Application Status and Development Trend of High-Rise Escape Devices

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Abstract: With more and more people working and living in high-rise buildings, there are more and more escape devices for emergencies such as dangerous situations (e.g., fire and earthquake) in high-rise buildings. At present, there are many high-rise escape equipment, but various high-rise escape devices show a series of shortcomings, i.e., it is difficult to achieve multiple people to escape at the same time, and rely on external driving force, poor economy, need professional training to operate, which cannot achieve the expected escape purpose. Thus, this paper summarizes the research status and application trend of high-rise escape devices, which can provide technical support for the study of high-rise escape devices and is of great significance.

1. Introduction

With the accelerating process of industrialization and urbanization and the rapid development of economy, skyscrapers have sprung up in all corners of the world [1]. People working and living in high-rise buildings are easy to ignore the potential safety hazards brought by high-rise buildings, i.e., how to escape quickly in case of dangerous situations (e.g., sudden fire, earthquake, etc.). Thus, the escape and self-rescue of high-rise buildings has become an urgent social problem to be solved.

(a) High-rise buildings under fire

(b) High-rise buildings under earthquake

Fig.1 High-rise buildings under fire and earthquake

Usually in multi-functional high-rise buildings, the internal structure is intricate. In case of fire, the air vents in the building will expand rapidly, and the fire and smoke will soon spread to all corners of the building [2]. The thick smoke will quickly cover the whole building, making it difficult for people inside to walk. When a sudden disaster comes, the elevator will not work because of power interruption, and the stairs will be blocked by a crowded crowd, so there is no door to heaven and no road to the ground[3]. Waiting for ground rescue has become the only hope of the people in distress, but often because of the high buildings, the ground rescue equipment may not be enough in height, but also because of the heavy of equipment cannot quickly rescue. Throughout the national fire situation in recent years, we can see that its harm has caused great losses to people's lives and property[4]. For China, there is a serious imbalance between its fire emergency rescue equipment capacity and the rapid development of high-rise buildings. First, the lifting and long-range shooting capacity of the equipment lags far behind the high development of high-rise buildings. The existing fire water tank truck has only 8 floors high and the highest ladder

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truck has only about 15 floors. For higher high-rise building fires, this emergency rescue equipment can only do nothing. Second, the equipment has huge volume and poor mobility, which is seriously affected by road traffic and the surrounding environment of buildings, and the opportunity is often delayed due to complex terrain and obstacles. Third, the rescue capacity of the equipment is poor. The existing ladder truck can only rescue 2 to 3 people at one time. Once there is a high-rise fire, it cannot meet the actual rescue needs on site[5].

Thus, how to get out of a burning building quickly and efficiently becomes a matter of life and death. Therefore, the high-rise escape device arises at the historic moment in such a situation.

2. Research Status of High-Rise Escape Devices

The high-rise escape device is mainly used for ordinary families and individuals. Its structure is usually composed of governor, safety belt, safety hook, steel wire rope, etc. For its application, the user first hangs the hook on the indoor window, pipe and other load-bearing objects, then ties the bandage to the waist of the human body, falls from the window and slowly falls to the ground. Each time, a single person who can carry about 100 kg can slide down freely[6]. The sliding speed is about 0.5 to 1.5 meters per second. It takes about one minute to fall from the 20th floor to the ground. It varies slightly according to the weight of the human body[7-10]. Note that the use of high-rise escape devices is not ideal, and they have not been widely used at present. In addition to family fire awareness and economic factors, the main reasons are that it is difficult to apply to the elderly, children, sick and disabled, multiple households may be intertwined at the same time, installation problems, regular maintenance and other reasons, so it is difficult to enter people’s homes.

In addition, experts suggest that if there is no effective high-rise escape device at home, you should be calm after a fire and choose the correct escape way, i.e., leave the room as soon as possible and expose it as much as possible to ensure that the search and rescue personnel are easy to find, escape from the stairs, extinguish the flames, avoid against the wall, reasonably jump from the building and escape through the escape pipe[7]. To sum up, there is no effective high-rise escape device, and people's escape are extremely passive. Therefore, the research on the escape devices of high-rise buildings should be stepped up at home and abroad. Throughout the world, the research and development of such devices are mainly in the forefront in Germany, Britain and Japan, with typical representatives such as hydraulic damping descent device, folding inflatable escape pod, spiral escape ladder and nylon membrane inflatable bag[8]. For China, the escape rope (Fig.2a), escape slide (Fig.2b), escape ladder (Fig.2c), escape umbrella (Fig.2d), escape pipe (Fig.2e) and escape silo (Fig.2f) are the main representatives.

(a) Escape rope

(b) Escape slide

(c) Escape ladder

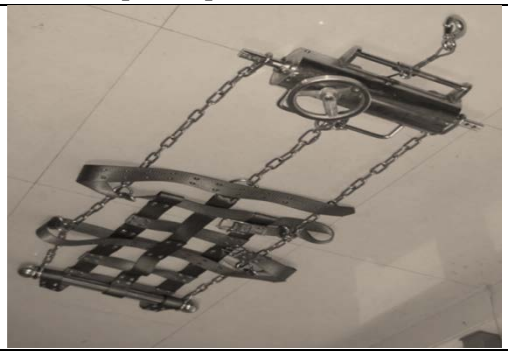
(d) Escape umbrella

(e) Escape pipe

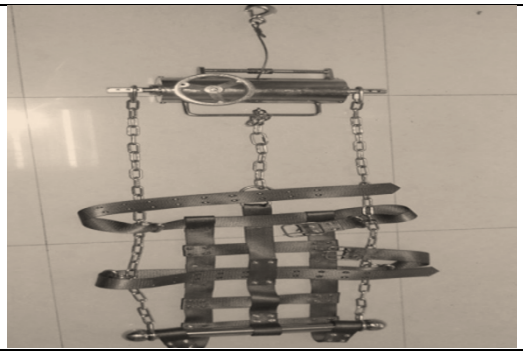
(f) Escape silo

Fig.2 Representative high-rise escape device for China

Besides, details of some typical high-rise escape devices are as follows. As shown in Fig.3, Oberon high-rise fire escape device [1] skillfully uses the principle of earth gravity, the lever principle, and the principle that the weight is directly proportional to the friction coefficient generated by the eccentric wheel of the lever. It solves the problems that have plagued people's rescue and descent of high-rise buildings, while almost applicable to women, the old, the young and all the crowd [11-15].



(a)



(b)

Fig.3 Oberon high-rise fire escape device

The spring based high-rise escape device can freely control the landing speed by applying torque to the coil spring to increase or reduce the friction between the coil spring and the steel wire rope. The escape elevator uses a special power supply to supply energy. The elevator car and cable are specially designed to ensure that the elevator can still work normally after a fire, which is extremely firm and can provide a safe passage for users. Furthermore, when studying escape by using the principle of air damping, Sha et al.[9] designed an air damping deceleration device. The damper uses the damping principle of flowing air to convert the potential energy released by people into air kinetic energy [16-18]. It uses the gravity of people or objects to drive the reel through the steel wire rope at a low speed, so that the big gear coaxial with the reel also rotates at a low speed, and the meshing pinion is driven at a high speed, and the fan impeller is coaxial, and the pinion also rotates at a high speed. To promote the air flow, the power limits its speed within a reasonable range to achieve the purpose of uniform descent of the human body. In the research on the descent speed of high-rise reducer, Zhang et al. [10] and others developed an intelligent control system based on the magnetic damping control principle and AVR microcontroller for speed control in the life cycle of spontaneous intelligence and advanced intelligence. In the research of spring damping reducer, Wang et al. [11] proposed a design scheme of high-rise escape device based on the spring unit. The design is based on the research scope of the spring diameter in the new application field when the torque T of the spring acts. The coil spring on the steel wire rope changes the size and spring diameter of the coil spring by applying torque T to the coil spring, so as to increase or reduce the friction between the coil spring and the steel wire rope by controlling the friction, so as to realize the purpose of freely controlling the descent rate [19-22].

In short, it can be concluded that all kinds of escape devices have been widely used in high-rise buildings, but the escape effect is limited by the environment, escape stability and braking laziness. In particular, there is no escape mode using the escapee's own gravity as the driving force, to

achieve the easy use, rapid and safe. Therefore, the design of uninterrupted high-rise escape device is of great significance.

3. Problems and Development Trend of High-Rise Escape Devices

High-rise escape device currently has the following three forms, that is, the first one is the liquid damping life-saving slow-down device, which uses the damping of liquid flow to convert load potential energy into heat energy to achieve slow-down. The disadvantage is that it needs to provide a hydraulic pressure source. The second one is the friction brake type (i.e., the life-saving descent device), which is a buffer device that uses mechanical friction to generate resistance to brake. The disadvantage is that it is difficult to control the friction resistance. The third one is the electromagnetic damping life-saving slow-down device, which uses electromagnetic induction and magnetic field to generate force on the current, and uses electronic technology to realize the automatic control of the life saving device. The disadvantage is that the human body cannot make the generator generate power for the control system to work at the beginning.

In summary, the problems of the high-rise escape devices for the high-rise buildings at home and abroad are as follows:

1) Most of the devices are of slow-down type design, and all need a fixed point. If the fire has spread to the entire building, using this type of slow-down device will cause the risk of falling and burns.

2) This type of device is cold in shape and has no affinity. Users generally place it in an inconspicuous place in the home. When a fire breaks out, it cannot be found in time, so it has its limitations.

3) A part of it is a res cue system, which is integrated with the building, with high technology content and high cost. This type of system can be developed to a certain extent in developed countries such as the United States, the United Kingdom, and Germany. In China, due to its own economic strength cannot guarantee the popularization of this type of system, the domestic high-tech rescue system is not feasible.

In short, the current domestic and foreign high-rise fire escape devices have certain limitations. This type of device basically needs to be attached to a tall building to work, and has no independence. If the building collapses or the building attachments fall due to a fire, this type of device will not be able to play a rescue role. In addition, some types of high-rise escape devices currently on the market still have a short time to come out and their functions have yet to be improved. In the actual operation process, there are some shortcomings, such as escape speed, low stability, and personnel landing. Problems, such as large impact at time, unsatisfactory coordination between work stoppage and damping system, should be solved in the future.

4. Conclusions

The frequency of high-rise building fire increases with the increase of the number of high-rise buildings. The development speed of fire-fighting equipment is far less than that of high-rise buildings. This contradiction promotes the development of high-rise building escape devices. Through unremitting efforts, the design of high-rise escape devices is becoming more and more mature, but there are still limitations. In order to further ensure the safety of people's lives and property, it is desirable to design advanced and efficient high-rise escape devices. In addition, considering the characteristics of high-rise buildings, many factors need to be considered in the selection and setting of high-rise building escape devices, such as escape efficiency, load range, descent speed, personnel psychology, maintenance, allocation quantity, etc. Therefore, it is also an urgent task to formulate a set of equipment standards for high-rise escape devices as soon as possible.

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