A remarkable, large fire occurred in a 20 stories high-rise apartments in 1996 in Hiroshima City. The fire spread from the fire origin apartment unit on the 9th floor up to the top 20th floor, very quickly by external flame spread through balconies. The authors investigated the evacuation behaviour of the occupants including reaction to fire cues, motives for starting evacuation, and choice of evacuation route by means of questionnaire survey and also peer interviews with some of them, focusing on the use of elevators in evacuation by floor height and/or age group in this very rare fire incident. From the investigation, the following results were obtained.

1. Probably due to the experience of many past small fires, there was a time lag between the perception of fire and starting the evacuation. Many respondents started their evacuation on the directions of others, not by direct fire cues such as smoke. Also, the reaction of occupants after the perception of fire is affected by their perception of the seriousness of the fire.

2. The likelihood of elevator use in evacuation is mainly related to the floor height in which the occupants live, but is not so closely related to the age of the occupants. The proportion of elevator use in evacuation grows dramatically from the 10th to 13th floor.

3. People are likely to choose ‘the route they usually use’ or ‘a safer route’ rather than ‘a closer route’.

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INTRODUCTION

A remarkable fire occurred in a 20-storey high-rise apartments on 28 October, 1996 in Hiroshima City. The fire started in an apartment on the 9th floor and spread to the top, 20th floor, very quickly (in less than 30 minutes) by external flame spread through balconies. As many of the occupants have lived there since it was built in 1972, about a half of them are now aged people. In this fire, the occupants including many aged people were forced to evacuate in smoke filled conditions because of the unusually quick upward fire spread, but very fortunately there was no fatality with only two injured.

This fire was a very important incident for reconsidering the issues in the evacuation plan for a fire in a high-rise building where many aged people live. After the fire, JAFSE (Japan Association for Fire Science and Engineering) established a 'Study Group on Evacuation Behavior in the Hiroshima Motomachi High-Rise Apartments Fire' headed by the first author. As the members of this study group, the authors conducted the investigation on the evacuation behaviour of the occupants including reaction to fire cues by means of questionnaire survey and also peer interviews with some of them, focusing on the use of elevators in evacuation by floor height and/or age group in this very rare fire incident. This report describes the results and issues obtained from this investigation on the actual evacuation behaviour such as the occupants’ reaction to fire cues, motives for starting evacuation, and choice of evacuation route etc.

OUTLINE OF THE FIRE

Fire development in time line

* Supposed time of fire ignition: around 14:27 (28 October, 1996)
* Automatic fire alarm operated: 14:33 (received in the control office)
* The fire brigade received notification: 14:34 (notified by the control office)
* The first arrival of the fire brigade: 14:37 (The fire was confined to the floor of origin)
* The fire spread to the balcony of the top (20th) floor: 14:53
* The fire was almost suppressed: 17:02

Damage caused by the fire

* Two injured (one occupant and one fireman)
* Fire damage: 66 units (16 totally damaged, and 50 partially damaged)
* Total burned area: 580 M²
Figure 1. The floor plan of the apartments on even-numbered floors.

Figure 2. The plan of an apartment unit.

Table 1. Subject of questionnaire survey

<table>
<thead>
<tr>
<th>Height of floor</th>
<th>Block 5</th>
<th>Block 6</th>
<th>Total</th>
<th>Number of respondents at home at the time of fire</th>
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<td>20</td>
<td>3</td>
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<tr>
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<td>5</td>
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<td>3</td>
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<tr>
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<td>12</td>
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<td>6</td>
<td>14</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td>77</td>
<td>87</td>
<td>164</td>
<td>35</td>
</tr>
</tbody>
</table>

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**OUTLINE OF THE APARTMENTS AND ITS FIRE EXPERIENCES IN THE PAST**

The Motomachi high-rise apartments is a 20 storey reinforced fire-resistive building, total area 172,000 M² containing about 3000 households. Figure 1 shows the floor plan on an even-numbered floor around block 6 where the fire started and Fig. 2 shows the plan of a unit for an even-numbered floor and an odd-numbered floor, respectively. This apartment adopted the so-called skip-floor style (only even-numbered floors have a common corridor to the stairs hall of each block; so people on odd-numbered floors have to use the private stairs down to the common corridor of the lower even-numbered floor). This apartment building had already experienced 69 fires including three fires which spread to the upper floors in 1980, 1985 and 1993 before this time. Most of other past fires were small and not so serious.

**OUTLINE OF THE INVESTIGATION**

The first investigation was done on 29 and 30 November 1996, and the second investigation on 16 and 17 January 1997. In the first investigation, we visited the households of blocks 5 and 6 and asked people who were in the apartments at the time of the fire to answer the questionnaire. In the second investigation, we interviewed some of the households from the first investigation who were cooperative to our survey to supplement
the questionnaire survey and explore the situation during the evacuation in depth.

The occupants from the 2nd floor to the 20th floor of block 5 (shown in pale grey in Fig. 1) and block 6 (dark grey) were chosen as subjects in this investigation. The total number of households chosen as the subjects was 338, 148 from block 5 and 190 from block 6. The fire started on the 9th floor, the location of which is indicated in Fig. 1. In this investigation, questionnaires of a total of 164 households, 77 from block 5 and 87 from block 6, were collected. The percentage of households responding was 48.5%. Table 1 shows the number of questionnaires collected on each floor. 77 respondents (about 47%) were in their home at the time of the fire.

RESULTS AND DISCUSSION

This paper describes the results of the questionnaire survey for 77 respondents who were in their home at the time of the fire.

Attributes of respondents

72% of respondents were 60 years and over as shown in Fig. 3. This proportion of aged people among the respondents is far larger than usual, even in this apartment building. The ratio of male to female is roughly one to three (Fig. 4).

Situation before the fire and cue for fire perception

Figure 5 shows the situation of the occupants when the fire started. Figure 6 shows whether there were disabled people in terms of mobility or not in each home including the answerers. As to the occupants’ situation at the fire ignition, 40% of them answered ‘watching TV’, followed by ‘sleeping’ (14%) and ‘preparing for meals or washing dishes’ (10%). As shown in Fig. 6, 17% answered that there were disabled occupants at home at the time of the fire. Figure 7 shows how the occupants perceived the fire. The primary cue to perceive the fire was ‘fire engine siren’ (26%), followed by ‘others’ notification’ (16%), ‘saw smoke outside the room’ (10%), and ‘fire alarm’ (10%). The ‘others’ notification’ was mainly made by ‘neighbours’ (55%).
Reaction after perception of fire

The results of the question on how serious the occupants felt the fire spread potential was to their own units and what kind of action they took at their perception of fire are shown in Fig. 8 and Fig. 9, respectively. As to the perception of the seriousness in terms of exposure possibility to their own units, 52% of respondents answered that they thought the fire ‘would not spread to their own unit’. Then, 18% said ‘hard to assess’ and 17% thought the fire ‘may spread to their own unit’. Only 9% of respondents answered that the fire ‘would spread to their own unit’. Since this apartment building had already experienced about 70 fires, most of which were not so serious, the occupants seemed to think that any fire would be suppressed at an early stage. This is supposed to be the reason why many of them started evacuation slowly.

As to the reaction after the perception of fire, those who ‘started evacuation anyway’ (44%) were the most, but less than half the total. Those who tried to help the neighbours such as ‘to help neighbours’ or ‘to notify neighbours of the fire’ were 17% collectively, while a total of about 22% answered they ‘stayed at home’ or ‘took no action’.

Motives for starting evacuation

Motives for starting evacuation were very varied and about a half of the respondents gave other reasons than the given alternatives, but 34% of them answered they started evacuation ‘because they were urged to evacuate by others’ (Fig. 10).

Means of egress and reasons why such egress was chosen

Evacuation using elevators is one of the most controversial issues in the case of fire in a high-rise building. In this fire, 47% used elevators for their evacuation, while 42% used stairs (Fig. 11). In addition, 7% used both elevators and stairs. As to the question why the occupants chose the elevator and/or stairs, the two most common answers were ‘because they use it daily’ (44%) and ‘because they thought it safer’ (29%) respectively (Fig. 12). These answers seem to be natural because the occupants know the building well, but are not so aware of the rules of evacuation in fire, such as not to use elevators.

Experiences during evacuation

Figure 13 shows the experiences during the evacuation. 57% of the evacuees answered that they ‘saw the smoke in the corridor’ and 24% said they ‘saw the smoke in the stairs’. Only 4% answered, ‘Smoke entered the elevator’.

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But the fire officials who witnessed smoke in the elevator of block 5 said it became so thick with time that when they used it for their operation they had to bend down without breathing apparatus. Although 24% of the evacuees saw smoke in the stairs during their evacuation, the smoke density was not too great and the evacuees could move down the stairs safely because the hall stair way on each floor is open to the outside.

Final destination of evacuation

71% of respondents answered they evacuated to ‘the ground’ and 8% answered ‘to the other block on the same floor’, followed by ‘the other floor’ (6%) (Fig. 14). However, 12% of respondents answered they did not move and stayed in their own units during the fire.

Evacuation behaviour by floor height

The relation between the evacuation routes and the floor height on which the respondents live was analysed, by dividing floors into groups: 3rd–5th, 6th–9th, 10th–13th, 14th–17th, and 18th–20th floors. This showed that the occupants on the 6th floor to the 17th floor were more likely to use the elevators because the floor they live on was higher (Fig. 15). As to the occupants on the 18th–20th floors, no one used the stairs and 89% of them used the elevators in evacuation, including those who used both the stairs and the elevators. Overall, as we expected, the higher the floor on which they live, the more occupants used the elevators.

For comparison, the frequency of respondents on each floor usually using the stairs is shown in Fig. 16. The daily use of the stairs also shows a tendency for occupants using the stair’s less, the higher the floor. It is considered that this custom is also associated with the choice of evacuation route as well as the floor height as shown in Fig. 17.

Use of elevators by age group

Figure 18 shows the use of elevators in evacuation by age group for the total 55 respondents who were at home at
Figure 17. Selected means of egress by frequency of daily use of stairs \((n=55)\).

Figure 18. Use of elevator by age group \((n=55)\).

Figure 19. Reaction after awareness of the fire by age group \((n=55)\).

Figure 20. Reaction after awareness of the fire by perception of seriousness \((n=77)\).

the time of the fire and evacuated down to the ground. The respondents, who are 60 and over, used the elevators slightly more than those who are 59 and under, but there is no meaningful difference between the two age groups because the average age in the higher floors is greater than that of the lower floors (Fig. 15).

Reaction after fire perception by age group and by level of seriousness in fire perception

Figure 19 shows the reaction by age group, ‘60 and over’ and ‘59 and under’ after awareness of the fire. The percentage ‘started evacuation anyway’ for ‘60 and over’ is 42% and that for ‘59 and under’ is 44%. So, there is no meaningful difference between the age groups in this reaction, even though there is some difference in other reactions such as ‘notified the neighbours’ and ‘tried to suppress the fire’.

However, as seen in Fig. 20, the percentage who ‘started evacuation anyway’ seems to be related to the level of anxiety that the fire would spread to their own unit. Those who thought the fire ‘would not spread to their own unit’ at their fire perception give the lowest rate of ‘started evacuation anyway’ (35%), while those who thought the fire ‘would spread to their own unit’ or ‘may spread to their own unit’ give the answer of ‘started evacuation anyway’ in 43% and 62%, respectively.

SUMMARY

A remarkable fire occurred in a 20 storey high-rise apartments in 1996 in Hiroshima City. The fire spread from the fire origin apartment on the 9th floor up to 20th floor, very quickly by external flame spread through balconies. We investigated the evacuation behaviour of the occupants by means of questionnaire survey and peer interviews, focusing on the use of elevators in the evacuation by floor height and/or age group. The results from the investigation are summarized as follows.

(1) Probably due to the experience of many past small fires, there was a time lag between the perception of fire and starting the evacuation. Many respondents started their evacuation at the direction of others, not by direct fire cues such as smoke. Also, the reaction of occupants after the fire perception is affected by their perception of the seriousness of the fire.

(2) The likelihood of the use of elevators in evacuation is mainly related to the floor height on which the occupants live, but is not so closely related to the age of the occupants. The proportion of elevator use in evacuation grows dramatically from the 10th to 13th floor.

(3) People are likely to choose ‘the route they usually use’ or ‘a safer route’ rather than ‘a closer route’.

(4) In this apartment building, horizontal evacuation was originally suggested in its floor plan, but it is hard to say that the occupants took their actions realizing this. In this regard, it is necessary that education and/or directions to the occupants could be improved so that they understand the advantage of horizontal evacuation in fire in this building.

In planning high-rise apartments buildings, from the view of increasing aged people as occupants, an evacuation plan considering aged occupants and/or the relation between usual routes and evacuation routes will increase its importance.
Acknowledgements

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REFERENCES