Fire Safety in a Modern Atrium : Site Visit and Visual Inspection

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INTRODUCTION

A modern atrium of good appearance was found in the city centre of Melbourne, Australia. This atrium is located in a mall with a big departmental store. It is of open design where various shopping levels are opened to the atrium. There is a historical building inside the atrium. The atrium is of cylindrical shape with a hollow glass cone placed above it. Very present environment was resulted and so many people were attracted to stay in the atrium.

Interest lies on the fire safety design provided in the atrium. A visual inspection was made while touring around the space. Fire protection systems which can be seen were recorded. The potential fire hazard was assessed by identifying different scenarios. It must be pointed out that those identifications come from observation as a shopper, rather than from the views of a fire engineer as no fire safety strategy nor fire protection systems details were obtained. The points raised come from general views of the public, but attempted to answer in a scientific manner.

THE ATRIUM

The atrium is of floor area 950 m^2 and height 76 m. It is of cylindrical shape at the lower part up to 26 m and the upper part is of conical shape. The total space volume of the atrium is 40,000 m^3 , with the cylindrical part of 25,000 m^3. A pictorial presentation on the atrium geometry, functional area and fire engineering systems observed are shown in Figure 1.

The cone structure above it is of 20 storey high which is about 50 m. It is covered by tinted glass and supported by structural frames. Daylight available can penetrate through the glass and fall to the atrium floor, giving a comfortable visual environment. The cone should be cooled by air for keeping the glass temperature not too high and preventing draught induced by natural convection. However, the cone itself can be used as a smoke reservoir in case of fire. There are horizontal vents at the top of the cone as shown in the figure, the total area is estimated to be 16 m^2.

The cylindrical atrium is opened to a 7 level shopping mall, housing a big departmental store, a food court, several restaurants and over 160 shops of fashions, shoes, gifts, accessories, homewares, essentials and decorative. The shopping mall can be accessed from the Ground floor (G/F) level and from adjacent shopping malls through bridges at levels 1, 2 and 3. The atrium floor is taken as a circulation area for human traffic flow. There are small shops of area from 10 m^2 to 100 m^2 in G/F, levels 1 and 2.

Dinning area were found at a corner of the atrium floor. There are 2 other dinning area at the level 2 atrium boundary, with one of them being a food court.

Levels 3 to 5 are corridors surrounding the atrium and are in fact the shop facade display of a big department store. The minimum width of the corridor is 3 m.

A zone where consists of a kids care centre, a TV game centre and an interior play ground is at level 3. The kids care centre is only accessible through the atrium surrounding corridor Parents can leave their kids in this zone while shopping in the departmental store.

Level 6 is a mechanical service area where it is unoccupied normally.

A historical building with a tower of height 50 m is sited inside the atrium. Many people were attracted to visit the atrium because of this special feature. There are 2 levels of shopping area labelled as M1 and M2. The M1 level is between G/F and 1/F of the atrium and used as an open dinning area, a kitchen and a retail shop. M2 level of the tower is used as a fashion shop and a shoes shop. Assess to the tower is from 2 staircases at level 1 of the atrium and other 2 staircases from G/F. Upper part of the tower is normally unoccupied.

A stage of 0.5 m high for performance show is located at the G/F. It is connected to level M1 of the tower but only accessible from the G/F of the atrium. Special events lasting from a day to a week such as fashion show, exhibition, seasonal sale and entertainment will be scheduled regularly for attracting more people to the mall.

HUMAN EVACUATION

This atrium is obviously a place of attraction to people. Survey in a quiet weekday afternoon at 4:00 p.m. illustrated that there were 40 persons sited in dinning area, 50 persons sited on the stage and 25 persons were either walking or standing in the atrium level, giving a total of over 300 persons staying inside the atrium or at the atrium surrounding corridor.

There are 3 groups of exits at the upper levels' corridors. Each exit group has 2 exit paths and to be used for escape in case of emergency. The measured maximum travel distance of a person at the corridor to the nearest exit is 30 m. Exit signs are seen but there is no indication that where is the shortest escape route from the atrium and where the exit will lead to. Those escape routes are not supposed to be used under normal situations.

Human flow traffic in case of fire is a point of concern. People staying in the atrium might not be able to know that there is a fire because the space is far too big. Evacuation in stages is not a practical method for those people wandering the mall. Evacuating so many people staying in the atrium or at the atrium corridor is not easy. The occupancy is even higher during fashion shows or singing performances. Exhibition boards and temporary display items placed in the atrium would block the sight of the exit signs and escape routes. Whether those people can escape within a short period of time after a fire is a big question.

Children left in the kids care centre might be safe, provided the staff are well trained and know what to do in case of fire. However, children staying at the TV game centre and the interior play ground might be trapped as they should have no practice in leaving the atrium. As a result, parents leaving their kids in there would go to this zone using the same escape route but travelling in the opposite direction. Traffic flow resistance would be significantly increased.

The use of circulation space as a dinning area would block the escape route and reduce the occupant flow rate. A longer travel distance and a longer escape time would be resulted.

FIRE ENGINEERING SYSTEMS OBSERVED

Sprinkler heads were found at the ceiling throughout the shopping area and the atrium corridor. Side-wall mounted sprinkler heads were found in the dinning area at G/F of the atrium and the M/F of the historical building tower. Sprinklers were not found in some balconies, including a 20 m^2 balcony at level 5 and 2 other 15 m^2 balconies in the atrium. However, 5 sprinkler heads were found at the bottom of the level 5 balcony where it is used as a canopy of the atrium; and 3 sprinkler heads at the bottom of the other two balconies.

Smoke detectors were found at the corridor ceiling, covering area of 50 m^2. Hydrant, hosereel and break-glass alarm were found near the exit at each floor. No smoke curtain was found for isolating the corridor from the atrium. Vertical plastic barriers of 1.2 m width and 0.8 m height were found at the corridor ceiling from levels 3 to 5. However, such barriers were not found at G/F, levels 1 and 2. It is not sure whether those barriers are good enough to be classified as smoke barriers.

Fire shutters are observed at distances 10 m to 20 m from the atrium boundary. The distances seem to be very long and there are retail shops in there. A fire alarm was observed at the top of each fire shutter. It is believed that the alarm will be sounded upon operation of the fire shutter. The fire shutter is supposed to isolate the TV game centre, the interior play ground and the adjacent shopping malls in nearby buildings from the atrium. There are 2 main entrances each of 4 m wide and 2.8 m high for the department store from the G/F to level 5 A metal shutter for security was found at each of those main entrances. A number of security shutters were found at bridges connecting to other buildings.

POTENTIAL FIRE HAZARD

Following the site visits and visual inspection on the atrium, the potential fire hazard scenarios are identified :

Fire might be started from the kitchen in the tower of the historical building. In fact, it is not a good practice to have kitchens at the atrium floor. The fire load density at the atrium will be increased. There is a higher chance to ignite the combustible contents because of the gas cookers and electric ovens for warming coffee and tea. Further, there are shops located above the kitchen which are selling fashion and shoes. Presumably, wooden and plastic products are found. Fire spread from the kitchen might ignite those combustible products and give out smoke and heat.

Another point of concern is the tower itself. Smoke liberated from a fire in the kitchen would give a wall plume flowing along the tower surface, entraining the surrounding air to give lots of smoke. It is very difficult to design workable smoke control system in such an arrangement. Perhaps the 'cabin' concept by Law [1] can be applied for enclosing the kitchen. However, why is a kitchen designated in the atrium ?

Spaces adjacent to the atrium are mechanically ventilated. Those spaces are owned by different people and so the operation schemes for the ventilation control are different. The resultant pressure distribution due to different operating conditions of mechanical ventilation systems would affect smoke movement. How smoke will spread from the fire room to that area not completely isolated from the atrium is uncertain.

It is nice to see no sprinklers in the atrium space [2] but there are sprinkler heads at the canopies over the atrium. This will create the same problems as from the high headroom atrium sprinklers. Activation of the sprinkler heads at the canopies would discharge water to cool the smoke layer and reducing the buoyancy. The downward drag of the water droplets acting at the smoke layer would pull the smoke layer down. Smoke logging would the be resulted. Hot steam generated would hurt the occupants trapped in the atrium.

SMOKE EXTRACTION SYSTEM

A stratified air layer might be formed at the atrium cone due to solar heat gain in the summer and the lower wall temperature in the winter. In summer, heating up of the cone glass wall will keep a hot air layer and induced cool air to enter the atrium. Draught might be resulted. Therefore, cooling the glass wall is necessary. In the winter, the cold wall will cool the adjacent atrium air and make it sinks to lower levels. Warmer ambient air will displace the cool air and air motion is induced. Air motion resulted will affect smoke movement, and might affect the performance of smoke control systems as well.

The space volume of the atrium is 40,000 m^3 and designing smoke extraction systems with an extraction rate of 6 air changes per hour means 6.67 m^3s^{-1}. It is very difficult to have fans with such a large volumetric flow rate. Several fans have to be installed but the spacing is important. Bearing in mind that the cone glass surfaces will induce air motion itself after heating up in summer and cooling down in winter. The pressure distributions arose from buoyancy and stack effects must be considered carefully [3, 4].

SPRINKLER ACTIVATION

There are sprinkler heads found in the atrium at heights 4.5 m, 5.6 m, 18.4 m and 22.2 m above the floor. Thermal activation of those sprinkler heads was studied using the fire safety calculation programs FIRECALC [5]. Suppose the ambient temperature is at 23 °C and the NFPA t^2 fire [6] was assumed at the atrium. The four types of slow (S), medium (M), fast (F) and ultra-fast (U) were considered. Heat release rate of the fire was confined at 5 MW and the burning duration is up to 30 minutes or 1800 s [7]. The sprinkler heads were assumed to have response time indices of 50 (fast response sprinkler head) and 200 $m^{\frac{1}{2}}s^{\frac{1}{2}}$ respectively, with activation temperature of 68 °C.

The activation time calculated from FIRECALC was shown in Table 1. It is observed that sprinkler heads will not be activated for height 18.4 m and 22.2 m above the atrium floor. It would take quite a long time to be activated even for the fast response sprinkler head under an ultra-fast t^2 fire.

CONCLUSIONS

Fire safety aspects in a modern atrium are discussed from the observation in a site visit. Visual inspection while touring around the atrium would bring many questions. For example, people might be concerned about having a kitchen in the atrium floor, and what happen when there is a kitchen fire ? Why are sprinklers located in some part of the building but not in the other part.

The followings are recommended from this preliminary study :

1. Kitchen should not be found in the atrium floor, particularly inside the historic building which is supposed to be well kept.
2. Smoke extraction systems to be installed below the glass cone and activated as soon as a fire is detected.
3. Proper training and planning of human evacuation in case of fire must be provided, especially in the zone with a kids care centre and a TV games centre.
4. Sprinklers at the high canopy of heights 18.4 m and 22.2 m are suggested to remove. It is difficult to have them activated as demonstrated by the FIRECALC studies. Even if they are activated, it seems to have no burning objects to cool.

Issues proposed in this paper comes from preliminary study, further studies with mathematical fire models [8] or physical scale models [9] will be performed.

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Table 1: Activation time of sprinkler heads

Height / s	Activation time / s							
	RTI = 50 $m^{\frac{1}{2}}s^{\frac{1}{2}}$				RTI = 200 $m^{\frac{1}{2}}s^{\frac{1}{2}}$			
	S	M	F	U	S	M	F	U
4.5	288	156	88	51	355	212	129	79
5.6	362	196	109	62	435	256	154	94
18.4	NA	NA	NA	NA	NA	NA	NA	NA
22.2	NA	NA	NA	NA	NA	NA	NA	NA

NA: No activation

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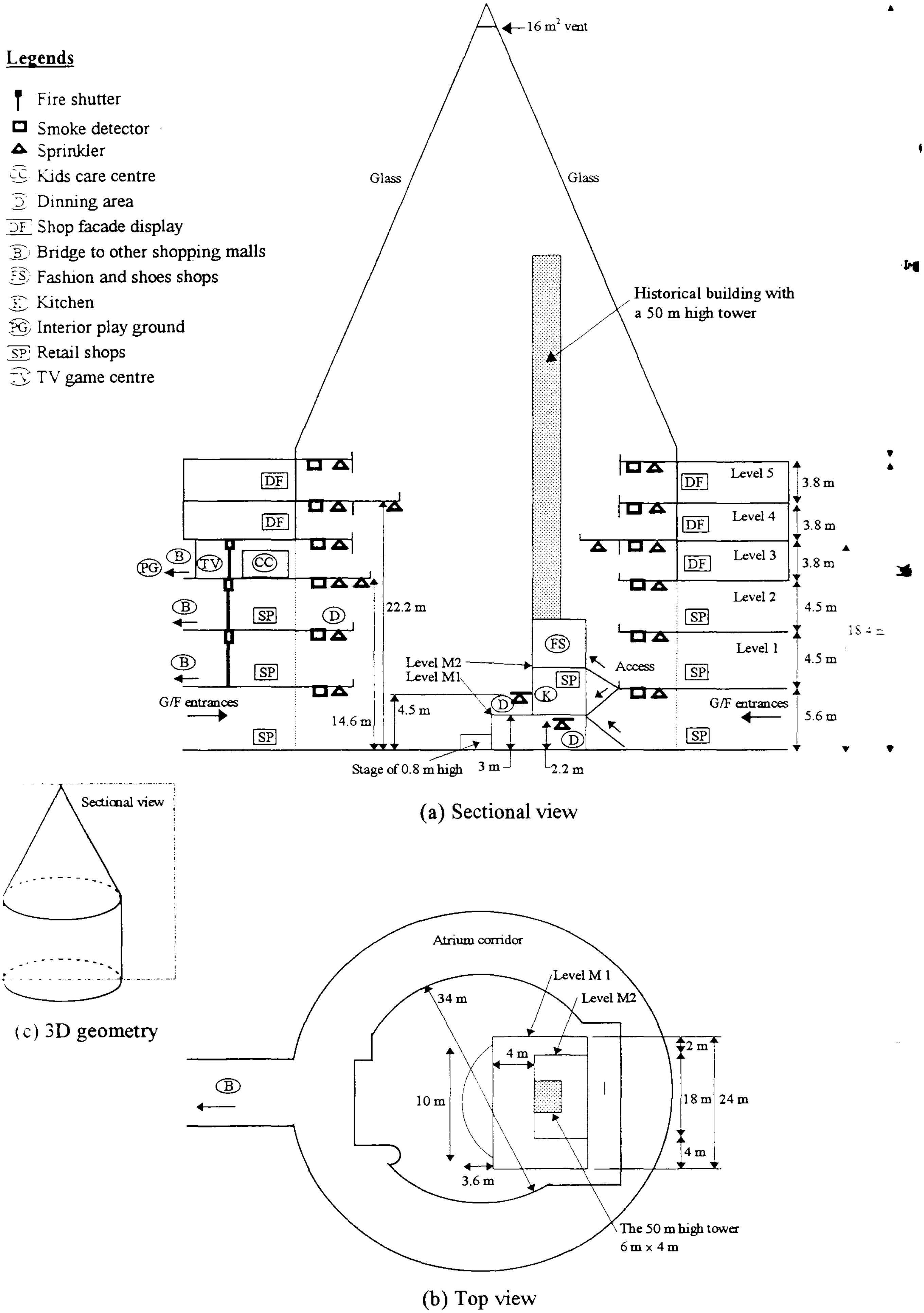
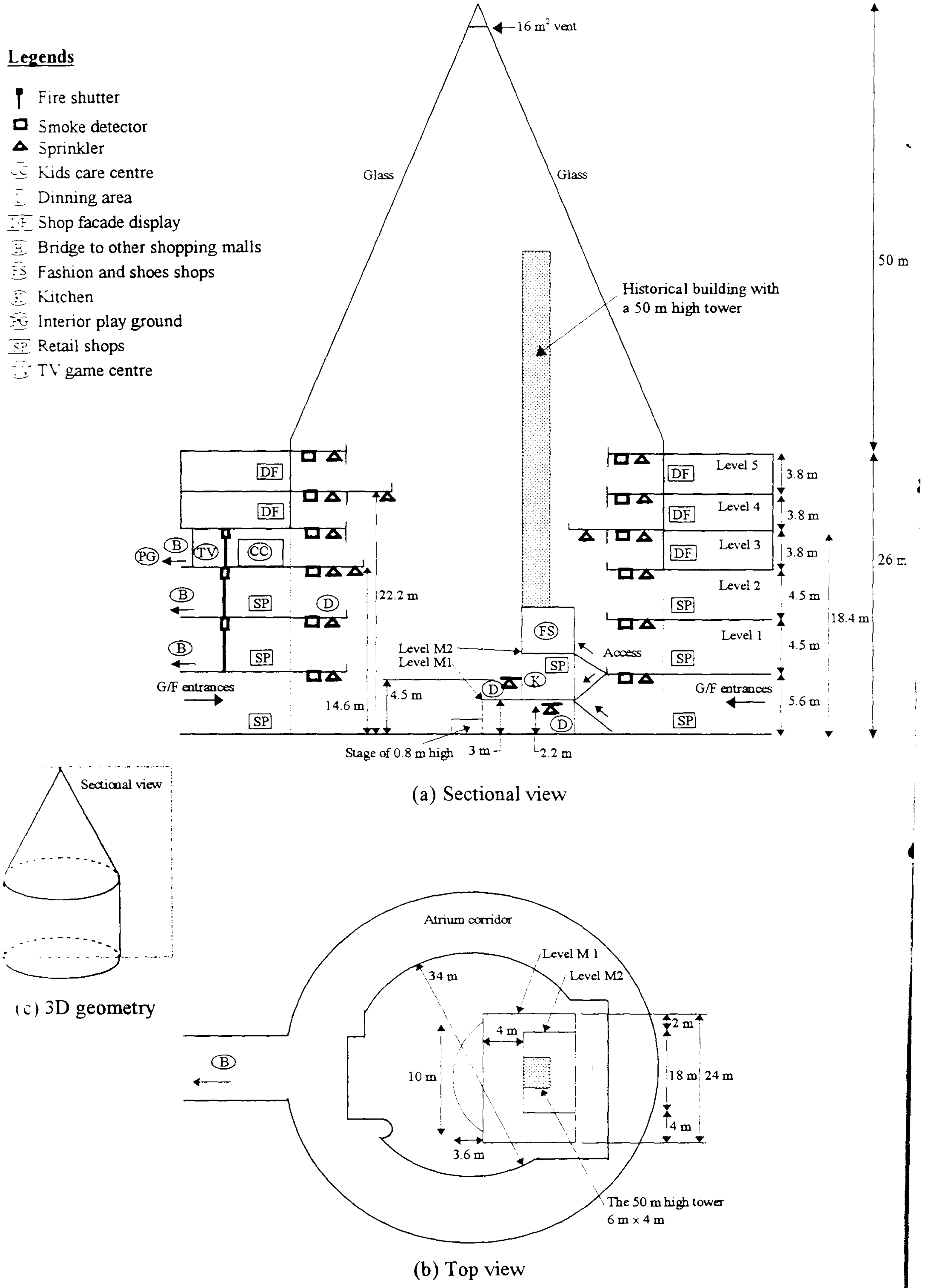


Fig. 1: The Atrium



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