGEMENT OF MEANS OF ESCAPE

Provisions for adequate arrangement of means of escape usually consist of maximum travel distance, common path of travel, length of dead-end corridor and distance between two exits. All of these are not necessarily required in every country. There are various combinations of requirements for each building use.

Maximum Travel Distance

For adequate arrangement of means of escape, the most fundamental requirement is thought to restrict travel distance to the nearest exit. In every country, the maximum travel distance is roughly 40 - 60 meters, as shown in Table 2.

In Australia, the maximum travel distance must not be more than 40 meters as a rule, except for assembly buildings and a ward area in hospital buildings. In France, the travel distance must not exceed 40 meters. In Japan, except for shop buildings, the maximum travel distance must not be more than 50 meters on less than 15 stories, and must not be more than 40 meters on 15 and more stories. And this length is increased by 10 meters, if the interior surface of the wall and ceilings of habitable rooms and corridors are finished with noncombustible or quasi-noncombustible materials. In the U.K., the maximum travel distance varies depending on building use and the number of different directions of means of escape. For example, in an office building, the travel distance must not be more than 45 meters where the travel is possible in more than one direction, and must not be more than 18 meters where travel is possible in one direction only. In the U.S., the maximum travel distance must not exceed 60 meters in buildings without sprinkler system, and must not exceed 76 meters in buildings protected by sprinkler system. And the maximum travel distance varies depending on building use. For example, the maximum travel distance must not exceed 91 meters in an office building protected by sprinkler system.

The maximum travel distance varies significantly depending on many factors, such as follows:

a) the number of different directions of means of escape
b) the layout of the floor area, 'open plan' or 'cellular plan'
c) the features of the building: construction type, building height, materials used, etc.
d) the particular occupancy of the building: sleeping room, high-density, etc.
e) the physical and mental capabilities of the occupants: unfamiliarity, disability, etc.
f) the equipments to mitigate hazard of fire: smoke control, sprinklers, etc.

In each country, some of these factors affect on the limitation of travel distance to the nearest exit. The maximum travel distance varies depending on the number of stories of a building only in Japan, and depending on the sprinkler system only in the U.S. The building use is considered as a main factor in the U.K. and the U.S. It is very difficult to find any kind of consistent rule to determine the maximum travel distance.

Why the travel distance should be restricted? There are two reasons found in the document [8]. The one is that the shorter the travel distance, the faster the escaping time to an exit. The other is that when the means of escape are logged with smoke from fire, if the travel distance is short, it is able to run through the smoked area. It is not necessary for escaping within the allowable egress time to restrict the travel distance, because the travel time within a floor or a room is usually only several tens seconds. And before the start of escape, more time is spent for detecting the fire, searching information of the fire, making decision to escape etc. The travel distance may not be limited also by the human ability of running through the smoke filled corridor. Nobody wants to escape through the corridor filled with smoke, if he or she does not know where an exit is. Usually it may not be expected to escape through the corridor logged with smoke.

It is thought that the longer the travel distance, the more the risk of means of escape to be blocked by a fire. In this respect, it is reasonable for reducing the risk to restrict the maximum travel distance. On the contrary, if one means of escape is available at any time, the limitation of travel distance will not be necessary. For example, corridors open to outside and area in the lower part of very large atria or like these spaces are safe under certain conditions.

In another aspect, the limitation of the travel distance may be required to make it easy to find out where the means of escape are. Even if the means of escape are available, it is difficult to use them without the knowledge about exits location. In case of buildings used by public, it might be the first time for most people to enter the building, so they might not be familiar with exits location. If exits are arranged regularly within a certain travel distance, everybody will be able to reach easily one of the exits. It is very important in fire to be able to recognize the building layout and to find out easily the means of escape. The easy exit recognition is also considered one of the performances of life safety in fire. The maximum travel distance shall be evaluated based on this performance.

Common Path of Travel

It is thought that the limitation of the length of common path of travel is one of the most important provisions for arrangement of exits. The common path of travel is restricted in every country. In Australia, the common path of travel must not be more than 20 meters in general, which is one-half length of the maximum travel distance. In Japan, the limitation of the common path of travel is defined as one-half length of the maximum travel distance required. They are about 20 - 30 meters. In the U.K., the length of common path of travel varies from 7.5 to 18 meters depending on building use and the number of different directions of means of escape. In the U.S., the common path of travel varies depending on the building use and whether or not the building is protected by sprinkler system. The shortest length is 6.1 meters in assembly buildings. The longest length is 30 meters in shop and office buildings protected by sprinkler system. (See Table 2.)

Two means of escape must be located as remotely from each other as practical to avoid the both to be blocked by the same fire. The shorter the common part of two means of escape, the better. Ideally, two means of escape are fully separated by fire-resistant construction and have no common part. However, it is very difficult to arrange two fully independent means of escape from every point of the floor area. For example, although a room of certain size should be provided with two doorways remotely at different side, it is necessary to allow a certain length of common path of travel. It has the risk that a certain number of occupants could not escape if only single means of escape is provided. The risk of common path of travel should be the same as the risk of a single means of escape. However, this concept is not defined clearly in any country. The allowance of common path of travel is not the same as the allowance of single means of escape.

The limitation of common path of travel is nearly one half length of the maximum travel distance in every country. It is interesting that the proportion of the common path of travel is equal among all countries, despite the maximum travel distance varies significantly depending on various factors. What is the meaning of 'one-half of the maximum travel distance'? It is suspected that the 'one-half' is only a round number. The absolute length may have no reasonable basis for life safety.

It is very difficult to make general rules on the features of exit arrangement. Common path of travel is one of the useful and simple rules. In some countries, other types of rule are given in regulations. In Australia, the U.S. and the apartments in France, the direct distance between two exits is restricted. In Australia, two exits must be not less than 9 meters apart, and not more than 60 meters apart. In the U.S., the direct distance between two exits must be not less than one-half of the maximum overall diagonal dimension of the building or area. In the U. K., there is a unique requirement for exit arrangement that the number of possible means of escape is judged by whether the angle between the two travel directions is more than 45 degrees or not.

It is thought that some rules of these kinds are necessary for adequate arrangement of means of escape. However, it is very difficult to evaluate the performance attained by these rules. Even if a certain rule is effective for a certain case, this fact does not assure that the rule is effective for every case. These rules are useful only for designing. In performance based standards, the arrangement of means of escape should be evaluated based on the availability of means of escape in fire.

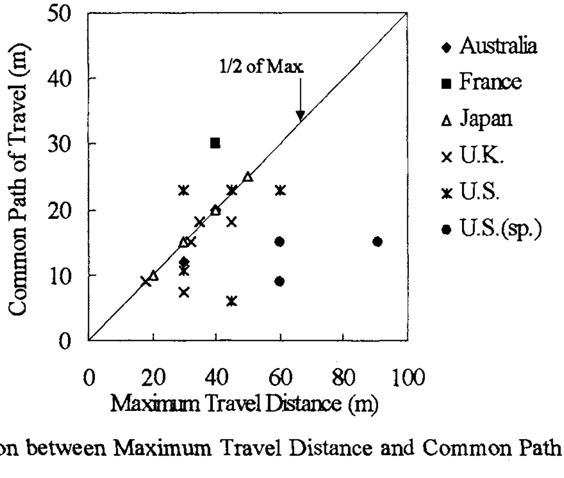

FIGURE 1 Relation between Maximum Travel Distance and Common Path of Travel

Dead-end Corridors

The length of dead-end corridors is limited. This requirement intends to prevent people from entering the dead-end corridors and going back, or to prevent people from being trapped by smoke in the dead-end corridors. So, the limit of dead-end corridors length should be short enough to be recognized easily that there is no exit.

The length of the dead-end corridors is limited to about 6 - 18 meters, as shown in Table 2. In Japan, the dead-end corridors must not exceed 10 meters in every building use. In the U.S., the dead-end corridors is more restricted. The length must be less than 6.1 meters in almost all building use. However, it is relaxed to 15 meters in hotel, shop and office buildings if protected by sprinkler system. The length of dead-end corridors is equal to or shorter than the limit of common path of travel in every country.

Surely no dead-end corridor is desirable. However, if no dead-end corridor is allowed, planning of building will be too restricted. An exit must be located at the end of the every corridor. The maximum length of dead-end corridors varies depending on many factors, as the way the maximum travel distance is restricted. It is not known what length of dead-end corridors is appropriate to prevent people from being trapped in case of fire. It depends on exit marking and human ability also.

CAPACITY OF MEANS OF ESCAPE

The capacity of means of escape is determined based on the occupant load factors in every country, except Japan, as shown in Table 3. First of all, the uses of every room and story are classified, then the expected number of persons is calculated in dividing the area by the occupant load factors specified for each use. The capacity of means of escape is required to be sufficient for the calculated number of persons.

The occupant load factors of the same use vary among countries, as shown in Table 4. For office buildings, the largest occupant load factor is about twice larger than the smallest one. For sales space of shop buildings, the largest occupant load factor is ten times larger than the smallest one. In Japan, there is no specification of occupant load factors in the regulations. The factors in Table 4 are given only in Guideline for Building Fire Safety Design published by BCJ for calculation method of estimating escape time [6]. Only in department stores and public assemblies, the stairs width and exit door width to stairs are required to be calculated directly based on floor area. On the other hand, for other building use, such as office building, only two stairs of 1.2 m width are required, if the maximum travel distance and other restrictions are allowable.

Table 3 shows the summary of the required capacity of means of escape in every country. In Australia and France, unit width of means of escape, and the number of persons served by one unit width is specified. The exit capacity is required in terms of number of units, then the actual width of means of escape is calculated on the basis of the unit width. In Australia, if the number of occupants in the story is more than 100 persons, the aggregate exit width is required to be 1 meter plus 25 cm for each 25 persons in excess of 100 persons. And if the number of occupants is more than 200 persons, the aggregate exit width is required to be 2 meters plus 50 cm for every 60 persons in excess of 200 persons. In France, two units width is required where the number of occupants is not more than 100 persons. The required exit width must be increased by one unit (60 cm) for every 100 persons in excess of 100 persons. And the exit stairs width is required for the total number of occupants on upper stories, not for the number of occupants on the story.

The unit width is about 50 - 60 cm usually, which is almost equal to the width of humans'

TABLE 3 Capacity of Means of Escape

	Australia	France	Japan	U.K.	U.S.
Stairs	Pn: · ~100 Ps. 1 m · ~200 Ps. $1+0.25\times[\frac{Pn-101}{25}+1]\ m$ · 201 Ps.~ $2+0.5\times[\frac{Pn-201}{60}+1]\ m$ School, Hospital + 1 m	ΣPn: · ~50 Ps. 0.9 m · ~100 Ps. 0.9 m×2 or 1.4 m · 101 Ps~ $1.2+0.6\times[\frac{\Sigma Pn-1}{100}]\ m$	Minimum General 1.2 m Assembly, School, Shop 1.4 m Assembly $0.17\times\frac{An}{10}\ m$ An: auditorium area (sq.m) Shop $0.6\times\frac{Amax}{100}\ m$ Amax: maximum area of upper floors (sq.m)	a) Total Evacuation $\Sigma Pn = 200w+50(w-0.3)(n-1)$ n: no. of stories served w: stairs width (m) b) Phased Evacuation Pn: · ~100 Ps. 1 m · ~120 Ps. 1.1 m · 120 Ps. ~ $1.1+0.1\times[\frac{Pmax-111}{10}]\ m$ * Stairs with largest width is discounted. Assembly · ~220 Ps. 1.1 m School, Hospital · ~150 Ps. 1 m	General 0.008× Pn m Minimum · ~49 Ps. 0.91 m · 50 Ps.~ 1.21 m Assembly (Theater type seating) · ~ 2000 Ps. 0.762AB · ~ 5000 Ps. 0.508AB · ~10000 Ps.0.330AB · ~15000 Ps.0.244AB · ~20000 Ps.0.193AB · 25000 Ps.~0.152AB * if riser > 17.78 cm $A=1+\frac{(riser)/2.54-7}{5}$ * B=1 if without handrail B=1.25
Corridor, Door	same as stairs, except · 201 Ps.~ $2+0.5\times[\frac{Pn-201}{75}+1]\ m$	same as stairs	Assembly(doors) same as stairs Shop: doors to stairs $0.27\times\frac{Amax}{100}\ m$ Amax: maximum area of upper floors (sq.m)	Pn (served) · ~50 Ps. 0.8 m · ~110 Ps. 0.9 m · ~220 Ps. 1.1 m · 220 Ps.~ $1.1+0.1\times[\frac{Pn-201}{20}]\ m$	General 0.005× Pn m Minimum 0.81 m

Ps.:persons, Pn: number of persons on n-th floor, ΣPn: total number of persons, [x]: the largest integer no more than x. (Gauss' notation)

TABLE 4 Occupant Load Factors (person/sq. m)

Type of Use	Australia		France		Japan		U.K.		U.S.	
Assembly	board room exhibition gymnasium spectator stand without fixed standing area church, cafe dance floor sport stadium library storage reading	.50 .25 .33 1.0 3.3 1.0 2.0 .10 .033 .50	theater fixed seating standing area multi-purpose hall sports use dance floor church assembly hall	 n 3.0 1.0 1.33 2.0 1.0	meeting room ~400 sq.m 400 sq.m ~ restaurant theater seating area standing area banquet hall	 1.5 .6 .7 n / 1.5 2.0 1.0	conference room exhibition hall standing spectator area assembly hall waiting room library	1.0 .67 3.3 2.0 1.0 .14	less concentrated without fixed concentrated without fixed fixed seat waiting space library reading area stack area	.72 1.54 n 3.59 .22 .11*
School	general classroom multi purpose hall staff room others	.50 1.0 .10 .25			classroom	n			classroom area others	.54 .22
Hospital	ward area	.10			ward area treatment area	n .2			sleeping dep. treatment dep.	.09* .45*
Hotel		.067			bedroom	n	bedroom	.13		.54*
Apartment							bedroom	.13		.54*
Shop	space for sales grand & lower level others storage area	 .33 .20 .033	space for sales street 1st / lower 2nd 3rd mall space low density area	 2.0 1.0 .50 .20 .20 .33	space for sales incld.corridor mall space restaurant sales space corridors	.5 .7 .5 .25	sales area supermarkets, department store others mall	.5 .14 1.33	street floor sales basement multiple street fl other floors storage,shipping mall	.36* .27* .18* .03* .20*
Office		.10	public access area no public	.10 .010	>60 m high <60 m owner for rent	.125 .16 .25	open plan type others	.2 .14		.11*
Remarks			If area public access are not defined. 1/3 of floor area is subjected.		n: number of seats				*:gross n: number of seats	

body. It is assumed that the capacity is a step function of number of lanes of movements and unit width. In the past, the codes of the U.S. used a unit width rule, too. Since 'the effective width model' was adopted, the capacity has been regulated in term of required width per person [9]. However, the proportion of required exit width per person is almost the same as before.

In the U.K., the required capacity of means of escape depends on whether a building is designed for total evacuation or phased evacuation. In a building designed for phased evacuation, the capacity of means of escape is required only for the maximum number of occupants on one story. The exit width is required to be 1.1 m plus 10 cm for every 10 persons in excess of 120 persons, if the number of occupants is more than 120 persons. In a building designed for total evacuation, the required exit width is calculated with an equation, described in Table 3, using the number of stories and stairs width. The first term of the equation implies required width per person, and the second term implies the number of persons, which can be accommodated in the stairs between floors.

Figure 2 shows how much width of stairs is required according to the number of persons. The requirements about number and arrangement of means of escape are not counted in this figure. The widest stairs width is required for shop buildings in Japan. The narrowest stairs width is required for a building designed for phased evacuation in the U.K., except for office and other use building in Japan.

The required width per person is compared. The stairs widths are in the range of 0.5 - 1.2 cm per person, as shown in Figure 3. These values are to ensure that evacuation can be completed within certain time, because the time for passing through the narrowest point of means of escape under crowding condition is controlled by 'flow rate'. Traditionally, without any engineering or scientific basis, it has been considered that 2 1/2 minutes is the maximum time allowable for escape to a safety place. And it is common in regulations that the flow rate in stairs is taken about 1.3 persons per meter per second (40 or 45 persons per unit per minute) based on many observations. So, it follows that the exit capacity is determined based on 200

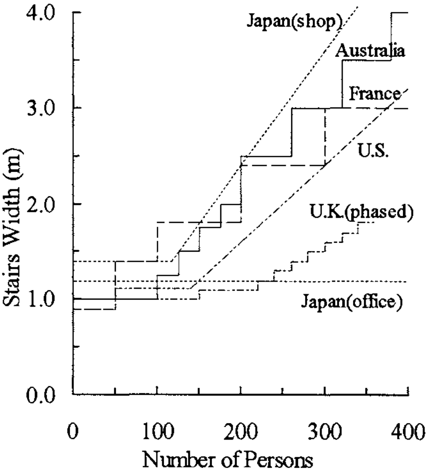

FIGURE 2 Required Stairs Width based on Number of Occupants

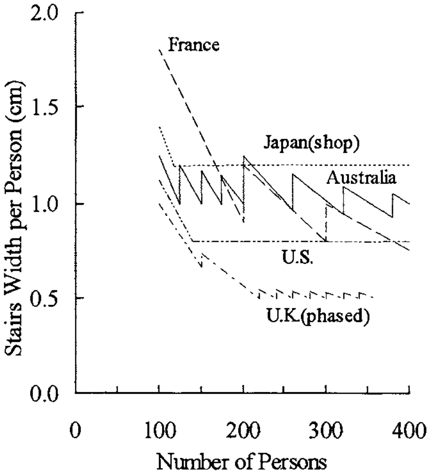

FIGURE 3 Required Stairs Width per Person

persons per meter, which is 0.5 cm per person. The required widths in every country are equal to or more than this value. It is suspected that the required width is increased taking into account the case a part of the means of escape is blocked by fire. This value is not important by itself, because the allowable egress time and the flow rate is not constant in real condition. It is important how to set the margin of the means of escape.

There are some ways to require the exit capacity based on the expected maximum number of persons to be used, such as follows:

1) All means of escape are used as intended.
2) All means of escape are used as intended, and the capacity is calculated by taking account safety factor, for example twice required capacity.
3) The largest means of escape are discounted, and the capacity of the rest means of escape are required to be sufficient to be served.

In case of multi-story building, two different concepts to require stairs capacity as means of escape are found. For total evacuation, the required capacity of stairs is based on the total number of occupants in a building. The very large capacity of stairs is required according to the number of persons served by the stairs. It is exactly so in case of France, for which the width of stairs increases as the number of stories served by the stairs. In the U.K., the concept is basically the same as in France, but the number of persons, which can be accommodated in the stairs between floors, is also counted as the capacity of means of escape. Therefore, the rate of the increase of stairs width with the number of stories is somewhat small compared with France.

For phased evacuation, the required capacity of stairs is based on only the occupants number on one floor or two if necessary. It is not required that the width of stairs is increased as the number of stories served, because it is considered that all occupants in a building need not escape simultaneously, if stairs are well protected. The capacity of stairs is enough only for the number of occupants on each floor. In fact, if the area affected by fire and smoke is confined only to the floor of fire origin, the number of occupants to be evacuated will be limited and the escape time will be short. However, if total evacuation is necessary, the escape for all occupants takes very long time and exits are crowded heavily.

The capacity of means of escape has been set by the escape time and the safety margin. However, there is no theoretical reason that traditional escape time, 2 1/2 minutes, is adequate for todays' buildings, and no reasonable way how to set the safety margin of the exit capacity. So, it is necessary to develop the reasonable method of determining the exit capacity with engineering basis.

CONCLUSION

There are a lot of common points in the structure of the provisions for means of escape in every country, because it is thought that when new provisions are introduced into the regulations in one country the similar provisions were often imported from other countries. At that time, the basis for the provisions might be not introduced together. The specifications were accepted exactly as they were, or adapted for the circumstances of the country. As a result, now there are many various provisions for means of escape. So, it is not right nor reasonable way to take one value and one rule as reasonable standard from these provisions.

From analyzing the present codes, rules and regulations, it is cleared that there are four performance requirements for means of escape, such as follows:

1. Availability of means of escape in fire:
    - evaluating redundancy or reliability of means of escape
    - --> allowance for single means of escape, or common path of travel
2. Easy recognition of exit facilities:
    - adequacy of arrangement of means of escape
    - --> limitation of travel distance and dead-end corridor
3. Escape time:
    - escape without smoke and other threats of fire
    - --> capacity of means of escape
4. Number of people in queuing:
    - prevent overcrowding
    - --> number of means of escape

Nowadays, many egress models that simulate the movement of people in fire are available. By using these models it is able to predict the escape time and the number of persons at any point at any time in a building. However, even if the result of simulation shows that all occupants escape safely within a reasonable time, any violations may not be allowed. The specifications of life safety provisions are not relaxed easily without reasonable basis. So, it is necessary to develop the evaluating method for the performance requirements for means of escape in fire.

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