A Case Study of Fire and Evacuation in a Multi-Purpose Office Building, Osaka, Japan

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ABSTRACT

On April 4, 1984 a fire occurred at the Science and Technology Center of Osaka. The building was a typical multi-purpose office building which contained the office of various learned societies whose occupants were regular users of the building, and assembly halls used by people less familiar with the premises. The purpose of this study is to form a basis for future guidelines for the evacuation of multi-purpose buildings, a building type which has become increasingly common in recent years. Our research group conducted a survey of people who were in the Center at the time of the fire using a questionnaire, and obtained detailed information about the fire and the various actions the evacuees took. On the basis of our survey we sought to analyse the characteristics of the evacuees, their reactions to spatial conditions during the evacuation, and how they experienced the sequence of events throughout the emergency. An important result of our analysis that emerged very dramatically was the difference between regular users of the building and those less familiar with it. The differences were; action upon becoming aware of the fire, criterion for selecting escape routes, and ability to effectively reach an exit.

TABLE 1. Floor by floor breakdown of the Building and the occupants.

<table>
<thead>
<tr>
<th>floor area</th>
<th>main use</th>
<th>number of occupants</th>
<th>number of rescued by window rescue</th>
<th>number of questionnaires collected</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>floor area burned</td>
<td>(m²)</td>
<td>(m²)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>1,177</td>
<td>assembly halls</td>
<td>70</td>
<td>70</td>
<td>-</td>
</tr>
<tr>
<td>7</td>
<td>1,177</td>
<td>restaurant, offices</td>
<td>94</td>
<td>94</td>
<td>-</td>
</tr>
<tr>
<td>6</td>
<td>1,177</td>
<td>offices, a.halls</td>
<td>85</td>
<td>83</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>1,177</td>
<td>offices</td>
<td>63</td>
<td>61</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>1,177</td>
<td>assembly halls</td>
<td>254</td>
<td>158</td>
<td>96</td>
</tr>
<tr>
<td>3</td>
<td>1,177</td>
<td>offices</td>
<td>50</td>
<td>48</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>1,176</td>
<td>exhibition halls</td>
<td>11</td>
<td>11</td>
<td>-</td>
</tr>
<tr>
<td>1</td>
<td>1,124</td>
<td>exhibition halls</td>
<td>14</td>
<td>14</td>
<td>-</td>
</tr>
<tr>
<td>B1</td>
<td>1,161</td>
<td>restaurant</td>
<td>29</td>
<td>29</td>
<td>-</td>
</tr>
<tr>
<td>B2</td>
<td>1,150</td>
<td>mechanical rooms</td>
<td>9</td>
<td>9</td>
<td>-</td>
</tr>
<tr>
<td>EV</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

12,485 473 (total) 679 577 102 - 458 (67.5)

*seven of these evacuated via life chute
METHOD

Our research group began our investigation two weeks after the fire. We wrote a 23 item questionnaire and the Fire Defense Board of Osaka distributed it to the 679 individuals who were in the Science and Technology Center at the time of the fire. Of the questionnaires distributed, 458 were returned to the Fire Defense Board (see TABLE 1.). Each step of the evacuation was analyzed and delineated.

ANALYSIS

The Fire, the Building, and the Occupants

Time. April 4, 1984, approximately 11:25 am.

Place. Osaka, West District, Science and Technology Center of Osaka, 3rd floor, a hallway near the west stairs.

The burned area. 473 m² of the floor and 62 m² of the ceiling surface on the 3rd floor, 88 m² of the exterior wall surface on the 4th floor.

Injured. 8 persons. All sustained carbon monoxide poisoning, all alive.

Cause. Arson suspected.

The building. A reinforced concrete structure 8 stories high. Essential facilities (elevators, main stairs, lavatories etc.) located in the center core. In addition to central stairs, enclosed stairs on the east and west ends of the building. These enclosed stairs are protected by fire doors which are kept closed.

Occupants. The regular users of the building occupied offices on the 3rd and 5th floors. The assembly halls on the 4th and 6th floors were being used for new employee training sessions, and the occupants were not familiar with the building. The occupants of the 7th and 8th floor were attending conferences and were not regular users of the building although most had been in the building before (see FIGURE 1.).

![FIGURE 1. Characteristics of the occupants](image-url)
The Fire and the Spread of Smoke

Discovery of fire. An employee of the Center working on the 3rd floor heard an explosive sound and rushed to investigate. The employee found the floor of hallway near the west stairway in flames, and the ceiling engulfed in smoke. An employee in charge of fire prevention who was working on the same floor told another employee to get a fire extinguisher and try to use it. He then ran to the 1st floor security office and told the security officer to inform the fire department. At the same time he alerted all of the floors over the public address system. The contents of the announcement he repeated was, "Do not use the Central stairway. Please evacuate via the east or west emergency stairways." The fire department records his call at approximately 11:32 in the morning.

The arrival of the fire department. At 11:39 the first group of fire fighters arrived and black smoke was pouring from a window on the south side of the 3rd floor. There were several hundred evacuees already in the streets surrounding the building. Many occupants unable to evacuate could be seen waving from windows between the 3rd and 6th floors.

The spread of smoke. Because the fire shutters for the central stairway were not closed, smoke spread to the floors above. FIGURE 2. shows the spread of smoke to the various floors at the time when the occupants became aware of the fire. The results of our questionnaire show that occupants of the 3rd floor did not see heavy smoke. This can probably attributed to the relatively early discovery of fire by the occupants of the 3rd floor.

Awareness of the Fire

In our questionnaire we asked, "How did you become aware of the fire?", and gave a series of multiple choice answers, letting the participants choose as many answers as they felt were appropriate. We also asked, "What made you believe it was a real fire?", but asked them to chose only one answer from the list available. The answers to these questions are compiled on a floor by floor basis in FIGURE 3.
A: seeing the fire
B: smelling
C: hearing explosive sounds
D: hearing the announcement over the public address system
E: hearing others yelling
F: opening their door and finding smoke in the corridors
G: smoke entering the room
H: being alerted by seminar leaders
I: being alerted by others (other than seminar leaders)
J: other

- those realizing the fire to be real in the above way
- those who answered that the above was a secondary reason for believing the fire to be real
- did not find the above to be the reason for believing the fire to be real

FIGURE 3. Analysis of how occupants became aware of the fire

31.6% of the occupants of the 3rd floor, where the fire broke out, reported hearing an explosive sound and wondering what it was. 52.6% of the occupants reported hearing others trying to extinguish the fire and knew something was wrong. 13.2% of the occupants heard noises and knew immediately it was a fire. 31.6% actually saw the fire and thus grasped the reality of the emergency.

Occupants on the upper floors (4-8) heard the announcement of the fire, opened their doors, and found the hallways filled with smoke. Most grasped the reality of the emergency in this way. Because of proximity to the source of the fire, smoke spread to the 4th floor faster than to the other floors. Training sessions were in progress and the doors to most of the rooms were closed, so most trainees did not become aware of the fire until their leaders alerted them. By this time, smoke was thick in the hallways. Occupants of room 404, which exited into an area adjacent to the central stairway, found smoke so thick that their leaders told them not to exit.

When occupants of the 8th floor became aware of the fire relatively little smoke had spread into the corridors. Most of the occupants on the 8th floor became aware of the fire by the public address.

Actions Taken

FIGURE 4. shows the various courses of action taken by the occupants. Five patterns emerged:

a) those who thought to extinguish the fire before evacuating
b) those who thought to set the fire alarm and/or evacuate others before

526
<table>
<thead>
<tr>
<th>Occupants who thought</th>
<th>Evacuated (18 persons)</th>
<th>Returned (5 persons)</th>
<th>Rescued (9 persons)</th>
<th>Evacuated (6 persons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>only to evacuate</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Evacuated</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Helped by others</td>
<td>Evacuated (27 persons)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Collected</td>
<td>Personal affects</td>
<td>Evacuated (44 persons)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Evacuated (59 persons)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Collected</td>
<td>Helped by others</td>
<td>Evacuated (67 persons)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Personal affects</td>
<td>Evacuated</td>
<td>Returned</td>
<td>Rescued (7 persons)</td>
<td></td>
</tr>
<tr>
<td>Evacuated (7 persons)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Confirmed fire</td>
<td>Helped by others</td>
<td>Evacuated (6 persons)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Collected</td>
<td>Personal affects</td>
<td>Evacuated (6 persons)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Evacuated (6 persons)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Confused</td>
<td>Evacuated (29 persons)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Helped by others</td>
<td>Evacuated (5 persons)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Personal affects</td>
<td>Evacuated (8 persons)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Evacuated (6 persons)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Confirmed fire</td>
<td>Alerted</td>
<td>Collected</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Evacuated</td>
<td>Led others</td>
<td>Evacuated (12 persons)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Personal affect</td>
<td>Led others</td>
<td>Evacuated (9 persons)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Evacuated (9 persons)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Confused</td>
<td>Evacuated</td>
<td>Led others (5 persons)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tried to extinguish</td>
<td>Evacuated (7 persons)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Confused</td>
<td>Rescued (5 persons)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Collected</td>
<td>Life chute (2 persons)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Personal affects</td>
<td>Rescued (4 persons)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Helped by others</td>
<td>Rescued (13 persons)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Helped by others</td>
<td>Rescued (9 persons)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Explanatory notes
- Confused - unstable psychological condition. Experienced confusion and disorientation
- Confirmed fire - tried to find the source of the fire or went into the hallway to confirm the fire
- Tired to extinguish - tried to extinguish the fire with a fire extinguisher
- Alerted - tried to set an alarm or alert fire officials
- Collected personal affects - spent some time arranging personal work area or collecting personal affects
- Led others - went into the corridor and led others to the stairs
- Evacuated - went into the hall and attempt to evacuate
- Returned - went into the corridor but returned to the room because of heavy smoke
- Life chute evacuated - evacuated via life chute
- Helped by others - those who received aid from others

FIGURE 4. Major patterns of evacuation

c) those who thought only to evacuate
d) those who experienced confusion and disorientation and then thought to evacuate
e) those who chose to wait for fire fighters to rescue them.
The distribution of occupants from these five groups and the floors they occupied is shown in FIGURE 5. Those who thought to extinguish the fire(a) were all occupants of the 3rd floor. Those who sought to alert or help others(b) were largely from the 4th floor. Those who thought only to evacuate(c) were from floors 4, 6, 7 and 8. That occupants of the 3rd and 5th floors were regular of the building and had their own offices probably accounts for the large proportion of them who thought extinguish the fire or alert and help others (see FIGURE 1.). On other floors where attendants of training sessions were largely unfamiliar with the building, the thought of direct evacuation was predominant.

Selection of Evacuation Routes

FIGURE 6. shows the responses to the following question: "How did you decide whether to evacuate through the hallway or whether to stay where you were?" Occupants on the highest floors were found to have evacuated quite quickly. It can be assumed that the absence of dense smoke on the highest floors (see FIGURE 2.) made it possible for occupants to quickly make the decision to evacuate immediately, followed the instructions of others and evacuated, decided they would be able to evacuate, found the choice difficult but decided to evacuate, wanted to evacuate but stayed where they were, decided it would be safest to stay where they were, were told by others not to evacuate, or other.
occupants of same room divided, some evacuating via the corridor, others via the window
all occupants evacuated via the corridor
all occupants evacuated via the window

FIGURE 7. Choice of evacuation route
TABLE 2. Case when occupants of the same room divided, some evacuating via the window, others via the corridor

<table>
<thead>
<tr>
<th>Room</th>
<th>Sex</th>
<th>Age</th>
<th>Position</th>
<th>Reason for Choosing Evacuation Route</th>
<th>Working Method</th>
<th>Evacuation Route</th>
</tr>
</thead>
<tbody>
<tr>
<td>606</td>
<td>F</td>
<td>24</td>
<td>Clark, regular user</td>
<td>Knew stairway</td>
<td>Office manager</td>
<td>Ladder truck</td>
</tr>
<tr>
<td>504</td>
<td>F</td>
<td>44</td>
<td>Clark, regular user</td>
<td>Announcement</td>
<td>Managing director</td>
<td>Ladder truck</td>
</tr>
<tr>
<td>502</td>
<td>F</td>
<td>30</td>
<td>Clark, regular user</td>
<td>Always used stairs</td>
<td>Office manager</td>
<td>Life chute</td>
</tr>
<tr>
<td>F</td>
<td>36</td>
<td></td>
<td>Clark, regular user</td>
<td>Knew stairway</td>
<td>Office manager</td>
<td>Life chute</td>
</tr>
<tr>
<td>F</td>
<td>39</td>
<td></td>
<td>Clark, regular user</td>
<td>Always used stairs</td>
<td>Office manager</td>
<td>Life chute</td>
</tr>
<tr>
<td>M</td>
<td>38</td>
<td></td>
<td>Manager, always used stairs</td>
<td>Regular user</td>
<td>Fast-time employer</td>
<td>Life chute</td>
</tr>
</tbody>
</table>

exit, and then to traverse the corridors into the emergency stairwells with little trouble. The upper floors also had a higher proportion of occupants to be instructed by others to evacuate. On floors 3, 5 and 6 where occupants were largely regular users of the building, those who chose to exit via the hallway were the majority instead of dense smoke.

In contrast, many occupants on the 4th and 5th floors decided not venture into the hallways or decided it was safe to stay where they were. The smoke was very dense on these floors by the time occupants became aware of the fire, and it can be concluded that the amount of smoke directly contributed to their choice to stay where they were.

FIGURE 7. shows the results to the question, "Did you evacuate via the hallway or did you evacuate via the window, using the hook and ladder truck or the life chute?" Occupants of the same rooms on the 5th and 6th floors were divided into both groups. Besides the amount of smoke, other factors were found to play a role in how the occupants chose to evacuate. TABLE 2. shows details of these occupants. Most of those who evacuated via the hallway were women employees who were familiar with the building.

That they knew the location of the emergency stairs or often used them can be cited as a significant reason for their choice. Those who elected not to evacuate were all men employed in managerial positions. Occupants of room 606 were largely unfamiliar with the building and those in room 504 were elderly men.

It can be said that sex, job and familiarity with the building are among the factors that contribute to the choice of evacuation route.
those who work in the building (mainly 3rd and 5th floor, 102 persons)

- 80% always use the stairway
- 80% knew the stairway
- 50% used the stairway in fire drills
- 0% had thought that in fire I would use that stairway
- 50% thought that using the stairway was safe
- 50% followed others
- 50% led by others
- 50% chose the direction with less smoke
- 0% there was a stairway nearby
- 0% saw the exit sign
- 0% I don't know
- 0% other

those who visited the building to attend a conference or employee's training for the first time (mainly 4th and 6th floor, 84 persons)

- 80% always use the stairway
- 80% knew the stairway
- 50% used the stairway in fire drills
- 0% had thought that in fire I would use that stairway
- 50% thought that using the stairway was safe
- 50% followed others
- 50% led by others
- 50% chose the direction with less smoke
- 0% there was a stairway nearby
- 0% saw the exit sign
- 0% I don't know
- 0% other

those who visit the building to attend conferences or employee's training, have used the building (140 persons)

- 80% always use the stairway
- 80% knew the stairway
- 50% used the stairway in fire drills
- 0% had thought that in fire I would use that stairway
- 50% thought that using the stairway was safe
- 50% followed others
- 50% led by others
- 50% chose the direction with less smoke
- 0% there was a stairway nearby
- 0% saw the exit sign
- 0% I don't know
- 0% other

FIGURE 8. Reasons for choice of the evacuation route
Reasons for Choice of Evacuation Route

FIGURE 7. shows the plans of floors above the 3rd floor. Generally, the occupants on these floors evacuated via the east emergency stairway. On the 6th floor, occupants of room 605 found that the poor visibility due to smoke made it difficult to navigate any but a straight corridor, and chose the west emergency stairway.

FIGURE 8. shows the relationship between the evacuee's familiarity with the building and their choice of evacuation route. The evacuation route is most likely chosen on the basis of amount of smoke in the corridor, but as on floor 3 and 5, regular users used stairs they were familiar with.

In contrast, occupants of floors 4, 6, 7 and 8 were less familiar with the building and allowed others to guide or instruct them as to their evacuation route. Many simply followed other evacuees to the emergency stairs. These cases illustrate decision making based on the instructions or guidance of others.

CONCLUSION

The results of this study are summarized below:

a) Regular users of the building will act in various ways that include trying to extinguish the fire, alerting others, or helping others to evacuate. In the case of those who are less familiar with the building, immediate evacuation is the normal pattern.

b) The choice of evacuation route depends mostly on the amount of smoke, but sex, job and familiarity with the building are important factors.

c) The choice of evacuation route will often be a regularly used route if the evacuee is familiar with the building. For those not familiar, following or relying on others is the norm.

d) If familiar with the building, occupants have little difficulty finding exits even in heavy smoke. If the location of the stairs is not known, finding an exit can be of great difficulty.

e) In all phases of the evacuation process, familiarity with the building was found to be the primary determinant of speed and ease of evacuation.