FIRE RISK ANALYSIS OF THE AIRPORT TERMINALS

M.Y. Ng
Department of Building Services Engineering, The Hong Kong Polytechnic University, Hong Kong, China

ABSTRACT

The new airport at Chek Lap Kok serves as a gateway to Hong Kong and acts as a transfer point to passengers for tour and business. The terminal building is expensive with billions of dollars of construction cost. Therefore, it is very important to ensure life safety and normal operation of the airport. Site visits without disturbing the normal operation of the airport were carried out to understand the safety aspects of the airport. The retail areas were identified to be the key area of concern. By touring around and observing what a passenger can see, fire safety in the retail areas was studied. A design fire was suggested for studying the probable fire environment in those retail shops. The two-layer zone model Hot Layer of FIREWIND version 3.5 was used as the simulating tool. Two retail shops were selected for a more detailed analysis. Key parameters such as the fire load density of each shop were estimated. The software FRAME version 2.0 was applied for the fire risk analysis.

Fire safety strategies in the retail areas were then developed. They should be defined and stated clearly in order to provide a safe, cost-effective and sustainable building. The strategies would be grouped under four headings, i.e. Passive Building Construction, Fire Services Installation, Fire Safety Management and Control of Risk Factors on the specific features mentioned in the airport terminals.

Keywords: retail areas, fire environment, heat release rate, flashover, fire risk analysis

1. INTRODUCTION

The new airport terminal in Hong Kong was opened on 6 July 1998. It is one of the biggest passenger terminals in the world and has an 8-level building of approximately 450000 m^2 of gloss floor area containing a wide variety of occupancies and functional areas [1]. The airport was built to stimulate economic growth by encouraging tourism and to handle an annual capacity of 35 million passengers and 1.4×10^6 tons of air cargoes [e.g. 1]. It is very important that fire safety provisions [2] should be provided properly to ensure life safety and continuous operation of the airport.

An accidental fire happened before the airport was in use. That fire was upgraded to a 'third-alarm fire' quickly and the flame and smoke also spread quickly throughout the building. Luckily, no one was injured [3]. It is very obvious that the target of the terminal building is not to have a fire, and even when a fire occurs, it has to be confined without spreading out to limit the number of occupants being affected and the losses incurred.

When there is a fire, it is characterized by the large number of people at risk. Frequent users, e.g. staff, are expected that they can easily recognize the nearest escape route to evacuate. However, for occupants who are infrequent users, such as the passengers and visitors, they are unfamiliar with the building and would have difficulties in locating the escape routes. Apart from the property losses caused by the heat, smoke and sprinkler water to the retail shops located in the airport terminals, time loss in replacing key fire-damaged objects would also be considered. The interruption to the business would pose a poor public image and cause a huge amount of monetary losses.

It was identified that the retail areas of the airport terminal building should be assessed. In order to minimize the risks of occupants and monetary losses, workable fire safety strategy should be provided for the airport terminals. The strategy [4] should be clearly identified so as to achieve not only a good standard of fire safety but also better buildings.

2. SPECIAL FEATURES FOR THE AIRPORT TERMINAL

Due to the architectural reasons, large halls were constructed in the departure areas and arrival areas. As the ceiling height of those halls is very high and the space volume is very large, conventional sprinkler heads and smoke extraction system cannot be designed easily. Cabin design was utilized in the shopping areas of those halls. Besides, the building facade and the restaurant areas are constructed with curtain wall. Extensive use of glass is used to give an aesthetic effect. On the other hand, parts of the departure hall are used as exhibition areas and coffee lounge areas, giving larger amount of combustibles.

The occupants would not be distributed evenly inside the terminal building. Except the retail areas of the departure hall and arrival hall, the departure hall and arrival hall would not be overcrowded with passengers normally. The staying time for the passengers in the departure hall and arrival hall would be long, i.e. 1 to 2 hours, for carrying out the check-in procedures in the departure hall of the non-restricted areas and security checking no matter in the departure hall or arrival hall of the restricted areas. Especially before the security counters, it is found that large amount of the passengers would be queued up.

In case of an emergency, the majority of escaping passengers will take their hand-carrying baggage with them. If the baggage is very large or heavy, this will not only hinder the evacuation of the passenger, but also affect the escape of the other occupants. The escape route may be blocked by the crowd movement inside the evacuation path if the escape route is too narrow.

The fire load density inside the terminal building would not be too high since the hand baggage of the passengers would only have very low fire load density [5]. But for the retail shops, fire load density in such areas would be very high. Therefore, they need to be grouped together and protected separately from other premises.

3. RETAIL AREAS

There are two retail zones in the non-restricted areas at the arrival level and the departure level of the airport terminals. Restaurants are found at the dining area of the departure level. In addition, fast food services are provided at the arrival level. Typical combustible contents are similar to those retail shops in elsewhere. There might be restrictions on the types of goods to be sold imposed by some building management team such as those in passenger terminals. Combustibles stored are basically newspapers and magazines; cigarettes and tobacco; alcohol and furniture including polyurethane sofa or cushion; coffee tables with wood or other timber products and chairs.

In order to realize the fire environment inside the shops, the two-layer zone model HotLayer in the fire engineering calculator FIREWIND version 3.5 [6] was used to simulate the fire environment. A design fire similar to burning a soft toy mountain [7] was used. The heat release rate Q (in kW) at time t(s) is given by:

$$Q = \begin{cases} 1000\left(\frac{t}{300}\right)^2 & t \le 342s \\ 1300 & t > 342s \end{cases} \quad (1)$$

To find out whether flashover would easily occur inside the retail shops, the minimum heat release rate Q_{fm} (in kW) for flashover was estimated using the equation by Thomas [8] for a shop of length L (in m), width W (in m), height H (in m) and with an opening of area A_v (in m^2) and height H_v (in m). For a retail shop with a door of ventilation factor $A_v\sqrt{H_v}$ burning an item of heat release rate greater than Q_{fm} is likely to have flashover. For example, a shop of length 7 m, width 7 m and height 2.3 m with an opening of width W_v 8.5 m and height 2.3 m would give A_v of 19.55 m^2, $A_v\sqrt{H_v}$ of 29.65 $m^{3/2}$ and so Q_{fm} is quite big at 12.3 MW. If the door is closed, leaving a gap of 0.01 m high, Q_{fm} is only 1.3 MW. Therefore, flashover can occur easily in an 'enclosed' retail shop.

Poor operation of retail shops such as excessive storage of goods because of high rental prices, blocking the sprinkler heads, and covering the extraction vents by goods might give rise to a very big fire. Therefore, the amount of combustibles should be restricted inside the shops. The shops should fulfill the upper limit on fire load density in local codes [e.g. 9], i.e. 1135 MJm^{-2}, and reduce the excess stock stored. Combustible items should also be kept away from the door sides so as not to block the exits.

4. THE SELECTED RETAIL SHOPS

From the tour round the retail areas in the new airport terminal, two retail shops for selling books, toiletries, food and bags at arrival level and books, magazines and stationery at departure level were selected for further fire risk analysis. The fire risks for the shops and their contents, for the occupants, and for the business activities were calculated using FRAME version 2.0 [10]. The results would be summarized below:

- Potential Risks

The potential risk for occupants in each shop is much higher than the risk of property loss and business interruption. More attention should be paid on the protection for occupants in the retail shops.

- Acceptance Levels

The values of the acceptance levels for all shops are greater than 1.0, indicating that the provisions are satisfactory.

- Initial Risks

For shops with initial risks less than 1.0, providing manual fire fighting equipment is sufficient. From the tour round the site, fire extinguishers, fire hydrants, and hose heel systems are found everywhere in the airport terminal. There are sprinklers installed inside each shop. Therefore, the level of protection for each shop is adequate.

- Protection Levels

The values of the protection levels for occupants are the lowest. Something should be done on providing better protection for occupants in the retail shops.

- Fire Risks

The fire risk is obtained as the quotient of the potential risk divided by the acceptance level and the protection level. For a building with adequate fire protection, there should be an equilibrium between the risk and protection, giving values of fire risk equal to or less than 1. A higher value indicates that fire safety provisions in the compartment should be upgraded. On the other hand, a lower value represents a better situation.

The values of fire risks for the building and its contents, and the activities in each shop are below 0.05, indicating that the risk of loss of property and business interruption is small and the protection is adequate. Although all the values of fire risks for safety of occupants are below 1.0, the values are much higher for both shops, i.e. above 0.6.

5. FIRE SAFETY STRATEGIES

Fire safety strategies are divided as:

- Passive Building Construction (PBC)

– Building Structure

The main objective of providing PBC is to confine the fire area when the 'preventive' defense line is broken when a fire occurs. Providing fire resistance construction is to ensure that the fire will be burnt out within the confined area when the combustible materials are consumed. The fire resistance period (FRP) [e.g.11] should be longer than the duration of the fire.

Extensive use of glass is employed for the building facade. To avoid imposing any hazards on the occupants or the fire fighting personnel, glass with special treatment should be installed to avoid breaking into small pieces in case of fire.

– Compartmentation

For the compartmentation inside the airport terminals, fire shutters satisfying the criteria of integrity or water curtains would be good in separating the areas of the big halls into several compartments in case of fire. This would block fire spreading from the fire zone to the adjacent premises. Other than fire shutters, smoke barriers or smoke screens would also be used to give smoke compartments. The smoke would be removed by means of the static or dynamic smoke control systems. About the retail areas, water curtain would also be installed in front of each shop so as to reduce the heat transmitting through the openings of the shop.

– Exhibition areas

The spaces of the airport terminals are not supposed to be used as coffee lounge areas and exhibition areas. Fire safety provisions may not be able to control a fire when the spaces are used as those purposes. Fire shutters satisfying the criteria of integrity should be installed to separate these areas. However, the best way is to stop using the space for those proposes.

- Fire Services Installation (FSI)

– Sprinkler system

Sprinkler will only work when the design is appropriate for that application. Inside the retail areas, discharging water too early before evacuation will wet the floor and give a slippery surface. Hot steam produced will hurt passengers. Therefore, Early Suppression Fast Response (ESFR) sprinkler heads might not be suitable to use.

In fact, sprinkler systems might not applicable to be installed inside the halls due to the high ceiling. The higher the ceiling, the lower the temperature of smoke when it reaches the sprinklers and so the time for the activation of sprinkler is delayed. Also, there may not be adequate water droplets to reach the fire area. Therefore, smoke temperatures at different ceiling levels above a fire should be predicted if sprinkler systems are chosen to be installed inside those halls.

- Smoke extraction system

  The smoke particles cooled down by the sprinklers would be pulled down. As the smoke vents of those shops are installed in the floor level, descending of the smoke layer would be further accelerated. If occupants are not evacuated efficiently, a dangerous situation would be occurred due to the high optical smoke density and low visibility. Therefore, when the smoke management system is activated, all the occupants should have been escaped.

- Fire Safety Management (FSM)

  FSM is adopted to minimize the occurrence of fire. This is including good housekeeping, staff training, the actions to be taken when fire is occurred and fire prevention. FSM should include at least, routine checking of the emergency systems; frequently fire emergency exercises for the operational staff, involving fire-fighting and rescue operations; minimum storage of dangerous or flammable goods; adding fire retardant to combustibles and good fire education for occupants.

- Control of Risk Factors (RF)

- Passenger loading [12]

  Except the retail areas, passenger loading inside the airport terminals would not be too high. However, before the security counters, it is always found that large amount of the passengers would be queued up. When emergency is occurred, the escape route may easily be blocked and increased the risk of occupants being subject to fire and smoke. Therefore, in order to minimize the staying time of the passengers inside the airport terminals, it is important to increase the number of security counters to be operated so as to shorten the waiting time for security checking of each passenger.

- Fire load density

  The amount of combustibles inside each shop of the shopping areas should be restricted to the maximum fire load density, i.e. 1135 MJm^{-2} as indicated in the local code [9]. Those combustible items should be kept away from the door sides in order not to block the exit and accelerate the spread of fire. Besides reducing the fire load, the location of the mobile combustibles would change the potential risk. Increasing the distance between the goods would reduce the fire risk.

  In case of fire, the majority of escaping passengers will take their hand-carrying baggage. Although hand-carrying luggage of the passengers would not pose a high fire load density [5], excessive combustibles carried by passengers should be prohibited.

6. CONCLUSIONS

Fire load density inside the cabin may be quite high if it is used as a retail shop. The ceiling of the shop might give strong downward radiative heat flux if it is heated up to high temperatures. Flashover may occur and sufficient amount of fresh air can be supplied through the open sides of the shop. Fire hazards on retail shops in a terminal building had been assessed by using the two-layer zone model Hot Layer in the fire engineering calculator FIREWIND version 3.5 [6]. Under a 1.3 MW soft-toy mountain fire, it is found that smoke would fill up the shop but the smoke layer temperatures are lower than the flashover temperature. However, the minimum heat release rate for flashover to occur should be considered. Depending on the geometry and ventilation conditions, flashover might occur easily for some shops with a fire of small heat release rate.

The fire load constituted by the airport terminals would be low if there are no shopping facilities inside the building. However, several retail shops are located inside the terminals, fire load density in such areas would be very high. If a fire occurred in any one of those shops inside the arrival hall or departure hall, flame and smoke would spread quickly to the other retail shops and the hall. Besides, two retail shops were selected for fire risk analysis with FRAME version 2.0 [10]. The results illustrated that something should be done to improve the provision for life safety, as this is the utmost important fire safety objective to be considered.

Safety of the airport terminals can be improved by applying proper fire safety strategies. The following are suggested to be included in the fire safety strategies of the airport terminal building:

- Smoke filling in the terminal halls due to a retail shop fire
- Water mist fire suppression system
- Drencher system

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