Development of New Performance Indices and Evaluation Programs Contributing to the Sophistication of Fire-prevention Performance of Non-residential Architectures

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Fire Standards Division, Building Department
OKEMOTO Keisuka, IWAMI Tatsuya, SUZUKI Junichi, MINAKAMI Tensei
Senior Researcher (Ph.D. in Engineering), Head (M.in Engineering), Senior Researcher (Ph.D. in Engineering), Senior Researcher (Ph.D. in Engineering)

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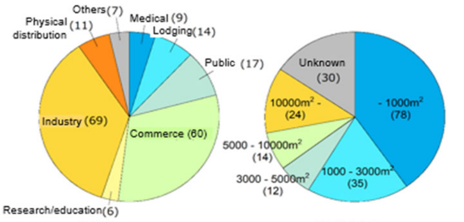
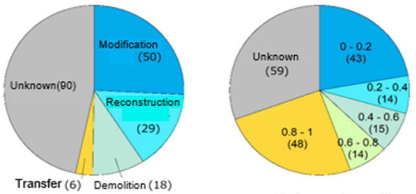
1. Introduction

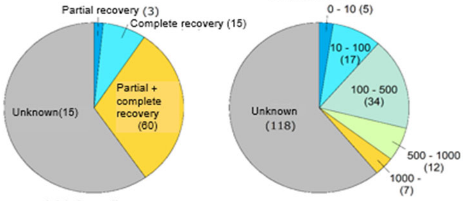
In the current research, we have been advancing the composition of the framework for the evaluation of function-maintaining performance after fire damage in a non-residential architecture. In this paper, we report on the results of the research and analysis of time-transitional changes of the functionality rate of architectures from the infliction of fire damage, through the repair, rebuilding, and other handling processes, and up to their recovery based on the press materials etc.



(a) Usage (b) Total floor area



(c) Means for recovery (d) Comparison with burned area



(e) Information on recovery time (f) Period for complete recovery

Fig-1. Examples of recovery from fire damage stored in the database

2. Database of Case Studies on Recovery from Fire

For the analysis of fire damage to architectures and the subsequent recovery processes, we used the press materials etc. issued in the 20 years from 2000 to 2019 to construct a case study database. There were 193 damaged buildings for which we were able to collect information on recovery from fire from press materials etc. Fig-1 shows a breakdown of the information. When we focus on (a), Usage, there was much information related to commercial facilities used by a large number of unspecified people or relatively large factories or warehouses. On the other hand, there was no information on houses or office buildings, which would be likely to have limited users. As for (e), the recovery period, there were a limited number of case studies that specified the specific period; there were 78 cases that specified either the period for partial recovery or complete recovery. Among them, we were able to confirm that some step-by-step recovery processes were implemented after partial recovery in 60 cases that were fully recovered.

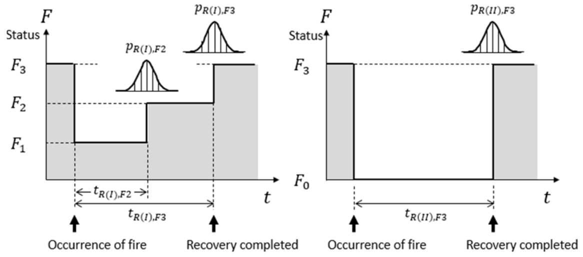
3. Overview of the Probability Model

Based on the results of an investigation on case studies of recovery from fire, we classified the the spatial and functional statuses of architectures in the recovery process into four statuses: F_0, F_1, F_2, F_3 (Table-1). The actual recovery processes could be further classified in detail; however, further classification was impossible due to the limitations of the information that we were able to collect from press materials etc. Furthermore, the handling of a damaged architecture was able to be largely classified into the case where it was partially corrected, it was reconstructed after demolition, and it was not reconstructed after demolition. Among them, cases in which buildings were not reconstructed after demolition were outside of the scope of the interest of our research; therefore, we regarded the remaining two cases as representative recovery scenarios.

Fig-2 names the cases of correction and reconstruction as Scenarios I and II, respectively, and shows a schematic illustration of the processes to the recovery of functionality rate after the fire in each of these scenarios. According to these scenarios, we conducted an evaluation—in terms of probability—of the recovery period to each space and functionality status t_R (in Scenario I, functionality status F_2 had the recovery period $t_{R(I),F2}$. In the same manner, F_3 had the recovery period $t_{R(I),F3}$; in Scenario II, F_3 had the recovery period $t_{R(II),F3}$).

Table-1. Classification of the space and functionality of architectures that experience fire damage

Status	Space	Functionality	Functionality rate
F_0	Not accessible anywhere	All stopped	0
F_1	Damaged part not accessible	Functionality of the damaged part at a halt	$\frac{A_{fl}-A_b}{A_{fl}}$
F_2		Functionality of the damaged part replaced by some other part	$\frac{A_{fl}-\alpha\cdot A_b}{A_{fl}}$
F_3	No restriction	No restriction	1



(a) Scenario I (modification), (b) Scenario II (reconstruction)

Fig-2. Step-by-step processes for the recovery of damaged architectures

4. Recovery Period

A large number of steps are required for the recovery of architectures that have experienced fire damage, including "investigation of the fire," "cleaning and/or (partial) demolition," "fund raising," "contracts with design and/or construction companies," "basic and/or construction design," "application for conformation of construction," "construction," and so forth. To understand the period of recovery to the status of each space and/or functionality t_R (days), it is necessary to clarify each of the periods required for each recovery process. However, there is great uncertainty in relation to the period required for each process because it is influenced by the specific condition of the owner, the social status on each occasion, and other factors. However, even under these circumstances, changes to the "construction" process, which is situated in the final phase of the recovery process, may be relatively small changes, and it is conceivable that it will cover a significant portion of the recovery period t_R.Thus, we regard the "construction" period, $t_{R,ref}$, as the standard time, and divide each recovery period t_R by $t_{R,ref}$ to acquire the time of normalization t_R^*; thus, we use a log normal distribution function to regress the relation with the recovery rate p_R.

$$p_R = \Phi\left(\frac{\ln(t_R^*)-\lambda}{\xi}\right) \qquad (1)$$

Here, Φ is a standard normal distribution function, and λ and ξ are the average and standard deviation of $\ln(t_R^*)$, respectively. As for the "construction" period, $t_{R,ref}$ (days), we used the report on the statistical survey on the commencement of construction to acquire the following regression equation.

$$t_{R,ref} = \begin{cases} 53.0A_{flr}^{0.250} & (RCconstruction) \\ 36.5A_{flr}^{0.229} & (Sconstruction) \quad \text{(days)} \\ 44.4A_{flr}^{0.209} & \text{(Wooden frame)} \end{cases}$$

(2)

Fig-2 and Table-2 show the results of the regression in the case studies in the database using equation (1). As for the number of the case studies that we were able to use for regression N=30 for $t_{R(I),F2}$, 35 for $t_{R(I),F3}$, and N=22 for $t_{R(II),F3}$. In either step, the regression of the data was, in general, excellent. The average of $t_{R(I),F2}$, $t_{R(I),F3}$, and $t_{R(II),F3}$ were, with respect to the standard time $t_{R,ref}$, 0.282 times, 1.12 times, and 3.38 times, respectively. The required time was shorter in this order.

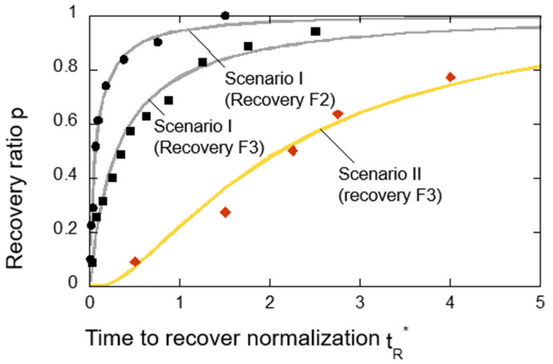


Fig-3. Recovery time to normalization and the recovery rate

Table-2. Results of the regression of the recovery rate curve

Scenario	Status	N	μ	σ	λ	ξ
I	Recovery F2	30	0.282	1.28	−2.81	1.75
	Recovery F3	35	1.12	4.13	−1.23	1.64
II	Recovery F3	22	3.38	4.26	0.743	0.975

5. Conclusion

In the probability model composed in this research, the recovery rate p_R under the conditions of the two scenarios—modification and reconstruction—was evaluated with the recovery rate curve based on the normalization time t_R^*. As a result, we have become able to use a relatively simple procedure to follow the recovery processes of architectures that have experienced fire damage.