

Preliminary exploration of escape slide¹

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Abstract. Using escape stairs is conventional way to escape from the fire building. But using the stairs as an escape path has many shortcomings, and in some conditions escape stairs cannot be used to escape in reality. Using ropes and other emergency tools to escape from balconies or windows is very dangerous. Escape slide, a new indoor fire escape facility, is put forward with the conventional design method and the function design method. The problems of structure, fireproof, lighting, ventilation, lighting, setting place, the exit of escape slide and alarm linkage are discussed. The advantages and disadvantages of escape slide are analyzed. Less occupation space, no energy consumption, fast escaping speed, safe use, easy protection are the advantages of the escape structure. Escape slide is an escape structure having research value and worth to popularize, and this structure is a supplement to the evacuation staircase.

Key words. Slide, escape, fire, construction.

1. Introduction

In modern buildings, the fire spreads quickly. When the fire starts, the evacuation time is very short. The escape route is used to determine the probability of survival. Staircase and elevator are two forms to solve perpendicular traffic problems mainly in buildings. In case of fire state, the elevator is forced to land on the first floor and cannot be used as an escape. Using staircase is the only way to escape. As a means of escape, staircase has many advantages. But it has many disadvantages, too. Staircase has strong ability to convey flow, but it occupies a large floor area at the same time; for the individual conveying speed it is not fast; relying on walking, people consume a lot of physical strength to evacuate; staircase cost is increased for the dual application of normal and fire status; all materials must comply with fire resistance requirements if the fire resistance requirement is necessary despite the large volume of stairwell; due to the large volume of stairwell, high capacity smoke device and large amount of lighting is necessary for large volume of stairwell. Is there other form of escape way beside the escape stairs? The fire development

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characteristic is depicted in Fig. 1.

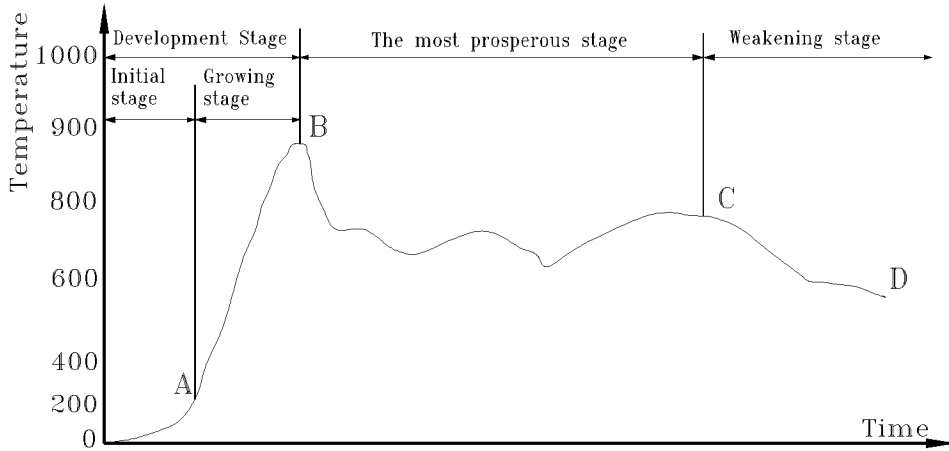


Fig. 1. Fire development law

Slide way is often disposed at mountain tourist attractions as recreation facility. People enjoy the scenery, and experience the joy of speeding down at the same time. Can we build a escape slide in the building construction as a form of escape? Parameters of commonly used staircases in high-rise buildings are listed in Table 1.

Table 1. Evacuation time in high buildings through the stairs in different number of layers and in different number of cases (the stair width being 1.1 m)

Number of layers	Evacuation time (min)		
	240 people per layer	120 people per layer	60 people per layer
50	131	66	33
40	105	52	26
30	78	39	20
20	51	25	13
10	38	19	9

2. State of the art

How to escape has been the focus of research, when the building or structure is on fire. Mathematical simulation method and other methods were used to study the fire escape by a lot of scholars. He Yijing used buildEXODUS to simulate the time of evacuation of high-rise dormitories [1]. Xie Haiming used three-bit simulation technology to make the fire evacuation drill more visualizable [2]. The smoke spread speed, temperature, the CO concentration, variation of visibility and evacuation behavior characteristic of indoor personnel in the high-rise building fire scene were simulated by Wang Hairong using FDS and Pathfinder [3]. Software simulation

was used to select the best escape route by He Peichong and Jiang Huixian [4][5]. Liu Yunxiang wrote programs named firesim to study the rule of fire [6]. Through simulation analysis, Weng Tao pointed out that the efficiency of orderly evacuation was much higher than that of evacuation together. Ran Haichao found the values of the actual evacuation might exceed the design values using the method of software simulation also [7]. Hou Lei pointed out through simulation that increase of exits can greatly reduce casualties [8]. Through the statistical analysis, Shi Xingjun also pointed out that lack of evacuation stairs and evacuation export blocked was the main reason for the increase in the number of fire victims [9]. Zhang Hao provided another way to escape from fire except regular evacuation channel, including rope, ladder, slide and air cushion [10]. Zhang Ruihua proposed a rescue apparatus for high-rise buildings, which can convert kinetic energy into electrical energy and then convert into heat by resistance [11]. Lin Li designed a slow-down escape device, which was simple in structure and could be used in reciprocating [12]. Zhang Rui put forward an expandable fire escape passage made by hinge, connecting rod and soft package material which was folded up in normal times and deployed automatically by water pressure and springs [13]. No matter software simulation or statistical analysis of historical data reveals the situation that often appears, that cannot use conventional escape routes to escape. While using the ropes, ladders, and other outdoor escape devices is very dangerous. It is lack of new type of escape facility in the room, though there are some inventions, but the practicality is poor. It is necessary to seek a reliable new indoor escape facility.

3. Methodology

3.1. The design of escape

The idea of the proposed slide is depicted in Fig. 2.

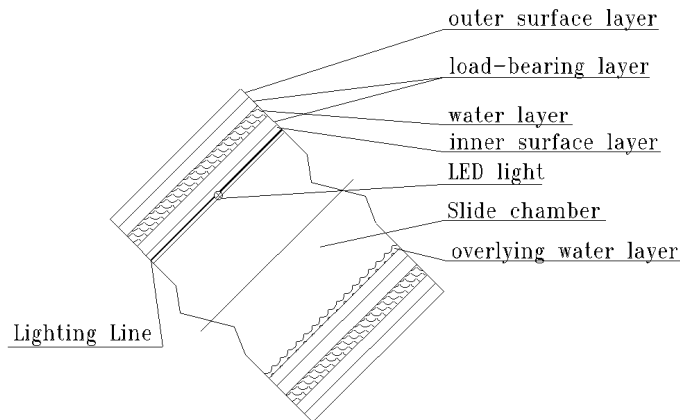


Fig. 2. Lengthwise profile of the slide

The escape slide is a circular or similar circular cavity structure. In the middle of the cavity there is a personnel evacuation channel. The slide wall is composed of a variety of materials. The walls of the slide are required to exhibit some properties such as load-bearing, refractory or lighter weight.

The slide wall is divided into intermediate structural layer (i.e., the load-bearing layer), inner surface layer and outer surface layer.

As for the load of slide, the structural layer is required to have a certain carrying capacity. Strong-bearing capacity materials can be used like steel and reinforced concrete. Outer layer of the slide is required to enhance the fire resistance and to have a certain aesthetic requirements. Outer layer may be a single layer of material or a composite material.

Table 2 presents the temperature of the main rib in the beam and the thickness of the protective layer under the action of fire temperature and Fig.3 shows the relationship between the temperature of the main rib in the beam and the thickness of the protective layer.

Table 1. The relationship between the temperature of the main rib in the beam and the thickness of the protective layer under the action of fire temperature

Thickness of protective layer of main reinforcement (cm)	Temperature of main reinforcement heated up for different times (°)									
	15 min	30 min	45 min	60 min	75 min	90 min	105 min	140 min	175 min	210 min
1	245	390	480	540	590	620				
2	165	270	350	410	460	490	530			
3	135	210	290	350	400	440		510		
4	105	175	270	270	310	340			500	

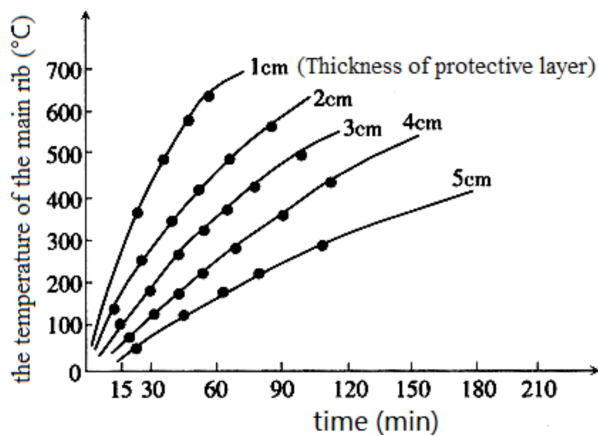


Fig. 3. The relationship between the temperature of the main rib in the beam and the thickness of the protective layer

The inner surface layer is required to conceal electrical lines and to installation of lighting fixtures. Further requirements of inner surface layer are a smooth surface on lower part and certain roughness on both sides. The inner surface layer is often required to use a variety of materials to meet the requirements. In hot regions, a method can reduce decline friction and reduce the friction damage to people and the burning sensation when sliding down which is forming a overlying water layer by turn on the water from the top of slide [1]. Figure 4 shows the cross section of the slide.

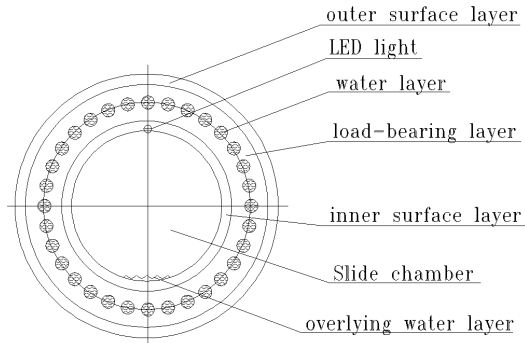


Fig. 4. Cross profile of the slide

Slide should be set to an inlet and an outlet; the middle should not be set to an opening. Normal closed door is set at opening of slide. Inlet door can be set to automatically lock, usually in the locked state, can automatically open fire, and should be able to manually open. Outlet door should open when people slid down, and it does not affect personnel slipping, automatically shut down after staff through.

Set the water layer in the wall is possible to improve the fire resistance. The water layer may be made of a plurality of tubular cavities, or other shape. Water is flowing in the time of fire; constantly take the heat to ensure that the internal slide at lower temperatures.

When the fire broke out, sending fresh air into the slide by the pressurized air supply system would positive pressure state in the slide chamber.

It is unnecessary to identify by eyes, because people in the chute is completely passive. The only thing to do for people is stepping on both sides of the slide by feet to control the rate of decline in the slide. Therefore, the chute cannot even install lighting, but in order to alleviate human stress, fear of emotions, low luminance lighting is appropriate. LED lights can be embedded in the upper chamber slide and supply pipeline embedded in the slide wall. Since LED lamp consumes very little electricity, power supply can also be powered by batteries.

By buried cable fixed temperature detector in the slide wall, the door of the slide opening will be closed when temperature in slide chamber in order to prevent overheating wounding. Cable fixed temperature detectors embedded wiring should adopt spiral, which rounded in the tube wall. In the top of the slide should be set smoke detector to detect whether there is smoke fleeing slide, and close the slide if necessary.

3.2. Possible use of premises and the use of forms

In the case of arrangement of the slide does not affect the perception, setting slide may be a good choice in the large space like tall plants. Slide can be made a spiral or a long slope or other curve, just paying attention to coordination with the chamber. Long slippery slope is more comfortable.

Layout method is similar to an outdoor staircase. We can use a long curve slope, and can use folded arrangement. Exhumation arrangement is a straight slope joins a chicane, and then joined a straight slope in the opposite direction, followed by a sharp turn and so forth. This arrangement requires less flat position, but the corner slide is relatively uncomfortable.

Because of the sharp turn, small radius of rotation makes people feel dizzy, but the position of plane occupied is small. On the contrary, large radius of rotation gives people a feeling of comfort, but the position of plane occupied is large. The slide can be constructed around some regions or rooms, such as shafts.

3.3. Some notes

A direct ground slide is ideal. But there are some benefits segmentation settings. Segmentation settings can avoid prolonged friction burning sensation or skin rubs; also can avoid entire slide can not be used for the smoke caused by fleeing into the slide; and people can also change the way of escape in the segment of slide, such as the slide change into the stairs or the stairs change into the slide. It is suitable for refuge floors to segment. Antechamber should be set at segment if the segment is not at refuge floor.

The position near the inlet of slide should ensure the safety for where people waiting in turn to access the slide. An antechamber of sufficient area should be set for people waiting to enter the chute. Where should have positive pressure air in antechamber on fire.

Though it is temporary safe for people evacuated to refuge floor or roof, to leave the building on fire is necessary for more security. The inlet of slide should be set at refuge floor and roof, so that people can be transferred along the slide to the ground.

The slide need combine with automatic fire alarm and linkage system. Cable type fixed temperature detectors installed in the inner wall of slide and smoke detectors installed in the top of the slide will transmit fire alarm signal to the control panel. In case of fire, the host command to open the chute entrance door, and to turn on the water in order to form overlying water layer, and to feed water pressure to flow in the water layer, and to light the lamp in the slide, and to send fresh air in the slide.

4. Result analysis and discussion

4.1. The disadvantages of escape slide

As a channel, the biggest problem is, that slide cannot fuse coordinately with other interior space which divided into rectangular space for its shape which presents an oblique curve. While the space occupied by the slide may be little, the space up and under the slide cannot be used suitably. The space of a straight slide occupied is small, while its projection area in the plane is large. Its application is limited and few people study it for this reason. The cavity shape of slide is depicted in Fig. 5.

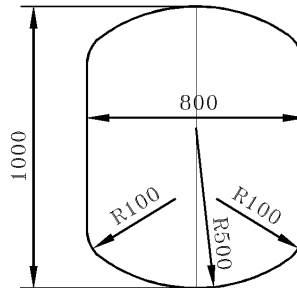


Fig. 5. Cavity shape of slide

Though the transport speed of slide using by single person is quick, fewer personal can use it synchronously. The slide has not a high efficiency as the stairs when a large number of people need evacuate. Table 3 contains the capacity comparison of down-stairways with different widths.

Table 3. Capacity comparison table of down-stairways with different widths [13]

Down-stairways width (m)	2.0	2.5	3.0	3.5
Practical traffic capacity (person/h)	8064	10080	12096	14112
Maximum traffic capacity (person/h)	8400	10500	12600	14700

Sliding to the ground directly from a certain height is or sliding from a high plane to a much lower plane suitable by the slide. Therefore exit cannot be set up every floor as the stairwell.

4.2. The advantages of escape slide

The angle of slide is generally between 20 degrees to 50 degrees [14]. People slide down in the escape slide just need a space which higher than person's head [15]. If people use the prone position, the slide can be made slimmer [16–17]. Small space structure can reduce the cost, for it need fewer building material, and need smaller-scale smoke control systems and lighting systems [18].

For a healthy adult it is not a difficult thing, evacuation from a higher floor by the stairs to the ground, but for the infirm and the disabled people this action is

difficult [19]. The momentum of decline comes from the weight of the human body in escape slide, it do not consume physical fitness [20].

For individual evacuee, who slides down along the escape slide will faster than the other who walks down the stairs.

Bumps, grazes, or even stampedes are often occurred when people are escaped down the stairs who will inevitably have to panic. The things will not happen escaping from the slide. Such an environment will help to eliminate fear, where the light is dim, and the body close to the chute, and field of view is limited to a narrow space.

Staircase design requirements to be considered when peacetime and fire-time, but the slide design requirements emergency use only for the only use of fire-time.

The slide is actually a pipe erected. Because of the small space volume, we can easily take some protective measures to improve its fire resistance. The same measures are difficult to achieve on the staircase. We can add a refractory material layer in the pipe wall of the escape slide and can add an integument of refractory materials on the outer surface of the slide, even can add a layer of water in the pipe wall, in which heat can be taken away by flow water so as to greatly improve the fire resistance. When we need to design a fire escape through the channel, the slide is most appropriate.

5. Conclusion

In order to find out a new way to escape from fire building in addition to the fire escape staircases, an escape slide is put out mainly through the method of function design in this paper, and a comprehensive analysis of its security is carried out including heat insulation, fire resistance, prevention of scratch damage, smoke prevention, air supply, lighting and fire alarm. Escape slide is a novel fire escape facility, which can enrich the means of escape, improve the building fire safety, and reduce casualties caused by fire. The use of it is more comfortable, and the elderly, children can use. It has good fire resistance and safety, and it can be widely used in industrial and civil buildings. It also has certain limitations, such as the relationship with the other building spaces is not easy to be deal with, and the exits cannot be set up each floor, and cannot be use by more people at the same time. The structure is particularly suitable for use in large space buildings and outdoor spaces. When being used in the reentry design and rotation design, it can also be used in other occasions. The deficiencies of the evacuation stairs are made up by this structure, which plays a complementary role and has broad application prospects.

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