Development of the Dynamic Simulation Program for Evaluation of Evacuation Safety in the Building Fire  
Part 2 Outline of the evacuation behavior model

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1. INTRODUCTION

It supplies in the evaluation of the evacuation safety performance at a building fire and calculation technique \cite{1} of the evacuation time of hand calculation level is supplied to practical use. These techniques are the one to calculate the evacuation completion time to the positive by treating easily and technologically as for the space size and the number of evacuee related to the evacuation flow of the maximum walking distance and the width of the problem in the escape route. However, the confluence in the escape route and the influence of the stay in the exit are appreciable enough or it is doubts.

Integration program of the fire properties forecast and the evacuation action forecast development was tried against the background of above.

When seeing from the side of the evacuation behavior forecast

1. Evaluation of traveling direction change by the fire expansion  
2. Problem in escape route (route confluence part and exit, etc.)

Two points of the evaluation of the controlling effect of the stay generation and the evacuation flow are raised as a purpose of development.

The system that reports this time restricts it to the introduction of the outline because of development though some the development researches into evacuation simulation exist.

2. EVACUATION BEHAVIOR CONTROL MODEL

2.1 Evacuation behavior control that uses potential method

In Simulation, the height distribution (potential distribution) is generated so that the value may become small direction of evacuation usually expected, and the evacuation is controlled. The control of the passing speed becomes possible by using the potential inclination and the value if a quantitative evaluation method of potential can be made
a rule though this potential distribution acts only on the direction evacuee are moved under the present situation, too. The advantage of the potential method moreover is expressible the potential distribution is overlapped in consideration of the influence of the risk factor due to a fire, and as for simulation developed this time, the potential distribution is changed according to growth, and the direction of evacuation has been changed properly.

2.2 Generation of potential distribution

Potential is decided depending on the Poazon equation. The Poazon equation is known as a model applied when the plasma behavior in the semiconductor manufacturing field is prediction for instance.

(1) Potential generation with escape route space system order

Potential rises while parting from the final evacuation exit when potential \( \phi \) at the final evacuation exit is given as a constant. Potential becomes a rapid ascent in the door opening that becomes connected part of the space, and potential of a room far from the final exit rises. Moreover, a positive value is set in the wall part so that the potential inclination \( \partial \phi / \partial x \) may become a positive inclination toward the wall.

(2) Potential generation by arrangement of obstacle

The obstacle set up in the room treats the outline part as well as the wall.

(3) Potential generation by arrangement of fire source

The radiant heat style from the flame is done that the range of the range above 3kW/m\(^2\) of impassable, and the outline part is treated as well as the wall the fire source. Simple calculation method (next equation) [2] assumed for the radiation from the flame to the calculation of the range of impassable to be discharged from the center thoroughly, and it operated on the safety side.

\[
q = x_f Q_f / 4\pi R'^2
\]  

(1)

In here, \( q \) is radial and incidence heat flux kw/m\(^2\) in vertical respect. \( x_f \) is a ratio lost as a radiant heat of all generation heat burning (=1/3). The heat release rate speed kw \( (R') \) of the fire source is distance [m] of the center of the fire and the point to receive heat. Fire source horizontal distance \( R=(R') \) from the center was set as the range of impassable.

This calculation method is to need an elaborate calculation on a receiving heat side near the flame.[3]

Moreover, it is likely to position on a dangerous side in the range where the heat release rate speed is large even in case of being in the above-mentioned condition. Horizontal distance \( (R-r) \) from outer was substituted and to become an evaluation of the safety side, it operated it. (Next equation)

\[
R = r + \sqrt{x_f Q_f / 4\pi q}
\]  

(2)
2.3 Evacuee model

Evacuee had human body space (BS) and personal space (PS), did the collision evasion with other evacuees, reduced PS, and the walking speed was assumed to be a model who depended on the size of PS. The outline is shown as follows.

(1) Human body space (BS) and personal space (PS)

Both BS and PS were assumed to be a circle, the radius was assumed to be BS=250mm and $PS_0=500$mm respectively, and minimum radius $PS_{min}$ of PS was assumed to be BS.

(2) Stay and collision evasion

Figure 1 shows the collision evasion model.

Other evacuee might exist in the moving destination requested according to distribution because the Potential distribution doesn’t consider the stay situation under the present situation.

In this case, it searches for the right and left $45^\circ$, $90^\circ$, and its possible part when moved distance cannot be adjusted to 1/2, right or wrong of the movement be judged, and it move.

Only $\Delta r$ expands PS when PS reduction radius $\Delta r=0.1$m of each frequency where PS cannot be moved when it is not possible to move can be decreased, and it move.

(3) Walking speed

Initial value $v_0$ at the walking speed was assumed 1m/s, and assumed to be a model by walking speed which PS was reduced in the collision evasion process was decreased.

It gave for the proportion to $PS/PS_0$ to reduce the calculation load though it was thought that the density of the pedestrian and the walking speed seen in the research in the past related and used and set exponential from [4].

3. CASE STUDY OF EVACUATION BEHAVIOR SIMULATION

Case study of the evacuation prediction was done for the room where two simple models of the space and fixed desks had been set up.
3.1 Result and consideration by simple space model

The system was executed for two spaces shown in Figure 2. As for floor space \((90m^2)\), number (67 people) of two spaces of evacuee, and width \((B_{\text{room}}=1m)\) of the exit, and the space are different because of the same article accompanying.

The result is shown in Figure 3 and 4. The majority of evacuee enter the state of the stay so that evacuee may concentrate from all semicircle directions on the exit in Case 1 in the early stages and the collision evasion is done. Because this state continues until final evacuee pass the exit, the evacuation time is longer than Case 2. As in figure, the density difference where both stay can be taken.

![Figure 2](image)

**Figure 2** Flat type and number of people of spaces that did case study

![Figure 3](image)

**Figure 3** Simulation result of Case1

![Figure 4](image)

**Figure 4** Simulation result of Case2

3.2 Comparison of simulation results of experiment of subjects leaving a room from classroom

The Tokyo University of Science architectonics department in class. The experiment of leaving a room from the room shown in Figure 5 was done. The experiment executed only (Case3) and a left exit when it used two exits and only use Case4 and a right exit were executed three times of use Case5 in total.

The subjects did not halt after it left from the room, moved to a place left enough from the passage, and had the outflow from the exit not limited. Figure 8 shows the simulation result of Case3 (In 7 seconds, in 25 seconds). It is understood that the densities of evacuee between desks toward a left exit are higher than the densities of evacuee toward a right exit when paying attention within the range enclosed with the dotted line in figure. This is remarkable in the result after 25 seconds.

The evacuation time of the subjective experiment and simulation was arranged to Table 1. A big difference is seen in the experiment result and the simulation result in
Case 4. This is because $PS$ reduces by the stay between desks, and the walking speed decreased. The necessity for correcting the recovery process of $PS$ (walking speed) including the collision evasion model will be thought in the future because it is done one by one at a usual walking speed in the experiment if a space area can be done forward.

**Figure 5** Simulation result of Case 3

**Table 1** Subjective experiment and comparison of evacuation time of simulation result

<table>
<thead>
<tr>
<th></th>
<th>Evacuation from left exit</th>
<th>Evacuation from right exit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Exp</td>
<td>Sim</td>
</tr>
<tr>
<td>Case 3</td>
<td>38.8 seconds (54 persons)</td>
<td>40.9 seconds (57 persons)</td>
</tr>
<tr>
<td>Case 4</td>
<td>58.5 seconds</td>
<td>78.8 seconds</td>
</tr>
<tr>
<td>Case 5</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

(Note: experiment result = Exp. Fill it in on simulation result = Sim.)

4. SUMMARY

In this paper, it has been understood that the stay by high density is formed when there are the evacuee from surroundings concentrations on the exit and narrow passages by the furniture arrangement, and the evacuation time extends as a result. Moreover, the result in which the accuracy of the recovery process of $PS$ (walking speed) is insufficient was obtained including the collision evasion model. The model’s improvement is scheduled to be executed using the subjective experiment including other models together continuously for the accuracy improvement in the future.

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ANNOTATION

If it is receiving heat of about $2\text{kW/m}^2$, it is possible to endure for a long time comparatively. The possibility of becoming under ten seconds when becoming $3\text{kW/m}^2$ is pointed out [5, 6].

It was assumed $3\text{kW/m}^2$ in consideration of surrounding potential's within the range of impassable rising.

REFERENCES