6th Asia-Oceania Symposium on Fire Science and Technology
17-20, March, 2004, Daegu, Korea

Evacuation from High-rise Buildings by Using an Evacuation Chair

Tomonori Sano[1], Yoshifumi Omiya[2], and Ichiro Hagiwara[3]

[1] School of Human Sciences, Waseda University, Mikajima 2-579-15,Tokorozawa, Saitama, 359-1192, Japan
[2] Department of Architecture, Tokyo University of Science, Yamazaki 2641, Noda, Chiba, 278-8510, Japan
[3] National Institute for Land and Infrastructure Management, 1, Tachihara, Tsukuba, Ibaraki, 305-0802, Japan

Abstract

Data on human behavior was collected and analyzed from reports of mass media and interviews to survivors from the twin towers of World Trade Center collapsed on September 11, 2001. The escape behaviors show some problems to be reconsidered on the evacuation design strategy for high-rise buildings. For solving these problems on evacuation from high-rise buildings, a new design strategy is required for safety evacuation. It was reported that a man who worked on the 69th floor of WTC1 was able to make an escape by using an emergency chair designed for down the stairs.
In this study, the experiments of using evacuation chair in twenty stories building have been carried out. This type of evacuation chair is handled by one person easily. According to the experiment results, descending speed of evacuation chair is a half of walking speed. It can be used in 1.2 meter width staircases.

1. Introduction

1 . Introduction

In almost all countries, using an elevator for evacuation in fire is not allowed. The notice such as “Don’t use elevator in case of fire” is posted on the wall of an elevator lobby or inside a car. This notice is well known in general. The discussion of using elevator for evacuation is begun today, but it has many problems.

Recently, by increasing high-rise buildings or developing deep underground spaces, the need for using an elevator as means of escape is arisen, especially for people with mobility limitations. In the U.S.,

Corresponding Author- Tel.: +81-4-2947-6854;
Fax: +81-4-2947-6854
E-mail address: sano-t@waseda.jp

the means of escape for disabled people are required by the building codes. In the U.K., the standard evacuation method for people with disabilities was published. However, in Japan, we have a requirement on means of access only for disable people. The fire safety for disabled people is a matter of concern.

In this study, by referring the reports of people escaped from WTC building in Sept. 11, the possibility and problems of using special equipment, evacuation chair, as means of escape are discussed.

2. Report about evacuation of a wheelchair user with special equipment for emergency.

The escape behaviors from the twin towers of World Trade Center collapsed on September 11, 2001, show some problems to be reconsidered on the evacuation design strategy for high-rise buildings. For solving these problems on evacuation from high-rise buildings, a new design strategy is required for safety evacuation[1].

It was reported that a man who worked on the 69th floor of WTC1 was able to make an escape by using an emergency chair designed for down the stairs. Usually he relies on an electric wheelchair for mobility[2,3]. When first plane hit the tower that day, he rushed to the stair well. However, evacuation for him would prove to be more difficult than many other occupants. But he used a special evacuation mobility device for physically disabled man, he was able to escape safely. Although it is designed to be guided by one person, three or four people handled this special evacuation chair. It takes about a half an hour to reach the ground floor.

The special equipment designed for emergency escape was used effectively. It is effective for a wheelchair user to evacuate from high floor. The evacuation chairs are purchased by the Port Authority after 1993 bombing on WTC.

3. What is evacuation chair?

3.1. The type of Evacuation Chair

Some kinds of evacuation chair designed for going down the stairs in emergency are appeared in FEMA's publication[4]. These evacuation chairs are divided into two types, such as manual wheelchair and electric wheelchair. In this study, we choose one type of evacuation chair for the evacuation of wheelchair users in WTC on September 11th, 2001. The reason we selected it is that the evacuation chair was used in real escape situation and it is a simple equipment with no electric power for mobility.

The manual shows that it should be used on straight fire stairs only with gradients between 28 and 39 degrees, the weight limit of passenger is 300 pound, and operator should be substantially equal to or weigh more than passenger being assisted[5].

Figure 1: Emergency evacuation chair

3.2 How to operate Evacuation Chair?

The operation of evacuation chair is as follows; [5]

1. At the fire exit landing, set evacuation chair upright and seat the passenger evacuee in the chair.

2. Pull back on the upper extension handle and balance the passenger's weight over the two main wheels.

3. Align evacuation chair squarely with the first flight of stairs, side nearest the handrail, and roll forward. As evacuation chair starts descending the stairs, slide grip to the top of handle.

4. Hold onto evacuation chair at all times and gauge your speed of descent to assure firm footing.

5. Press downward on extension handle for smoothest ride.

6. When the wheels first touch the next landing, hold evacuation chair in balance and swivel to face the next flight of stairs. Repeat step #3.

7. Continue this procedure until reaching a safe lower or ground level, assist passenger out of evacuation chair.

4. Experiments

This experimental study was designed to determine the descending speed of assisted evacuation chair, to examine the effects of training, and to investigate the usage of an evacuation chair.

The experiments of using evacuation chair in twenty stories building have been carried out. The outline of experiments was shown in Figure 2 and Figure 3. The movement of subjects and evacuation chair in staircase on one floor was recorded by two VCR cameras and the tracks of evacuation chair path were measured by motion capturing system. To measure the movement of evacuation chair, one maker was set on upper right of the evacuation chair's handle. The numbers of examinees are twenty. Their age is between 20 and 30. The experiments were carried out on the assumption that the fire broke out in the high-rise building. The examinees carried down one person with an evacuation chair quickly and safely. An adult man carried down by an evacuation chair was 65 kilograms in weight. He was a man of average weight in Japan. During each experiment, the time of each floor landing was measured continuously from start floor to end floor by a stopwatch. The subjects were divided into two groups. One group had been done on-site training before and the other group had not been trained. Before the experiments, oral explanations of using evacuation chair were given to all subjects. After the all experiments, subjects filled out the questionnaires.

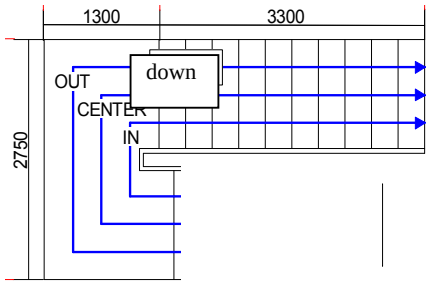

Figure 2: Scale of staircases

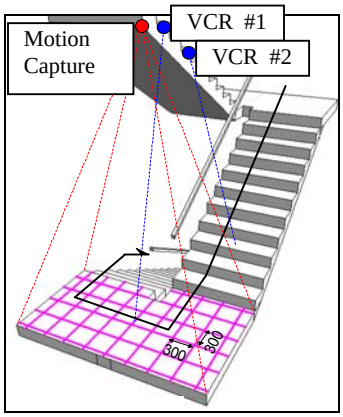

Figure 3: Outline of experiments

Table 1: Number of Subjects

	male	female
trained	10	4
untrained	4	2

5. Results

5.1 Descending speed of evacuation chair

Figure 4 shows that the average descending speed of assisted evacuation chairs by one floor. The average speed of untrained group is between 25 to 35m per minutes and the speed of trained group is between 30 to 45m per minutes. And the average speed of trained group in second experiment is between 50 and 60m per minutes. The speed reduction by descending continuously is not evident. The speed on second experiment of untrained was faster than that of trained group. It can be explained that the first experiment acted as on-site training. It is apparent that on-site training improves the operation of evacuation chair and increases the descending speed.

The figure 5 shows the average descending speed of evacuation chair assisted by female. There is a little difference between the speed of untrained and trained group.

The figure 6 shows the average descending speed of evacuation chair assisted by male. The average speed in the second experiment is faster than that in first experiment. In the second experiment, the speed of untrained group is similar to that of trained group of the 8th floor to the end. It can be explained by the improvement of the operation.

Figure 7 shows that the time of evacuation chair at the landing and at the steps. At the landing, there is a little difference of time between trained and untrained group. Though, at the landing untrained group spent more time than trained group. It is obvious that descending time is greatly influenced in the operation at the landing.

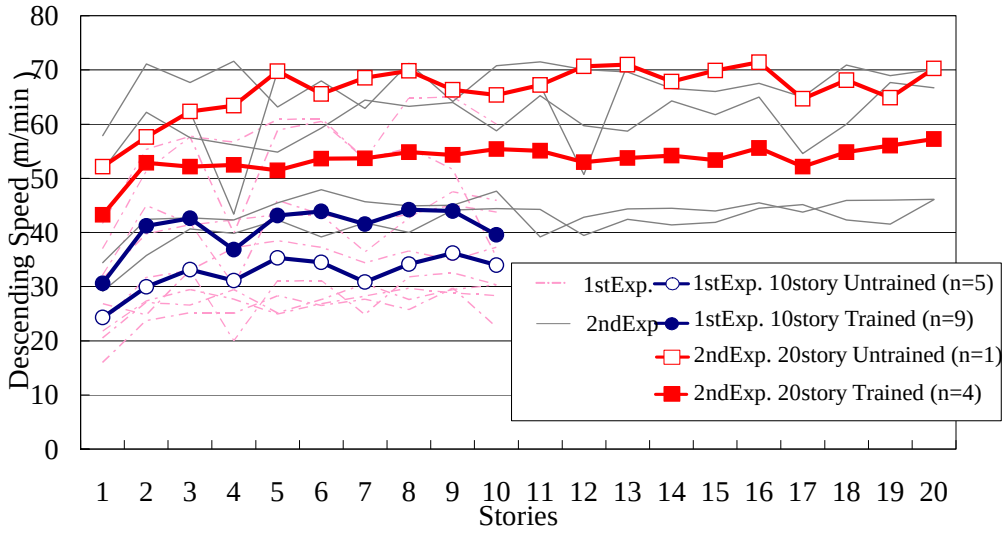

Figure 4 Average descending speed of evacuation chair

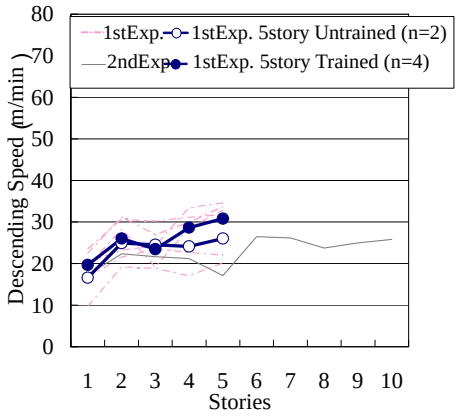

Figure 5 Average descending speed of evacuation chair (Female)

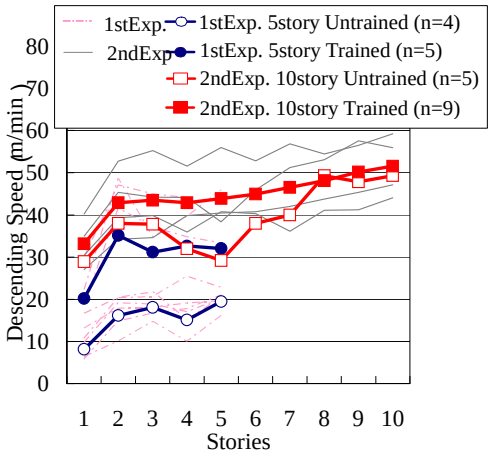

Figure 6 Average descending speed of evacuation chair (Male)

5.2 Effectiveness of training

Figure 8 indicates that the descending time of evacuation chair in five times repeated experiments. This diagram tells us that every subject decreased the descending speed by every experiment. The difference of speed is the largest between first and second experiment. After fourth experiment, the difference is not remarkable. It can be explained by experience of operating evacuation chair.

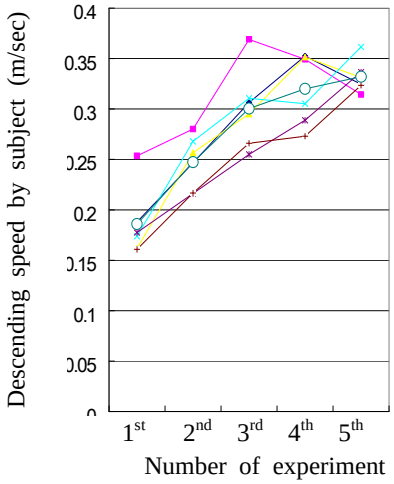

Figure 8 Number of experiments and the descending speed of evacuation chair (steps)

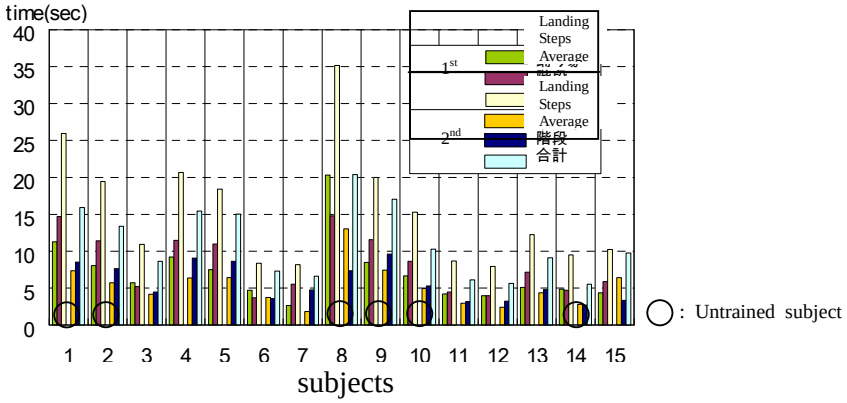

Figure 7 The time spent at the landing and steps

5.3 Descending time of evacuation chair by the floor

Figure 9 shows that the descending time of starting floor which has the largest difference among subjects. In the diagram, a shading shape indicates an untrained person's data. In the second experiment, untrained-male shortened descending time by a half or low compared to first experiment. Though trained-male didn't shorten time less than half. There is not big difference of descending time between male and female.

5.4 Track of evacuation chair in the landing

Figure 10 shows that the tracks of evacuation chair at the landing and descending time by a floor. The curve line in the left diagram indicates the path of the upper right corner of the handle of evacuation chair. These are the characteristic case. The right diagram shows that the descending time of each subject, who had been trained and untrained.

The tracks can be classified into three patterns. They are a trapezoid shape as No.1, a triangle shape as No.4 and a round shape

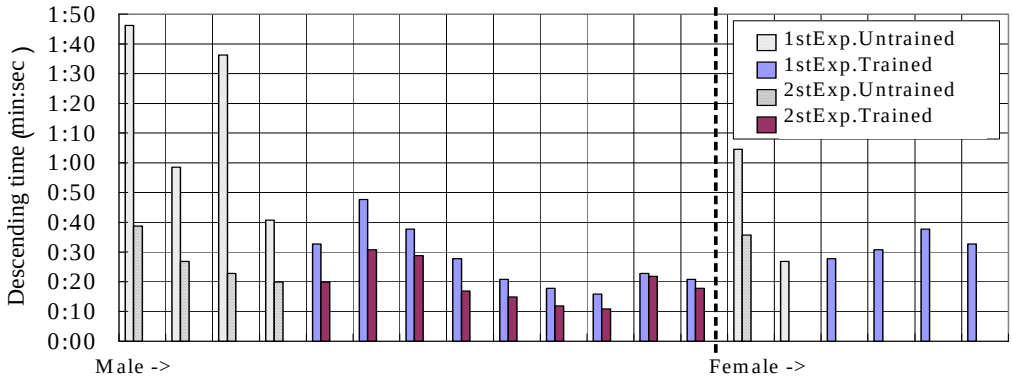

Figure 9 Descending time (Starting floor)

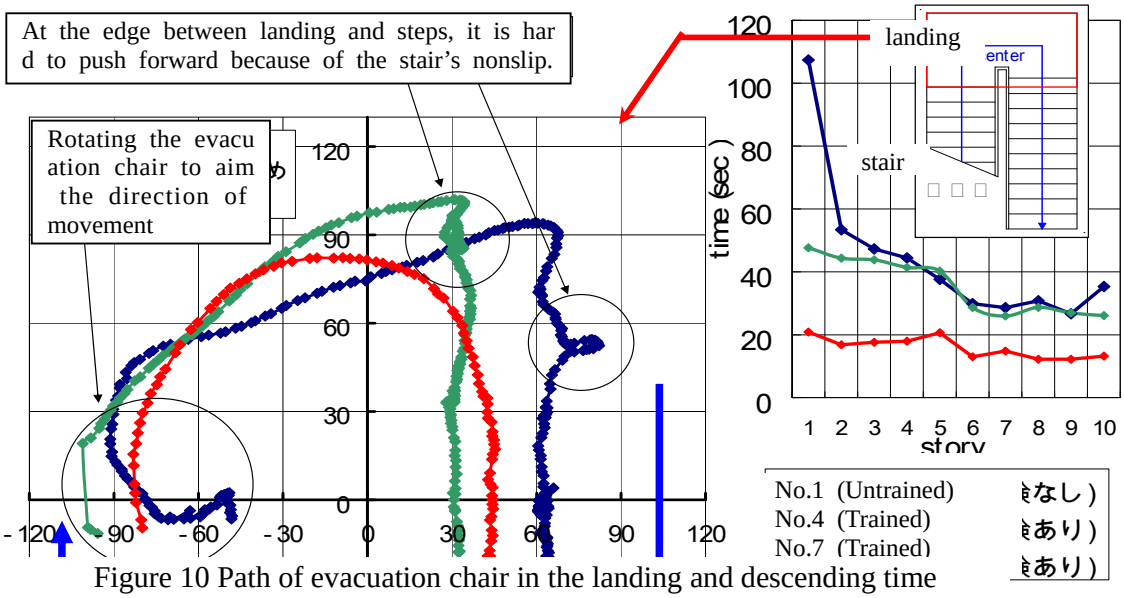

Figure 10 Path of evacuation chair in the landing and descending time

as No.7. Untrained persons, such as No.1, tended to move on the box-shaped track according to the landing shape. Untrained person moved on a large circle first, but they gradually tended to move on a small circle.

It is certain that the operation of evacuation chair in the landing is difficult for untrained person and it takes more time than trained person.

5.5 Questionnaire

Figure 11 to 13 shows that the result of questionnaire about the operation of evacuation chair. Figure 11 tells us that many people answered that on-site training must be needed, and there was no one who answered that no training was needed. Figure 12 shows that the most difficult point to operate evacuation chair occurred on the edge between a landing and a step. It can also be seen in the subject's movement recorded by VCR camera.

Figure 13 shows that more than a half of subjects thought that the highest floor they could carry one person down by evacuation chair was about 20 stories.

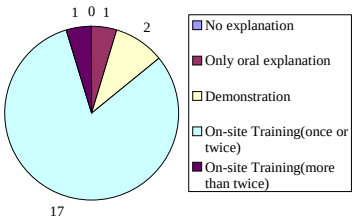

Figure 11 Questionnaire: What kind of training should be done before using evacuation chair?

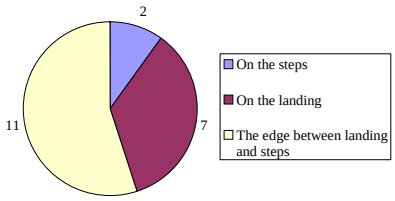

Figure 12 Questionnaire: Where do you think the operation of evacuation chair is difficult?

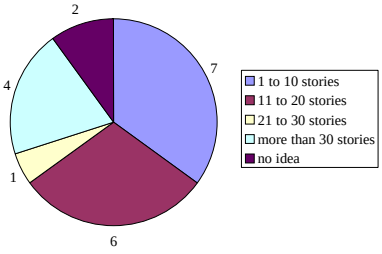

Figure 13 Questionnaire: How many stories can you carry down one person by evacuation chair?

6. discussion

The remarks appeared by this experimental study is as follows;

1. The descending speed of evacuation chair assisted by trained person is about 30 meters per minutes by one floor. It is approximately a half of walking speed for descending stairs.

2. The operation in the landing is more difficult than that in steps. Untrained person spends much time in the landing.

3. On-site training must be done before using an evacuation chair.

7. conclusion

The experiment to appear the availability of using evacuation chair in case of fire is carried out. The results show that an evacuation chair is effective for a wheelchair

user to evacuate from high-rise buildings. Further investigation into the conflict in other evacuees and the method of transfer from wheelchair is required. And we left the problem untouched, such as obstruction by other evacuee in the staircases, installation location, and required number. Assistants for disabled people should be trained on the special device in fire drills.

References

1. T.Sano, I.Hagiwara, A.Tanaka, "Evacuation design strategy for high-rise buildings", Proceedings of the CIB-CTBUH International Conference on Tall Buildings, CIB Publications No.290, **2003**, 567-572
2. Fink.M., Mathias. L., "Never Forget, An Oral History of September 11, 2001", Haper Collins Publishers, NewYork, NY, **2002**,124-127
3. G.Proulx, R.F.Fahy, "Evacuation of the world trade center: What went right?", Proceedings of the CIB-CTBUH International Conference on Tall Buildings, CIB Publications No. 290, **2003**, 27-34
4. FEMA, "Emergency procedures for employees with disabilities in office occupancies." Pub. No. FA154, **1995**, 10-11
5. EVAC+CHAIR Crop., "Operating Instructions and Training", http://www.evac-chair . com