Experimental Study on Starting Time of Evacuation in Sleeping Condition

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ABSTRACT

On evacuation in fire, the time of determine to start evacuation from perceiving fire cue is usually longer than the time for moving out of buildings. There are not a few fire cases that delay of starting evacuation caused loss of human lives. The starting time of evacuation is an important factor in evacuation at fire. On the past studies about the starting time of evacuation, it is estimated by actual fire cases. In this study, we collected and analyzed the starting time of evacuation when the drill fire bell sounds during sleeping condition.

As a result, About 90 % of all participants starts to evacuate within 120 seconds from "the operation of emergency bell" in the state of sleeping. Action such as "waiting for the indication of the emergency broadcasting" and "waking up a person at the room" were taken until starting evacuation after they woke by emergency bell.

KEYWORDS: the starting time of evacuation, experimental study, sleeping condition, emergency bell

INTRODUCTION

When a fire occurs, the safety of those who evacuate are given by the following three "Time". [1]
1)The time of hazard generation: Time from fire break out to generate hazard

2)The starting time of evacuation :Time from fire break out until starting evacuation
3)The time taken evacuation : Time from starting evacuation until finishing it
All occupants must have finished to evacuate to secure their safety when the space where they live endanger their lives. It is necessary to delay the hazard generation time by a fire and smoke, and finish to evacuate promptly for that.
There are a few cases [2][3] that the starting time of evacuation is majority occupied in all evacuation time and it becomes an important factor in the evaluating evacuation safety.
The literature [4] shows a way of shortening the starting time of evacuation,

- Improvement of reliability of warning system which contains maintenance
- The improvement of the reaction of man for the alarm: adds correct information on a fire is offered promptly to the emergency bell because person does not relate to evacuate only by the emergency bell.

The starting time of evacuation means the period elapsed from fire break to the beginning of evacuation. The time of perceiving fire cue means the period elapsed from fire break to evacuee's perception for the fire. The initial response time for evacuation means the period elapsed from evacuee's perception for the fire to the beginning of evacuation. Therefore, the starting time of evacuation equals the time of perceiving fire cue plus the initial response time.

I suppose that the starting time of evacuation by present disaster prevention plan indicator[5] is uniformly provided by the area of the fire room etc. In actual fire, there are not a few cases that require longer time than indicator from perceiving fire cue until starting evacuation. The starting time of evacuation largely influence the evaluating evacuation safety, but there are few studies about it. The reasons are as follows. The evacuees rarely remember the starting time of evacuation. Even if they remember it, it is not reliable because their conditions under evacuation are not normal psychologically. Moreover, getting its data with an experiment is difficult.
Thus, there are a lot of problems in reliability and the generalization of data about the starting time of evacuation. Currently, there are not accumulated data enough to apply generally either.

STUDY IN THE PAST ABOUT THE STARTING TIME OF EVACUATION

Murosaki [6] tried to clarify the realities about the starting time of evacuation from the analysis of a past fire case. "Important fire case 112 " [7] and "Fire statistics data of Kobe City Fire Station" are used as past fire case data. The average times of it are 3.0 minutes (Kobe City), and 4.07 minutes (Important fire case 112) from" fire breaking out" to" find it".

Nakade[8] analyzed "Important fire case 112," and report that they can't obtain the starting time of evacuation by "Fire statistics data of Kobe City Fire Station" .But they can presume the starting time of evacuation by "report time to fire station" even if enable to obtain "the starting time of evacuation". They report the influence of the time from fire break to perceive fire cue for the initial response time for evacuation. According to their report, the longer the time of perceiving fire cue is, the shorter the initial response time for evacuation is.

Murosaki paid attention chiefly at "time for initial response", they analyzed, the "action for initial response" was assumed to be classified into three of (1) report type (2) inducement type (3) extinction types in study [9]. However, they has not arrived to do a quantitative analysis about the starting time of evacuation.
Hagiwara [10] extracted the time from perceiving fire cue to starting evacuation by the questionnaire survey after a fire occurred at a multistory condominium. As a result, it made clear that the initial response time is nearly 5 – 10 minutes.
Hokugo [11] did the research to aim to develop a practicable calculation method a for starting time of evacuation to the realities under a general situation. It was assumed that the starting time of evacuation was able to be given generally by probability distribution from the fire statistics data (Limited to the residential fire) .
In study[12], "the perceiving time of fire cue" was explained by "the report time to fire station," they analyzed the relation between "the factor that provide the report time" and "the report time". As primary factors for "the report time", they target the building used, the structure, the time of fire break out, the building height. The data concerning the attribute in the fire breaking out building used and "the report time," We use the fire statistics data offered by the Fire Fighting Science Synthesis Center. They includes the attribute about the fire breaking out building and the report time.

An experimental research was conducted in foreign country [13], the time from operation of smoke detector alarm to awake is investigated on young person (of the university student etc.,) who has usual hearing in the state of sleeping. Loudness of sound of smoke detector alarm is rung for three stages (85dBA,70dBA,55dBA). Moreover, to understand the factor which influences them, the questionnaire survey is executed. As a result, the time taken to awake from the state of sleeping -

- It is not very different on 85dBA and on 70dBA, and be late on 55dBA.
- If there is sound of air-conditioning. it is late on 55dbA but awake on 70dBA,
- The person with a light sleep is generally early. The person with a deep sleep is late on 55dBA and on 70BA.
- When smoke detector alarm rings, person still stays up and the television and the video are seen, the reaction is delayed a little on 55dBA and on 75dBA.

The result of the experimental research[14] in the state of sleeping is reported intended for the adult (30-59 years old) and children (6-17 years old). Smoke detector alarm(60dBA) rang while sleeping in own house, the questionnaire survey is executed, the relation the waking time and time of sleep ("Initial", "Middle term", and "Latter term") is analyzed. As a result,

- The most understood when child's ratio which did not awake far higher than adult did, and it was understood that adult wake up within 30 seconds from smoke detector alarm was rung.
- When smoke detector alarm was rung in "Initial" that sleep is deep, a lot of children did not wake up.
- There is no difference even if participants know the alarm's ringing.

These observed data is the one that time taken from "emergency bell operation" until awaking while sleeping, and no one that time taken from "emergency bell operation" until "starting evacuation".

The result of these studies about the starting time of evacuation is shown in Figure 1, which pays attention especially at the time taken and the summary.

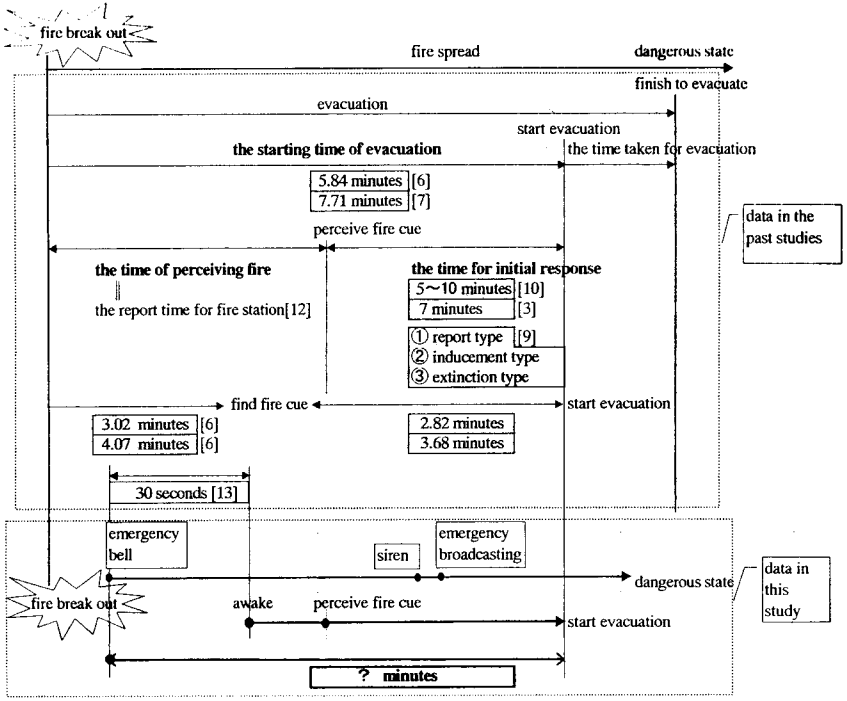


FIGURE 1. The relation between fire spread and evacuation

Thus, "the perceiving time of fire cue" can be presumed by the "fire breaking out time" and "the report time for fire station", or "the fire breaking out time" and "the operation time of the general alarm equipment". Currently, analysis about "the time for initial response" in quantitative have not being done. Moreover, the starting time of evacuation that we use in this study are calculated from fire cases or from questionnaire survey after them. Analysis of this case data is valuable because of it's reality. It is not reliable that the data is not accumulated and time description concerning evacuation is majority by the memory of those who are struck.

In this study, we pay attention to "Training at midnight" done as part of the training of Disaster Protection Center of Hiroshima City, collect and analyze observed data about "the starting time of evacuation" <from operation of the emergency bell through the fire perception until starting evacuation> while sleeping.

OUTLINE OF COLLECTING THE STARTING TIME OF EVACUATION DATA IN TRAINING AT MIDNIGHT

Purpose of collecting data in training at midnight

We aim to obtain how much time taken from those in the state of sleeping from waking by the general alarm system to starting evacuation and the factor influence the starting time of evacuation. In this experimental data, "the starting time of evacuation" means the period elapsed "operated time of emergency bell" to "the time that participants go out of the room"

Content of training at midnight

Training at midnight in Disaster Protection Center of Hiroshima City is training that it is assumed that fire break out while sleeping, the general alarm system is operated and trainee actually evacuate. It is one of curriculums of the staying training on the second one night stay, the lecture and training concerning disaster prevention are taken in daytime.

The operation pattern of the general alarm system is the order of the emergency bell, the siren, and the emergency broadcasting. The operation time of the general alarm system is different according to training. Basically, it is operated at the dawn by the judgment of the staff when trainee fall asleep. Trainee start to evacuate to the ground, and must to evacuate by judging the scene because the evacuate route is shut intentionally. The fire room is assumed one room, and smoke (harmless the one) is tossed to the passage on vicinity of the fire room.

Every time, the appearance of this training at midnight is taken of a picture with a fixed video camera in seven places on Disaster Protection Center of Hiroshima.
Those who attend have responsibility in the work handle extinction and escape guide on emergency, such as the staff in accommodations in the hotel and the inn, related to fire fighting, and the hospitals, etc.

Experiment condition

Plans
The plan of fourth floor with the staying room where training at midnight is done at the Disaster Protection Center of Hiroshima City is shown in Figure 2 with the position where the video camera is set up. There are six Western-style rooms and four Japanese-style rooms.

Operation of general alarm system
Emergency bell →siren → emergency broadcasting (assumption of fire room and instruction of evacuation)

Measuring sound power.
It is measured beforehand that the situation of the sound power such as the emergency bells which the trainee hears while sleeping.
The measurement method: Two noise meters are set on each room (the door is closed) and the passage, sound power are measured.

Measuring object: Emergency bell, siren, and emergency broadcasting
The measurement place: About the emergency bell, is on two points(position go to bed) in each room (ten rooms in total), and two places on the each passages
About the siren and the emergency broadcasting, each one point of Japanese-style room and the Western-style room
Measure unit: dBA

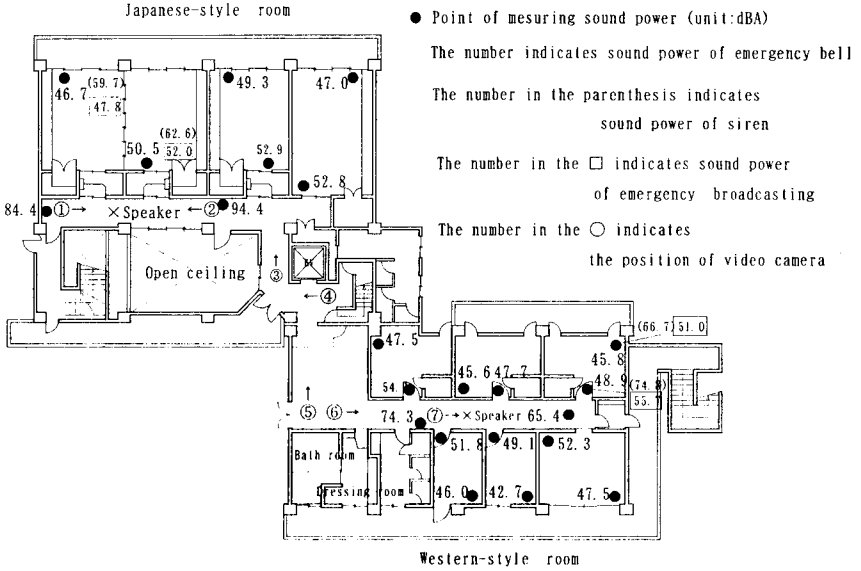


FIGURE 2. Plan of training at midnight be done and the result of measure sound power

As shown in Figure 2, the sound power of the emergency bell is around 50dBA in the room, and has the difference of 3-5dBA between the door side of the room and on the interior side. It is an emergency broadcasting, a siren, and an emergency bell in the order with large sound. Moreover, the sound power of the emergency bell set up on the Western-style room side is smaller than the Japanese-style room sides, but sound power heard in room is not quite different between the Western-style room and Japanese-style room.

Method of collecting about the starting time of evacuation

We get the videotape and the questionnaire offered Disaster Protection Center of Hiroshima City. The videotape shown the training at night and the questionnaire are also after December 1998. The questionnaire survey is done for grasping their character and Level of intoxication, Level of sleep, trainee ask for filling it at the end of the staying training.

RESULT OF COLLECTING DATA ABOUT THE STARTING TIME OF EVACUATION

The outline of analyzing videotape

We read the starting time of evacuation and the operation time of the general alarm system from videotape, and measured the time from that trainee perceive a fire with the emergency bell etc. , until they start to evacuate.
"Start to evacuate" means that the participants go out from each room.
We now get 40 videotapes about training at midnight, and pay attention to the time of starting evacuation and research evacuation. As a result, the time from the emergency bell until participant starts to evacuate are shown in Figure 3.

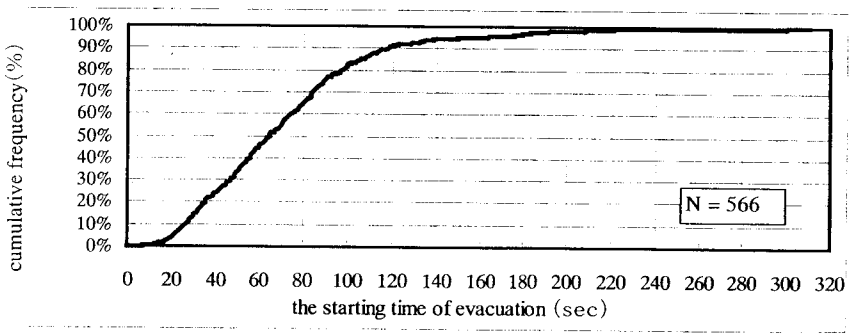


FIGURE 3. The starting time of evacuation

We understand that about 90 % of all participants start to evacuate within 120 seconds from the operation of the emergency bell.

And, Fig.4 shows the relation between the time "from emergency bell to emergency broadcasting" and "from emergency bell to start evacuation. We get the result that the time from emergency bell to start evacuation isn't be affected by operated time of emergency broadcasting.

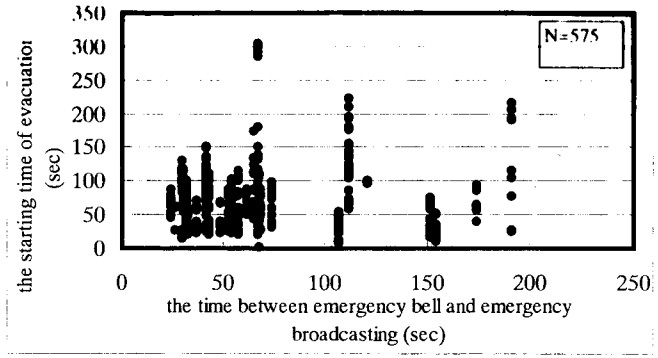
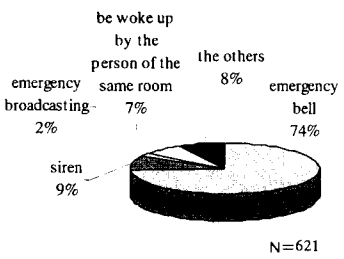


FIGURE 4. The time from emergency bell to broadcasting and the time from bell to start evacuation

The result of analyzing questionnaire survey

Action before trainee starts to evacuate

The result of the questionnaire for those (The number of sample objects is 533 people) who attend training at midnight is shown in Figure 5 and Figure 6. The answer of "Emergency bell" occupy 74% to the question of "Reason to have awoken" (Figure 5). The most answer to "What did you do from awaking to going out of the room?" is "The emergency broadcasting was waited", "The person of this room was woken up" "Nothing was done". We can grasp the pattern that trainee awakes by operating the emergency bell, and one person awakes in the same room and waking up the other person in the room, and waiting for the emergency broadcasting, then starts to evacuate together (Figure 6).



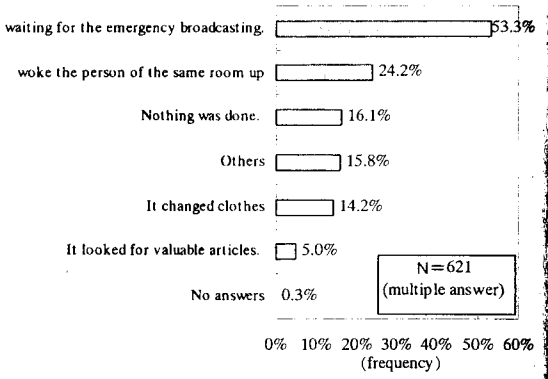


FIGURE 5. The reason of awaking **FIGURE 6. The action from awaking until go out of the room**

Factor which influences the starting time of evacuation

We analyzed relationship between 3 factors - "Level of intoxication (question 3)", "Sleep time", "Level of sleep (question 4)" – and "the starting time of evacuation".

1) Level of intoxication

About the level of intoxication, we first asked the presence of the drinking, and heard the person who had drunk the level of intoxication (1.no drinking, 2. It got drunk a little . 3. It got drunk very much, 4. It got dead drunk). The relation between "Level of intoxication" and "the starting time of evacuation is shown in Figure 7. As a result, within about 70 seconds from emergency bell, it shows tendency to that the more little " the level of intoxication" is, the earlier "the starting time of evacuation is.

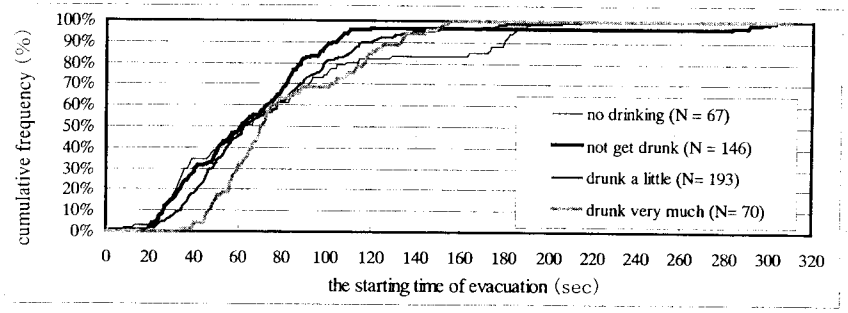


FIGURE 7. The level of intoxication and the starting time of evacuation

2) Sleep time

"Sleep time" (time from going to sleep to the emergency bell operation) is calculated at the time of the emergency bell operation read from the videotape and the answer to question 4 (time which went to sleep). The relation between "Sleep time" and "the starting time of evacuation" is shown in Figure 8. We can't get striking relation between "Sleep time" and "the starting time of evacuation".

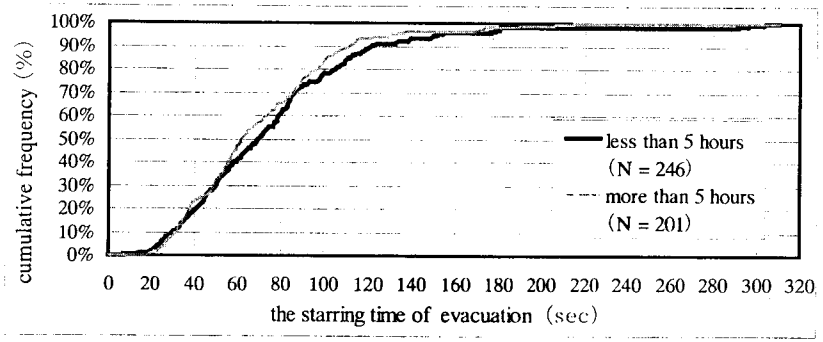


FIGURE 8. The sleep time and the starting time of evacuation

3) Level of sleep

We heard "Level of sleep" dividing into three stages (1. Light , 2. Usual, 3. Slept well(deep)). The relation between "Level of sleep" and "the starting time of evacuation" is shown in Figure 9. It shows tendency to that the lighter "Level of sleep" is, the earlier "the starting time of evacuation is.

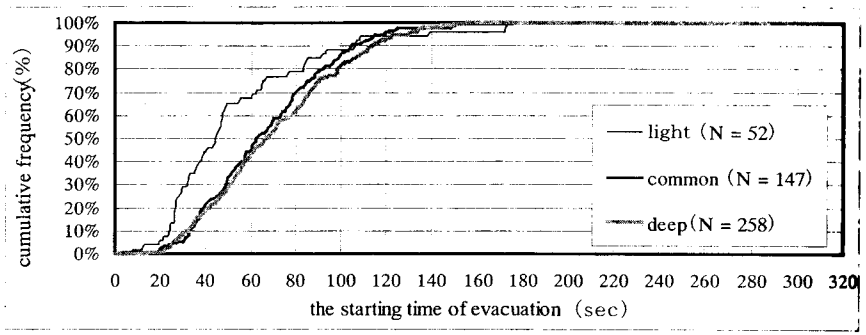


FIGURE.9 The level of sleep and the starting time of evacuation

As this result is compared to experimental research [13], the both of them are correspond in the point that the starting time of evacuation of the person with a light sleep is generally early.

As mentioned above, it is difficult to say for any factor to influence strongly to the starting time of evacuation. As a reason, we cannot obtain the starting time of evacuation in individual. We can obtain the factor in each individual from the questionnaire form, but only data in each room about the starting time of evacuation because we analyze it from videotape.

CONCLUSIONS

We took the starting time of evacuation in the state of sleeping from videotape which took a picture of the appearance of training at midnight, and analyzed The factor which influenced the starting time of evacuation.

(1) About 90 % of all participants start to evacuate within 120 seconds from "the operation of emergency bell" in the state of sleeping.

(2) It is difficult to say for any 3 factors("sleep time", "The level of intoxication", "the level of sleep") to influence remarkably to "the starting time of evacuation".

(3) There is a pre-evacuation of "emergency bell operation" → " awake" → "perceive fire cue (grasp situation)"→ "wait emergency broadcasting instruction", and "wake up the other person in the same room" →"the starting evacuation".

The result of training at midnight is valuable data of understanding person's evacuation in the state of sleeping by the experiment. It is training to the last, and

we can't say that this result shows the evacuation in actual fire. The reason for those who attend training recognized the necessity of the starting evacuation at the same time as recognizing the operation of the general alarm system. Even if the operation of the general alarm system, the person usually doesn't recognize it an equal sign of actual fire. Actually, it will require time further until starting evacuation.

Consequently, the result in this study shows the starting time of evacuation in the state of sleeping on the best condition. We guess that this time is considerably more earlier than it in actual fire.

In the future, from this observed data, we want to examine and propose that the starting time of evacuation is relevantly set as the input value on evaluating evacuation safety.

** This research was done as an activity of "Committee about evacuation at a fire" of JAPAN ASSOCIATION FOR FIRE SCIENCE AND ENGINEERING.

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REFERENCES

1. The method to design for synthetic fire safety of buildings Vol.3, pp.142, Tokyo, April., 1989 (in Japanese)

2. Nakano,M., Kubota,K., Ebihara,M., Notake,H., Kaneko,H., Ohmiya.Y., "Study on egress behavior in the case of Hiroshima Motomachi High-rise apartment", Summaries of technical papers of annual meeting AIJ ,Fire Safety, No.3048, Tokyo, July.,1997 (in Japanese)

3. Ohmiya,Y. and Mizuno,M. and Nakano,M., "Human Behavior in the Hotel Fire at Shirahama, Part1,Part2,", Summaries of a meeting for reading research papers of Japan Association for Fire Science and Engineering, pp.172-179, tokyo, May, 1999.

4. "Series human and building 1 Environment and space" Asakura Company, pp.148-149, Tokyo, 1997 (in Japanese)

5." The guideline of fire protection plan in building", The Building Center of Japan, pp.143, Tokyo, 1995 (in Japanese)

6. Murosaki,Y. and Ohnishi,K. and Nakade,S., "A Study on Disaster Prevention and the Initial Evacuation Period(Part1)", Summaries of technical papers of annual meeting AIJ , No.5362, Tokyo, Aug., 1986 (in Japanese)

7. "Evaluation and Analysis the risk from real fire" – Important fire instance 112 – , Addition and Exclusion Decree Publication of Japan, Tokyo, 1981 (in Japanese)

8. Nakade,S. and Murosaki,Y. and Ohnishi,K., " A Study on Disaster Prevention and the Initial Evacuation Period(Part2)", Summaries of technical papers of annual meeting AIJ , No.5363, Tokyo, Aug., 1986 (in Japanese)

9. Murosaki,Y. and Ohnishi,K. and Nakade.S., "A Study on Disaster Prevention and the Initial Evacuation Period(Part3)", Summaries of technical papers of annual meeting AIJ , No.5310, Tokyo, Oct., 1987 (in Japanese)

10. Hagiwara,I. and Tsukagoshi,K. and Satoh,T., "A Study on fire safety design Evacuation Behavior in high-rise residential fire", Summaries of technical papers of annual meeting AIJ , No.3021, Tokyo, Oct., 1990 (in Japanese)

11. Hokugo,A. and Hagiwara,I., "Estimation of Elapsed Time from Ignition to the Beginning of Escape Statistical Data of Fires" ,Summaries of technical papers of annual meeting AIJ , No.5414, Tokyo, Sep., 1991 (in Japanese)

12. Hokugo,A. and Hagiwara,I., "Estimation of Elapsed Time from Ignition to the Beginning of Escape Statistical Data of Fires(part2)" ,Summaries of technical papers of annual meeting AIJ , No.5414, Tokyo, Sep., 1991 (in Japanese)

13.E,HARRIS NOBER. and HENRY PEIRCE. and ARNOLD WELL.,"Waking Effectiveness of Household Smoke and Fire Detection Devices", FIRE JOURNAL, pp.86-92, Tokyo, July, 1981.

14.Dorothy Bruck.,"Non-awakening in children in response to a smoke detector alarm", Fire Safety Journal 32, pp.369-376, Tokyo,1999.

Study on Human Evacuation Plans during Mine Fires Using Genetic Algorithm

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ABSTRACT Mining fire is one of the critical disasters in coal mine. When it breaks out, it can destroy generous coal resources, roads and equipments, and kill miners. Sometime mine fires induce coal- dust and/or gas explosives thus enlarge fire risks and fire scopes. This is one of the main reasons that mine fires are dangerous to miners.
In this paper, Genetic Algorithm (GA) is used to study human evacuation plans during mine fires. GA is introduced in section 1; mathematical models of optimal control of airflow states under influence of mine fires, the selections of coefficients of GA, and how to evacuate fire risk sites are proposed in section 2; and an computation example is taken in section 3.
KEYWORDS: Mine Fire, Human Evacuation Plan, Genetic Algorithm.

1 INTRODUCTION

Mining fire is one of the critical disasters in underground coal mining [1]. Once fire accidents happen, they cause a large loss of livers, destroy generous coal resources, roads and equipment. If they are not handled properly and timely, they maybe induce more serious consequences such as gas or/and dust combustion and explosion leading to the further expansion disasters. According to differences of fire causing, mining fires are divided into two types, breeding fire and exogenous mine fire [2,3]. From some reports 85% of the total number of mining fires is breeding and 10~15% is exogenous.

Mining fires break out and continue in confined scopes where the ventilation network is very complicated. They have their own characteristics during their starting, propagating and fire fighting [4,5]. The burning objectives of mine fires are different from those which are obvious in the surface. The toxic and high temperature fumes such as CO, H_2, and HS produced during mine fire are fairly dangerous, in the meantime density of O_2 declines quickly, so miners who inhale polluted air can be poisoned or even die. Smokes, which fire emits, reduce visibility to shelters and itineraries for avoiding fire, at the same time, they hinder miners from evacuating fire places and fire fighting. Moreover, thermodynamics effects of high temperature airflow disorder mine ventilation systems, when fire scopes attain some extents, air quantities of