Development of the Dynamic Simulation Program for Evaluation of Evacuation Safety in the Building Fire Part 1 Outline of Improvements of the Zone Model BRI2002

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1. INTRODUCTION

When the evacuation safety performance of the building is evaluated based on a technological technique, it is general to confirm evacuation is completed before evacuation properties and the smoke liquidity are forecast, and the occupants in the building is exposed to smoke.

The smoke properties forecast is often done to the evacuation forecast by using two layer zone non stationary forecast calculation program in the technique in accordance with the evacuation safety verification method of Building Standard Law. As this procedure, the evacuation forecast is first done, and, as a result, it is general to assume the opening and shutting of the obtained door to be a precondition, and to forecast the smoke properties.

This research purposes at this evacuation properties and the smoke liquidity and it has aimed to develop an integrated program that forecasts non stationary at the same time. Moreover, it was assumed that it also aimed at the simplification of I/O, and a graphic function was provided. A new program was made by using the one that some functions were added to BRI2002 [1] for the forecast of the smoke properties for evacuation properties forecast and a graphic function.

The outline of the function to add to the smoke properties forecast program is described here. This main item is smoke and heat detector, the shutter, fire retarding door and smoke control system, operation of sprinkler, damage of the glass and fire source model.

2. ITEM ADDED TO SMOKE PROPERTIES FORECAST PROGRAM

2.1 *Synchronization of the detector, fire retarding equipment, and smoke control system*

The forecast of the synchronization of smoke, the heat detector, and the fire retarding door and the shutter smoke control system was enabled. However, after the fixed time that user input, it was possible to start in consideration of the action time after the detector had reported because it did not automatically synchronize with warning the detector according to equipment.

It was ceiling style models(2) such as Watanabe and Tanaka who had considered the influence of the high temperature layer formed under the ceiling for the operation forecast of heat and the smoke detector was introduced. The RTI-C model was used for the heat detector operation forecast.

2.2 *Operation of sprinkler (SP)*

The operation of the SP was made to be predictable, and after it had operated, it is enabled that a selection of the fire source model assumed to be constant without increasing the heat release rate. However, this has not gone because it is difficult for the zone model to consider the influence that the layer receives as the temperature of the layer decreases by the SP operation. The ceiling style model and the RTI-C model were used similar to the heat detector operation forecast.

2.3 *Damage of the glass*

A simple model to which the glass was damaged was introduced because of the layer and the receiving heat from the flame.

2.4 *The model's addition*

Fire growth rate (α) was input and it was made to select this time the default growth fire source when the fire source was assumed though it was necessary to input the data following. The combustible density, the combustible gross weight, and the fire continuance time can be selecting input.

2.5 *Change, addition, and simplification of I/O data*

The input was simplified by Graphic user interface, and the output was shown in the figure by all data. The opening and shutting of the opening used to take evacuation is decided according to the forecast result by the evacuation properties forecast program described later. The position and the specification, in the position of the fire source, the position of the detector and the sprinkler, the specifications, and openings can have been

easily input. (Thing damaged because of synchronization with situation of usual opening and shutting and evacuation action temple and detectors and heat)

3. OUTLINE OF PHYSICAL MODEL

3.1 Detector and Operation of sprinkler

1) Temperature forecast of ceiling style

Watanabe and Tanaka's models [2] were used for the temperature forecast of the ceiling style in two environment layers. Ceiling style temperature rise forecast equation [3] from the fire source and the center by Alpert in the ceiling of the end at horizontal distance r to the detector, ceiling height H , and heat release rate Q becomes the next.

$$\Delta T_{alp}(H, r) = \begin{cases} 16.9 \left(\frac{Q^{2/3}}{H^{5/3}} \right) & \left(\frac{r}{H} \leq 0.18 \right) \\ 5.38 \left(\frac{Q^{2/3}}{H^{5/3}} \right) \left(\frac{r}{H} \right)^{-2/3} & \left(\frac{r}{H} > 0.18 \right) \end{cases} \quad (1)$$

At temperature (T_s) of the above part layer, temperature (T_a) of a lower layer, height (Z_a) of the above part layer bottom, and height (H) of the ceiling, the temperature rise value becomes Equation 2 in the under according to the forecast type that uses two layer zone model together with the ceiling style model.

$$\Delta T_c(H, r) = \left\{ 1 - \left(\frac{Z_a}{H} \right)^{5/3} \right\} (T_s - T_a) + \Delta T_{alp}(H, r) \quad (2)$$

Temperature (T_c) of the ceiling style is obtained by Equation 3 in the under above.

$$T_c = T_a + \Delta T_c(H, r) \quad (3)$$

2) Smoke detector operation forecast

Similarly, model (2) of Watanabe and Tanaka, etc. was used. Ceiling style absorption sectional area (ϕ_c) is requested by Equation 4 in the under.

$$\phi_c(H, r) = \left(\frac{\gamma_s C_p}{X_c \Delta H} \right) \Delta T_{alp}(H, r) \quad (4)$$

In here, (γ_s), (X_c), and (ΔH) are comparatively of bringing in calorific values of the fuel here to convection of heat release rate (Q) of the fire source near each unit area of the fuel. The type of the forecast of the density of smoke that uses two layer zone model together with the ceiling style model becomes following (5).

$$\phi(H, r) = \left\{ 1 - (Z_a / H)^{5/3} \right\} \times \phi_s + \phi_c(H, r) \quad (5)$$

Density (C_{sc}) of the smoke that flows in the ceiling (decrease in lights coefficient) is forecast by Equation 6 in the under.

$$C_s c = \frac{353}{T_s + \Delta T_c} \times \phi(H, r) \quad (6)$$

Moreover, the A1Pert equation shown as follows was used for the ceiling equation flow velocity forecast equation.

$$u_{alp} = \begin{cases} 0.946(Q/H)^{1/3} & (r/H \leq 0.15) \\ 0.197(Q/H)^{1/3} (r/H)^{-5/6} & (r/H > 0.15) \end{cases} \quad (7)$$

(C_{sc}) However, if flow velocity (u) is 0.05m/s or more, the smoke detector operates more greatly than the operation densities.

3) Heat detector and sprinkler operation forecast

Temperature (T_e) of the sensation of heat part is calculated by Equation 8 in the under.

$$T_e = T_c - \frac{\exp\{-R + \ln(R(T_c - T_\infty))\}}{R} \quad (8)$$

In here, coefficient (R) becomes following (9) from peculiar RTI and flow velocity (u) to the equipment.

$$R = u^{1/2} / RTI \quad (9)$$

(T_e) However, the heat perception or the sprinkler operates more than the operation temperature.

3.2 Heat balance and temperature of the glass

1) Heat balance of the glass

Figure 1 Heat balance of the glass

The heat balance of the glass is shown from Figure 1 by Equation 10 in the under.

$$C_{GLS} \rho_{GLS} \frac{dT_{GLS}}{dt} = q_R(i) + q_C(i) + q_R(j) + q_C(j) - 2q_{R,GLS} + q_F(iFR) \quad (10)$$

The fire source and (GLS) show the glass each radiation element, the convection element, and (iFR) the heat flux, (R), and (C). (q) Here

The temperature of the glass at time ($t+1$) can be calculated from Equation 10 by the following Equation 11.

$$T_{GLS}^{t+1} = T_{GLS}^t + \frac{1}{C_{GLS} \rho_{GLS}} \left(q_R(i) + q_C(i) + q_R(j) + q_C(j) - 2q_{R,GLS} + q_F(iFR) \right) \quad (11)$$

The heat balance of the glass thinks about the radiation of the flame by the center of the height of the glass at the center of the height of the average flame.

Moreover, the receiving heat from i layer becomes Equation 12 below at $Z_{GLS} < Z_a(i)$ for instance though the receiving heat from the each level will be calculated respectively.

$$q_R(i) = \varepsilon_{i,a} \varepsilon_{GLS} \sigma T_a^4(i), \quad q_C(i) = h(T_a(i) - T_{GLS}) \quad (12)$$

2) Receiving heat from flame

It is s (m) as for the distance of the flame and the glass. It is (θ) as for the angle of the line where the normal on the glass side is connected with the glass and the flame. 30% of distance generation of heat is assumed to be a radiation element. An incidence heat flux becomes following (13).

$$q = 0.3Q \cos \theta / (4\pi s^2) \quad (13)$$

It is following (14), considering ratio $(\alpha = 1 - e^{-kL})$ absorbed to the layer of smoke.

$$q_f(iFR) = \left(0.3Q \cos \theta / (4\pi s^2) \right) \cos \theta \left(1 - e^{-kLs} \right) \quad (14)$$

Here, Ls is a part layer penetration distance on (m),
 k is absorption factor (1/m) = (m²/m³).

3.3 Fire source model

The αt^2 model was introduced. (α) Peel user can be input. In addition, Slow, Medium, Fast, and Ultrafast can be selected. The maximum value can be set.

Moreover, various fire continuance times can input the selection by selecting the fire continuance type. As usual, time, the combustion speed or the heat release rate can be input.

4. SUMMARY

Evacuation properties and the state of the smoke liquidity are developed and an integrated program that forecasts non stationary at the same time is being developed. It reported on the outline though the one that a part of function was added to BRI2002 was used for the smoke properties forecast.

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