Development of New Performance Indicators and Evaluation Programs to Contribute to the Advancement of Fireproof Performance of Non-residential Buildings

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1. Introduction

This research described herein concerns methods to rationalize fireproof performance indicators for non-residential buildings utilizing the comprehensive assessment of fire-related risks. This paper introduces the framework of the research.

2. Indexing using comprehensive risk assessment

Fireproof performance of buildings is primarily divided into multiple target performances such as evacuation safety, collapse prevention, and fire spread prevention. Risk assessment frameworks that have been introduced in the past often covered specific target performances. In other words, performance has been verified by confirming whether the safety of the building or occupants is ensured against the design fire source under assumed fire scenarios appropriate for the evaluation of each target performance. In contrast, this research comprehensively evaluates the damage patterns that can result from a single fire source, and then incorporates the results into the evaluation of the associated target performance. This allows for relative positioning between target performances.

Fig. 1 shows the event tree assumed in this research. In this Figure, the fire scenarios that could occur in one of the compartments of a building are classified into 22 patterns based on a combination of eight probabilistic events: (1) fire breakout, (2) smoke intrusion, (3) smoke control and evacuation failure, (4) fire intrusion, (5) fire growth, (6) compartment breakthrough, (7) collapse, and (8) fire spread to adjacent buildings. The damage caused by a compartment is assumed to be independent of other compartments. However, smoke and fire intrusion from the adjacent compartment is separately evaluated to take into account the spreading effect of fire.

3. Performance indicators

The target performances that constitute the fireproof performance of a building are broken down into seven items given in **Table 1**. By linking these performances to an appropriate damage indicator L (amount of damage or probability of damage occurrence), the results of risk assessment can be used to evaluate target performance. The damage indicator L is primarily a reverse indicator of target performance. Therefore, as shown below, the reverse of the amount of damage L normalized by the reverse of the amount of damage L_0 under the reference condition is defined as the performance indicator F.

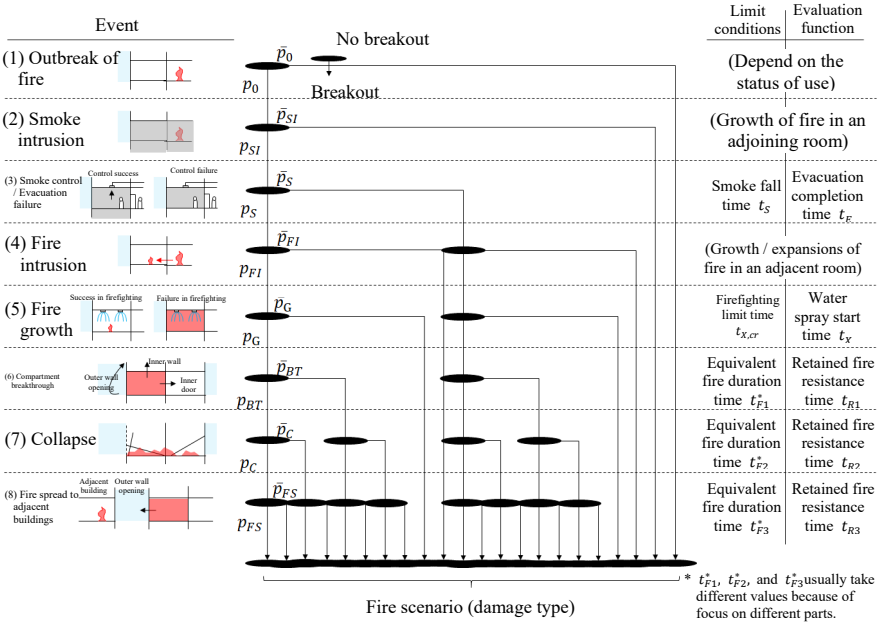

Fig. 1: Event tree focused on fire intrusion in each compartment

Table 1: Examples of target performance and damage indicators

Target performance	F value	Example of damage indicator L
Fire prevention performance	F_1	Probability of fire
Fire growth prevention performance	F_2	Fire growth probability
Collapse prevention performance	F_3	Collapse area, collapse probability
Fire spread prevention performance	F_4	Number of burned buildings, fire spread probability
Evacuation safety performance	F_5	Number of people who cannot evacuate, Probability of evacuation failure
Firefighting activity support performance	F_6	Probability of firefighting failure
Functional continuity performance	F_7	Renovation cost, Number of days for restoration

$$F_i = \frac{1/L_i}{1/L_{0,i}} \quad (i = 1, \cdots, 7)$$

Table 1 lists examples of damage indicators L suitable for evaluating each target performance. Although the properties of the seven target performances are different, they are associated with the common event tree to allow comparison among them.

4. Case study

To examine the characteristics of performance indicator F, we conducted a case study for an office building of S structure, three stories high and total floor area of 3,168 "m^2" as shown in **Fig. 2**. In this study, we focused on the three fireproof specifications shown in **Table 2** (fire resistance time t_R (RS) of the main structure parts, installation of sprinkler system (SP), and compartmentalization of room D (C)), and examined the relationship between the combination of these specifications and the performance indicator F. However, the evaluation targets are four target performances that can reflect the effect of fireproof specifications at present (i.e., collapse prevention performance F_3, fire spread prevention performance F_4, evacuation safety performance F_5, and functional continuity performance F_7).The damage indicator L, shown as a boxed line in **Table 1**, was used in the calculation of each performance indicator F.

The calculation results are shown in **Fig. 3**. While the installation of sprinkler systems (SP) and compartmentalization (C) improved all target performances, the strengthening of major structural parts (RS) showed no effect only in the evacuation safety performance F_5. This is a measure where strengthening of the main structural parts (RS) is effective after the fire has grown and reflects the different nature of the measures required to improve the F_5 value. Note that compartmentalization (C) is also generally regarded as a measure that is effective after the fire has grown, but the division of room D reduced the time to become aware of the fire and the time to walk, which led to reduction in the evacuation

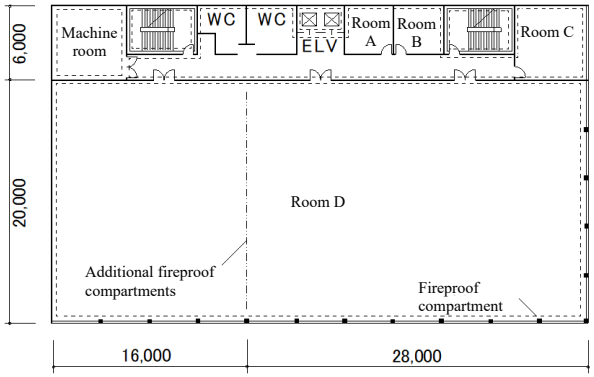

Fig. 2: Reference floor plan of target building (Unit: mm)

Table 2: Calculation conditions

Conditions	Item		Basic plan (O)	Improvement plan
RS	Fire resistance time t_R	Main structural part	60 min.	90 min.
		Outer window	20 min.	
SP	Sprinkler system		None	Available
C	Number of fire proof compartments in Room D		1	2

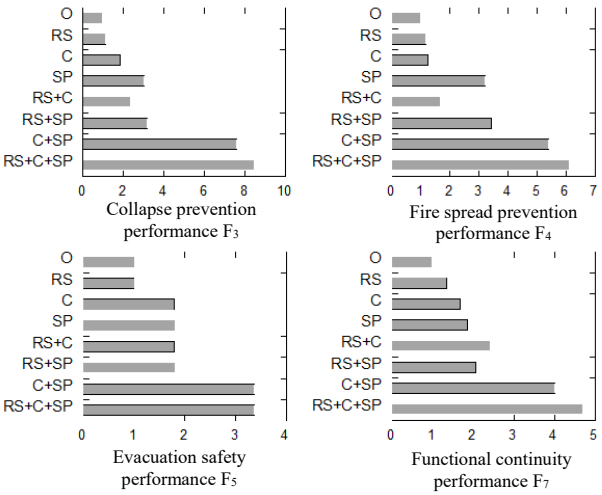

Fig 3: Calculation result of performance indicator *F*

completion time t_E. However, given that the ratio of transit time of an evacuation exit to t_E is often not small, it is generally expected that the effect of improvement in F_5 value by compartmentalization (C) will only be limited.

5. Conclusion

This research proposes a new performance indicator F considering the quantification of the evaluation axis and the ease of interpretation of evaluation results. In the future, we will continue to improve the performance indicator F by reviewing the calculation methods of event occurrence probability p and performance indicator F.