STRATEGIC FIRE ESCAPE BY ELEVATORS FOR SUPER-HIGH-RISE BUILDINGS

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ABSTRACT

The statement "In case of Fire, Don't use the Lift" appears at each landing in Hong Kong. In accordance with it, people are encouraged to use staircases during an outbreak of fire. This concept has been in the human mind for a century. As the buildings are getting higher and higher, we really need for someone to walk down 100 storeys in order to escape from a building on fire? The idea of using elevators for fire escape is not new. A review on works done by some pioneers is made in this paper. It is actually not easy to implement this idea to ensure the safety of occupants can be guaranteed by using elevators instead of staircases. Considerations in both technical and psychological aspects are highlighted in this paper. The aim of this paper is to activate more inputs and thinking from researchers around the world so as to come up with a perfect strategic fire escape plan by elevators for super-high-rise buildings.

1 INTRODUCTION

Fire safety design in buildings is one of the major issues of life safety design in buildings. It can be approached in 4 aspects, namely prevention from having a fire, controlling the spread of fire/ smoke, evacuating the occupants to places of safety, and rescuing people. Obviously, evacuation is not the first step for fire safety design. When there is failure to prevent the fire and to control its spread, evacuation of the occupants becomes necessary. However, absolute prevention of fire and controlling fire spread appears impossible. Therefore, the safe evacuation of occupants should the major concern for architects, building control officers, building designers, building managers and insures, as well as the occupants themselves. Moreover, fire is only one emergency situation. Other incidents such as the leakage of gases, bomb threats, earthquakes, and other violent situations should also be considered. Some of these incidents, even with the best fire protection and management systems, cannot be prevented. Provision of effective evacuation facilities in buildings appears indispensable.

As the population increases and valuable land becomes scarce, especially in those well-developed and developing countries, large complex buildings are constructed. Today it is not uncommon for a large building to have more than 50 storeys and to accommodate more than 10,000 occupants. In the near future, buildings more than 100 storeys are expected to be constructed everywhere in the world. Considerations should therefore be given to improve the efficiency of the evacuation system in such super-high-rise buildings. This paper aims at providing a view in incorporating elevators in the evacuation system and to activate more debates, inputs and thinking from researchers around the world so as to come up with a viable strategic fire escape plan by elevators for super-high-rise buildings.

2 REVIEW OF CURRENT SITUATIONS

In the existing code of practice on Building Works for Lifts and Escalators, Hong Kong, 1993, sign(s) bearing the characters "when there is a fire, do not use the lift" should be displayed on the outside of a liftwell at each landing level. Similar requirements are enforced throughout the world. In addition, elevators which are in normal service should return non-stop to the main terminal, and in case of fire, they should respond to corridor calls. It indicates that such elevators are not designed as a means of escape in case of fire (Sumka 1987).

Staircases are considered as the escape routes of multi-storey buildings in accordance with the traditional prescriptive code of practice. However, it has been found (Egan 1986) that evacuees will normally experience fatigue while travelling down in about 5 minutes (i.e. about 300 seconds). The average speed of the evacuees travel down one storey with normal headroom of 2.5 m per floor in Hong Kong is about 16 seconds (Pauls 1987). In this connection, fatigue will occur while the evacuees have travelled about 18 storeys. For buildings over 100 storeys, people may need to have 5 stops for travelling from the topmost floor to ground level. If an evacuee requires 60 to 120 seconds for the rest at each stop, he/she will require about 1900 to 2800 seconds for travelling from the 100th floor to ground level. This indicates that the time for vertical movement in a super high-rise building is extremely extensive. Therefore, if one believes that evacuation is an essential strategy for fire safety design in buildings, mechanical means for vertical transportation appears necessary for super high-rise buildings.

The idea of using elevators for fire escape is not new. Bazjanac (1973) studied the performance of elevators in high-rise buildings under emergency situations. He indicated that the automatic elimination of elevators from service in case of emergency is incorrect. With the assistance of elevators, the evacuation time could be reduced. However, elevators should only be used in case of emergency when their operation is safe. With proper planning and control of evacuation process, elevators can accomplish safe evacuation for high-rise buildings. Recently, many researchers have carried out the studies on elevator evacuation. For example, Klote (1993) developed a methodology (the ELVAC programme) in calculating the evacuation time by means of elevators; Croner et al (1992), Klote et al (1992) etc. studied the human behaviour of the people using elevator evacuation. In addition, elevator evacuation can be used for the disabled (Fox 1991; Kose 1995).

3 SYMPOSIA ON ELEVATORS, FIRE AND ACCESSIBILITY

Actually, The American Society of Mechanical Engineers had paid attention to this issue since 1991 by organising two national symposia on relevant topics. The first symposium was held in February, 1991 in Baltimore, Maryland. Its purpose was to educate code users on the intent and application of the current requirements and to explore alternatives which could improve the national standards. Following the first symposium, the ASME A17 Code Coordination Committee met to identify potential areas for revisions to the A17 and NFPA standards and to the Model Building codes. The second symposium was held four years later in April, 1995 in the same city. The purpose of the second symposium was to continue the discussion regarding elevators, fire and accessibility in the hope of gaining even greater coordination between the ASME A17 and the Model Building Codes.

In the 1995 symposium, various issues were addressed to identify the needs of elevators to service during fire outbreak. Nick (1995) concerned about the high temperature inside the machine room during fire outbreak, thus endangering the lives of passengers since all electro-mechanical and sold state devices were subject to maximum operating temperature levels. Solutions to problems related to elevator reliability during fire conditions in terms of electrical power dependability, microprocessor control sensitivity, smoke, heat and water were suggested (Brooks Semple 1995). The issue of standby power and elevator safety was discussed (Caldwell 1995). Codes regarding elevators for emergencies were discussed and analysed by Gatfield (1995).

The concept of an emergency elevator evacuation system (EEES) was developed (Klote 1995) and that included the elevator equipment, hoistway, machine room, elevator lobby, as well as, protection from heat, flame, smoke, water, overheating of elevator machine room equipment and loss of electrical power. One point that is worth to note is that the EEES took into account of human behaviour so that the building occupants were willing and capable of operating the system in an emergency. However, it was admitted that the EEES was successful for a small number of passengers only. The integration of smoke control systems and fire protection systems along with evacuation procedures for the use of elevator systems during fire emergencies in the 21st century were discussed by examining a total approach for the safe use of elevators for occupant evacuation during fire emergencies (Chapman 1995).

Regarding human concerns, Levin (1995) and Holt (1995) believed that passengers would only use the elevator systems for evacuation during fire provided that good education and adequate information had been provided to the passengers so that they trust upon the reliability of the systems because passengers would always seek to minimise their risks during a fire emergency.

4 THE PROBLEMS

Based the extensive survey presented above, a comprehensive summary of issues related to the safe evacuation of occupants is included below. We are concerning about both hardware and software problems. Hardware problems are associated all sorts of technical features of elevator systems that ensure safe operation during fire emergency. Software problems are related to human behaviour and two factors must be considered here. People must first of all understand how to use the system during emergency and they need to trust the system and are willing to use it. Secondly, the designers must ensure high risk will not be the result if people fail to use the system properly.

4.1 The danger of machine failure

This is a hardware problem. The failure may be due to power failures, destruction of elevator control mechanisms and wiring due to high temperature, and other damages to the equipment in general. Normally, the maximum ambient temperature inside a machine room is limited to 40°C. During fire emergency, the temperature will be much higher than this level. For example, designers have been expressing concerns about the high temperature that may destroy the microprocessor controllers. However, it is believed that such problem is not difficult to solve if the whole system has been designed based on a very stringent specifications on high fire rating.

4.2 Obstruction of the firefighting/ rescue personnel to the dangerous area

This is a software problem. The use of elevators by the evacuees in case of fire may interfere with operations of firefighting/ rescue personnel. Occupants endeavouring to escape may congest the lift lobbies and the associated regions. Accordingly, the firefighting/ rescue personnel may find it difficult to reach the area of danger.

4.3 Inadequate elevator operation configurations

This is a hardware problem. The capacity of an elevator system is generally designed for normal up-peak demand, say 15% if total population within a period of five minutes. During fire emergency, occupants of every floor gather in the lobby of every floor, waiting for services. Certainly, the capacity is not adequate to handle all these passengers. Normally, there are quite a number of stops within one round trip and therefore, the evacuees inside the elevators and those waiting for elevators may be frustrated when they need to wait for quite a long period of time before getting to the main terminal. Also, at present, the emergency standby electrical generators are only adequate for the operation of the firefighting elevator and one elevator running at a particular time. For full operation of the whole elevator system for evacuation, the rating of standby generators must be very much increased.

4.4 Elevators passing through zones of danger

This is both a hardware and software problem. The heat and smoke may cause mechanical failure or malfunctioning of elevators, or live loss. For example, elevator doors may unscheduledly open on floors engulfed in fire; smoke that penetrates into the hoistway will endanger the evacuees in the elevators because the amount of oxygen inside the hoistway will be greatly reduced and passengers will suffocate.

4.5 Water exposure

This is a hardware problem. Water exposure to elevators during fire extinguishment may influence the normal operation of the elevators. There are electronics and electrical circuitry on the car top and on the walls of hoistway and they are not resistive to water spray. Effort should be taken to study the effects of water on elevator safety.

4.6 Complex psychological reaction of the evacuees

This is a software problem. Escape process involves spatial problem solving process (Lo and Will 1995). Cognitive mapping plays a central role in the people's ability to solve spatial problems (Passini 1984). The elevator system in a building which is the major means of vertical transportation will be stored as an image on the occupants' cognitive maps. Such image will then influence the movement of the occupants under emergency situation.

In super high-rise buildings, the image created by the staircases may not be clear as they are seldom used by the occupants for vertical movement during normal situation. Accordingly, in a traditional escape system, directional signs have been provided to influence the "normal" movement patterns of the occupants and divert them to the staircases. However, if the elevator system is adopted as part of the escape system and directional signs are also used to facilitate the use of such system, majority of the evacuees will use the elevators for escape. The capacity of the elevators may not cater for total evacuation in a building. This indicates that some of the evacuees need to wait for sometime before they can enter the elevators. It has been found that the stress level of the evacuees will be increased with time (Proulx 1993). Although the evacuees will normally not experience panic (Wood 1972; Sime 1980; Bryan 1991; Lo 1996), the increase in stress level owing to the waiting time will redefine the perceived level of threat of the evacuees. This will impair the decisional control which is one type of personal control for the people to exert over threatening circumstances (Averill 1973) and influence the evacuees' decision to wait for the elevators.

More than that, when one elevator car arrives at a floor with number of passengers much beyond the rated capacity of the car, the situation may get worse because people under panic will all force into the car. The result is that the elevator cannot operate at all. This situation is highly possible and hence, the controller must ensure the elevator car(s) can accommodate all passengers before taking a stop at a particular floor. Otherwise, the disaster may even be larger.

5 THE DESIGN AND CONSIDERATIONS

The problems highlighted in the aforesaid section include technical (hardware) and psychological (software) aspects.

5.1 Suggested solutions to hardware problems

For tackling item 4.1, if the military grade of integrated circuits and electronic components are employed for elevator controllers, just like that used in traffic light controllers, the system can stand high temperature for a much longer period of time until all occupants have arrived at safe locations. Of course, some sort of warning must be available to warn the occupants not to use the elevator system in case the temperature inside the machine room has reached an intolerable level. To handle item 4.3, an improved control scheme may serve the purpose. It is true to say that the elevator system, designed for normal operation, cannot handle all occupants during fire emergency. However, fire outbreak will initially occur at a particular location instead of the whole building. .Floors close to the fire source should be given priority so that elevators will serve these floors first. Of course, a good information system is definitely necessary to instruct the occupants where is the fire source and which floors are given priority to use the elevators. Regarding standby generators, the design can be based on the normal full-load capacity of each elevator drive so that standby electrical capacity will not be too high. The elevator controllers must co-ordinate with one another so that no two elevators accelerate or decelerate at the same time because it has been proved that the power consumption of an elevator will be much higher during acceleration and deceleration, currents being three times or four times of the rated values. Regarding item 4.4, it was proposed during the 1995 ASME symposium that all elevator shafts should be pressurised and all lobbies should be enclosed and pressurised while air intakes for the elevator shaft and lobby pressurisation systems should be from a smoke free location and all elevator lobbies should have access to a pressurised stairway without passing through another fire area (Chapman 1995). In this way, smoke and heat cannot get into the hoistway and endanger the lives of passengers. Further than that, Chapman suggested all elevator systems should be made resistive to water, thus tackling item 4.5. Actually, this is technically possible but the cost will be quite high because water resistive design will increase the ambient temperature of the components and thus the components must also be heat resistive.

5.2 Suggested solutions to software problems

To handle item 4.2, certain elevators that have been assigned as firefighting lifts must not be used for evacuation, similar to current practice. Also, passengers reaching the main terminal must leave the building immediately so that the lift lobby will not be overcrowded. For item 4.4, the control system must be able to identify the location of the fire source(s) and prevent the elevator cars from stopping at these floors. If the lobbies are enclosed and pressurised, the situation will be totally different. These floors must then be given first priority for evacuation.

Regarding item 4.6, in order to deal with the complex psychological reaction of the evacuees, it appears that the evacuees' personal controls on the threatening situations should be considered. If the evacuees can stay at a place of safety (temporary), their stress can be psychologically reduced. The decisional control of the evacuees can assist the evacuees to escape in a rational manner. The elevator system should be considered to operate between such temporarily safe place and the ground level (discharge floor). In addition, such temporarily safe place can serve as a basis for the firemen to fight the fire. Once people have reached a temporarily safe place and see firefighting personnel there, they will be psychologically relieved and more confident of their personal safety. The firefighting/ rescue personnel can assist the evacuation process by using the elevator system. It is considered that a temporarily place of safety should be a designated floor which is separated from other parts of the building by adequate fire resisting and smoke checking construction. In Hong Kong, designated refuge floor, usually the mechanical floor housing the electrical and mechanical building services equipment, should be provided for super high-rise buildings at 15 storey intervals under the Code of Practice on Means of Escape in Case of Fire, 1996. Such floors can be used as the basis for transmitting the evacuees to the ground level.

Another point mentioned in item 4.6 addresses the fact that it is better not to serve a floor unless the control system is sure that the car(s) is(are) adequate for all passengers at that floor. Here, the idea of using computer vision to recognise the number of passengers waiting at the lobby seems to be the only way out. Computer vision systems have been developed and implemented for elevator control (So 1992, 1993; Alani 1995). By using computer vision, it is possible to count the number of passengers waiting in a lift lobby as well as in each elevator car. The controller then decides on the number of cars that must be sent to serve an individual floor so that all passengers can be served simultaneously unless the number of passengers far exceeds the system capacity.

6 CONCLUDING REMARKS

The basic reason why the authors believe that the elevator system must be used as a means of evacuation during fire emergency has been discussed in this paper as the introduction. A comprehensive literature survey on recent research into the issue has been carried out. It seems that people who support the idea have been increasing in number during these few years, and in particular, lots of attention has been paid to such issue by the American Society of Mechanical Engineers. It is the desire of the authors that such issue can extensively and intensively be looked into by members of the International Association of Elevator Engineers. Problems that are intrinsic to the implementation of such idea have been highlighted in the paper and possible solutions have been proposed for further discussion. This paper does not provide solution or design guideline but the aim is to stir up interests among our members so that advancement in technology can be made to bring this idea to a realistic manner. Lots of recent research have been concentrated on hardware or technical developments while the consideration of human behaviour has got less attention. It is hoped that researchers in this area will look deeply into the study of human behaviour during fire emergency to make the idea of elevator evacuation really work safely and effectively.

7 ACKNOWLEDGEMENTS

The authors would like to thank Mr. John Inglis for his kind contribution of lots of important information and documents related to this issue. The project is partially supported by the Strategic Research Grant #7000505 of City University of Hong Kong. We are also indebted to the support from the International Association of Elevator Engineers (HK-China Branch).

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