Performance-based Fire Safety Design in Japan

M. TSUJIMOTO
Dept. of Geotechnical and Environmental Design,
Nagoya University
Chikusa-ku, Nagoya 464-8603, Japan
E-mail: mtsujimoto@genv.nagoya-u.ac.jp

K. HARADA
Dept. of Architecture and Environmental Design,
Kyoto University
Sakyo-ku, Kyoto 606-8501, Japan
E-mail: harada@archi.kyoto-u.ac.jp

ABSTRACT

This paper is to report the revision of building codes in Japan towards harmonized regulatory system based on performance concept for fire safety. The building code of Japan covers passive fire protection systems such as fire resistance construction, limitation of wall lining materials and so on. At this moment, BSL is going to include more functional concept in replace of regulations based on the specifications of materials and constructions. So- called performance evaluation methods are going to be included to check the conformity with functional requirements for structural fire resistance and for egress safety. This paper summarizes BSL revision into functional statements.

KEYWORDS: Building regulation, fire safety, performance-based

1. INTRODUCTION

It is natural to accept that the end of law such as Building Standards Law, is to realize the society as Roscoe Pound mentioned in 1921;

> "One such postulate, I think we should agree, is that in civilized society men must be able to assume that others will do them no intended injury -- that others will commit no intentional aggressions upon them." [1]

In the field of building and construction, for example, to built the fence which is easy to collapse in case the foreknowable force is operated from outside, or to turn out a fire resulting in injury or death in case the fire protection manager of common building does not take proper care against fire, is the intentional aggression.

In each case, the judicial decision according to the Civil Law or the Criminal Law was given using Building Standards Law (BSL) or Fire Service Law (FSL) as a standard of judgement what is the intentional aggression. In this context, the safety regulations are the criteria to judge for the fundamental Laws (e.g. the criminal law, the civil law).

From the engineering side, it is more rational to represent the intentional aggression by performance-based words, for example, to suffer a irrecoverable damage by the collapse of the building in case the foreknowable force is operated from outside, than specific expression such as to prohibit a brick-built building. It is the reason that performance based code is a common trend in rationalizing building and fire regulations.

The BSL was revised in June 1998 to include functional statements in part, while excluding the equivalency clause between specification. This type of change is in coordination with the performance based codes as in some advanced countries such as UK, Australia, New Zealand, Sweden and so on, even though the changes are not drastic. In June 2000, BSL and its associated technical standards will be in effect. In preparation to that, performance evaluation methods were developed for structural fire resistance and egress safety.

This paper summarizes BSL revision into functional system and possible future development for harmonized fire regulation.

2. DEVELOPENT OF PERFORMANCE CONCEPT IN BUILDING CODE

2.1 Historical Development[2)]

The BSL was established in 1950. Uniform Building Code in U.S. was its copybook at those times. It was a list of acceptable materials and construction methods without specifying the necessary functions nor the degree to which those functions are required (performance). First drastic change was made in 1959 to introduce the concept of performance of materials and construction. Materials are listed in categories. Specific testing methods such as non-combustibility, fire resistance were designated in order to classify new materials into the categories in BSL.

The code had an equivalency clause since those days. However the number of application was quite few, because of the lack of framework to discuss the equivalency between specification A and specification B_1, B_2, B_3,....

Article 38 in former BSL (equivalency clause) : *The provisions of this chapter or those of others or ordinances based thereon shall not apply to buildings using special building materials or methods of construction unanticipated thereunder. if the Minister of Construction deems that the said building materials or methods of construction are equal or superior to those specified in the said provisions*

2.2 Increase of FSE under Equivalency Clause

Fire safety design methods attained popularity during 80's in Japan. A milestone was a project on Development of Total Fire Safety Design System (1981-85 fiscal) hosted by MoC (Ministry of Construction). This five-years project aimed to develop fire safety engineering (FSE) frameworks. The project resulted in publication of a design guideline[3)] in 1987, which is a source of fire safety strategy and engineering tools. Since then, the number of submittals to equivalency clause is greatly increased up to today as shown in Figure 1.

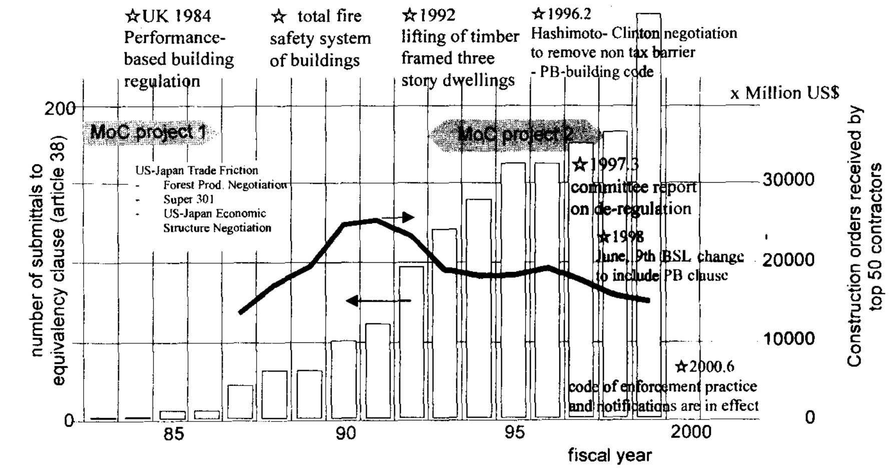

Figure 1 Increase in the number of submittals to equivalency clause (article 38) and corresponding key event since 1980[4)].

3 BUILDING CODE REFORM

3.1 Departure from Equivalency Clause

The change is described in NKB format in Figure 2. The revision in 1998 was to include an idea of functional equivalency in part-by-part manner. Associated performance scales are to be included for each corresponding part.

Due to this change, the equivalency clause was deleted because the article 38 just states the equivalency between specification without the statements of functions or performance. From the legislators' viewpoints, equivalency clause is a threat for public safety. By applying the Article 38 to specific projects, one can forget all about other articles, which makes BSL powerless. Then the minister of construction can decide everything as if he/she were an absolute monarch. General public may concern that the Minister can harm public safety if he/she listen only to a specific body when making decisions. That is why we threw away the equivalency clause and adopted functional system. As will be shown later in this text, functional requirements are clearly stated in the code. So called "performance evaluation methods" for structural fire resistance and for evacuation safety are to be specified for measuring if a specific design solution is in compliance with code requirement in a clear and transparent way.

In an engineering sense, it is quite difficult to catch up all the issues in regulation system and to interpret them in an engineering manner. However during MoC's another project on Development of Evaluation Methods of Fire Safety Performance of Buildings (1993-97 fiscal years, see Figure 1) and other activities, new engineering methods, especially simplified calculation methods have been collected and proposed for use as components of performance evaluation methods. Some of the tools has already been applied in the previous case study workshops in Ottawa[5] and Maui[6] Conferences on Performance- Based Codes and Fire Safty Design Methods Simplified hand-calculable methods are the basis for the performance evaluation methods to be included in the new BSL system.

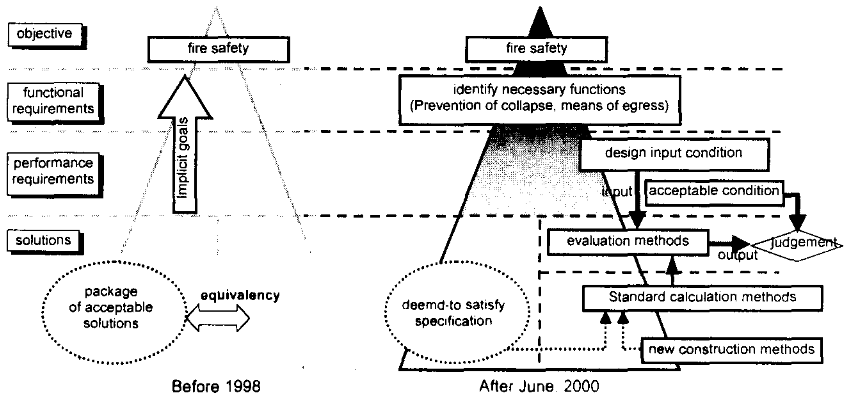

Figure 2 Addition of Performance Evaluation Methods to BSL (represented in NKB format, does not necessarily reflects the actual code structure)

The revision of building standards law and associated enforcement order, notifications are carried out in bottom-up approach, rather than the clean sheet approach. The area of changes are summarized by Yusa and Tsujimoto[7] as shown in Figure 3 and Figure 4. The changes can be classified into two parts. One is to introduce performance evaluation methods. There will be two evaluation methods. One intends structural fire resistance. The other corresponds with evacuation safety.

The other is to rationalize remaining prescriptive regulation to harmonize with performance-based style. It includes adoption of new testing methods based on performance measurements such as in ISO test series.

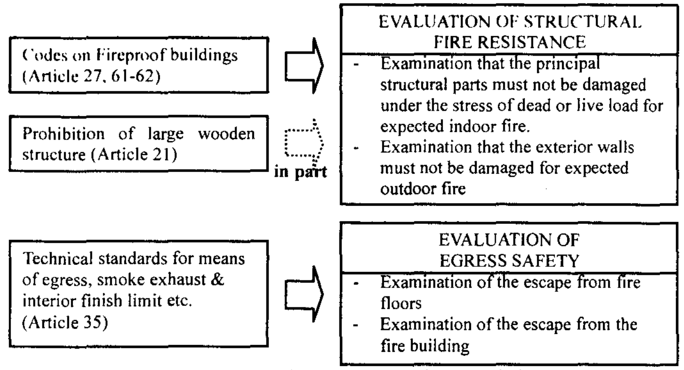

Figure 3 Introduced parts as performance-based methods in the BSL

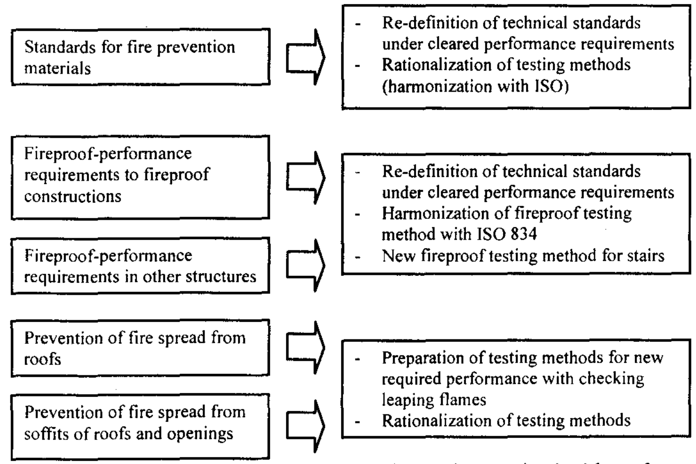

Figure 4 remained parts in prescriptive style, but harmonized with performance-based methods with rationalization

3.2 Functional System associated with Performance Scale (Evaluation Methods)

To introduce functional system into the BSL, MoC and technical supporters analyzed the building specifications (耐火建築物= Fireproof Buildings) and broke them down into some pieces of functional requirements. The details of new evaluation (safety checking) methods are not released yet. However several proposals have been made by fire research/engineering community in Japan through the work in a committee for developing fire safety guidelines at Building Center of Japan (Jan., 1999 - Feb., 2000) as well as through the voluntary work in Fire Safety Design subcommittee in Architectural Institute of Japan. Figure 5 shows the functional system discussed through the MoC project (MoC Project 2 in Figure 1). We put five functional terms to meet with fire safety requirements; reduction of fire occurrence, evacuation safety, prevention of collapse, assurance of fire fighting, prevention of urban fires.

However we are concentrating on only two of them, fire resistance and egress safety evaluation, which are hatched in Figure 5. Namely, the following two evaluation methods were developed:

(E1) (Specific type of) buildings shall not collapse during complete process of fire.
(E2) (Specific type of) buildings shall be evacuated with acceptable safety.

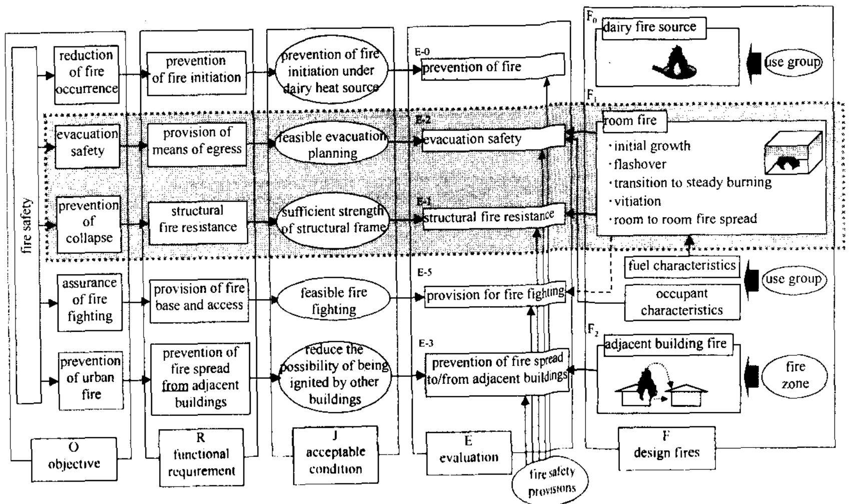

Figure 5 Schematization of performance-based fire safety design[8] and performance evaluation system (hatched box)

3.2.1 Performance Evaluation of Structural Fire Resistance

To prevent the structural collapse during and after fire, the strength reduction of the load bearing elements shall not fall short of its service load. Namely the margin of strength M

$$M(t) = R(t) - S(t) > 0, \quad t = 0 \sim \infty \tag{1}$$

would be a performance scale, where S is the service load, R is the strength (resistance). It is practical to write down

$$M(t_b) = R(t_b) - S(t_b) > 0 \tag{2}$$

where t_b is the fire duration time (plus some post fire period). Thus it is possible to adopt time as a performance scale by

$$t_{margin} = t_{fr}(S) - t_b > 0 \tag{3}$$

where t_{fr} is the time to failure under specific service condition S. The flowchart for evaluation is shown in Figure 6.

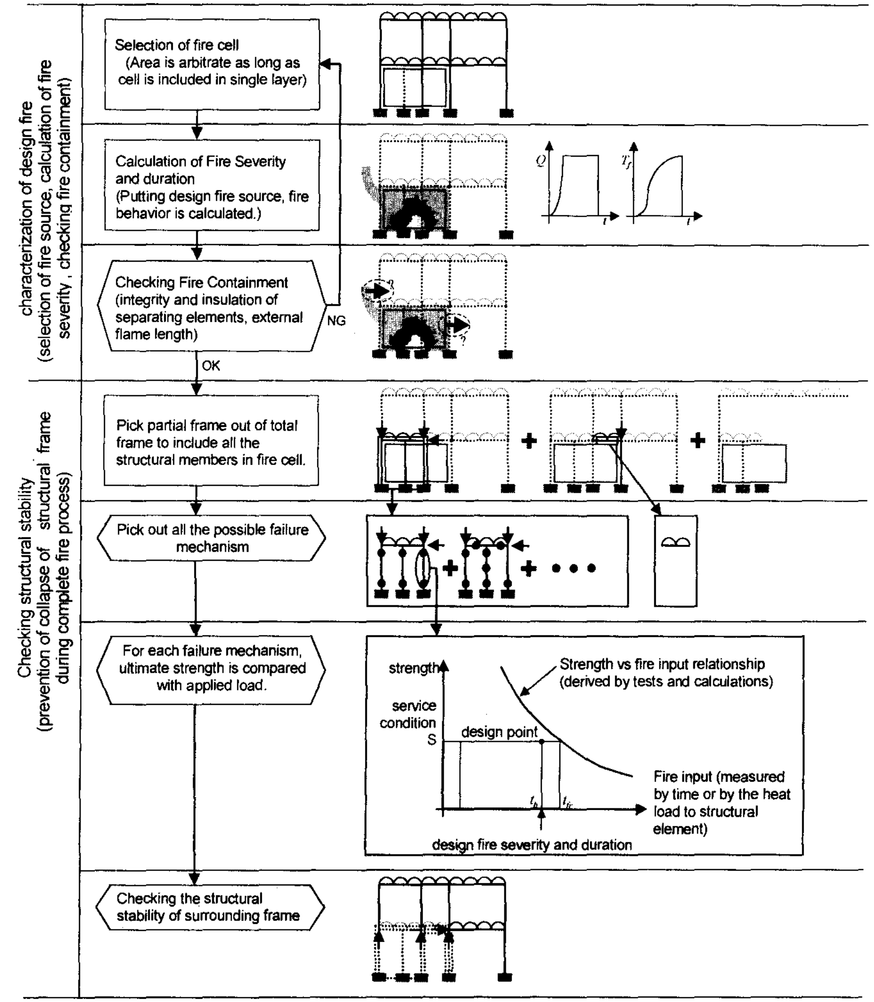

Figure 6 Flowchart for the Evaluation of Structural Fire Resistance (Technical Proposal)

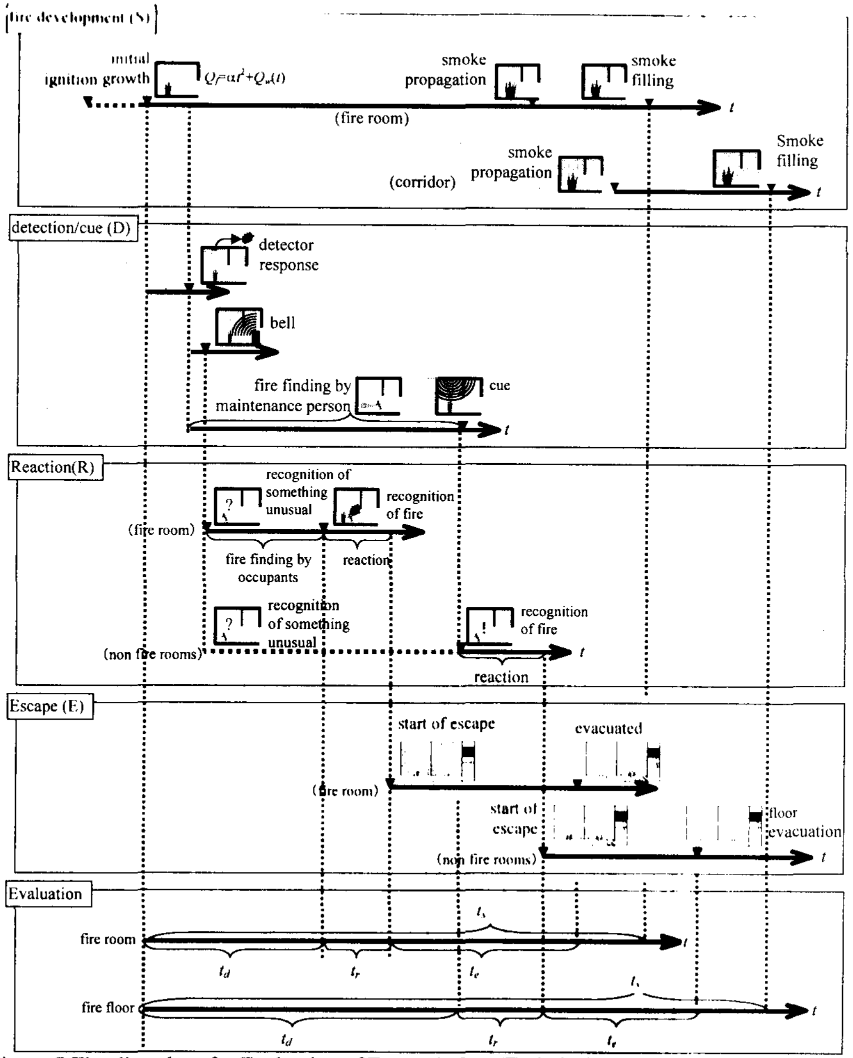

Figure 7 Timeline chart for Evaluation of Egress Safety (Technical Proposal)

3.2.2 Performance Evaluation of Evacuation Safety

The functional terms in egress may corresponds with (1) safety from fire phenomena, (2) safety from congestion (3) clarity and continuity of the egress routes, and (4) redundancy of the routes (at least one evacuation route regardless of fire location) and so on. However these are summarized into one performance scale described by time.

Figure 7 shows the timeline chart for evaluation. Theoretically it includes the combustion characteristics of contents (slow, medium, fast), occupant characteristics (awake/ asleep, familiar/ unfamiliar, able/ disabled), detection and cue, extinguishers, smoke control and so on. In place of the complete set of provisions, a performance scale can be described by escape time margin[9],

$$t_{margin} = t_s - (t_d + t_r + t_e) > 0 \qquad (4)$$

which shall be positive for safe evacuation, where t_d is the time to detection [s], t_r is the time for initial response [s], t_e is the escape movement time [s], and t_s is the time to untenable condition (smoke filling) [s].

In the BSL, only several provisions are regulated. The rest are regulated by other laws or left to owners choice. Thus the evaluation method takes into account only some of the provisions listed in Figure 7 as trial design parameters. Other provisions are assumed or fixed by prescription.

3.2.3 Linkage with Prescriptive Part of Regulation

In the new system, not all of the building regulation goes to functional system. The linkage between prescriptive and functional system is to be established. One of the examples is the combustibility of interior linings regulated in public buildings. In a functional manner, the reasons for limiting combustibility could be either (1) reduction of ignition frequency especially in rooms with daily energy source or (2) limitation of fire spread during early stage of fire. In the performance evaluation, interior linings are required not to accelerate the fire growth rate during fire. In case of combustible interior finish, heat release rate of a model fire is increased as a penalty.

4. INSTEAD OF SUMMARY

If you search the items "Performance-based" and "regulation" by Yahoo USA, you can hit 5135 pages (2000.5.3). And if you add "building" to the keywords, you get 2626. In the case of yahoo Japan, "性能規定:Performance-based" and "法:regulation" hit 502, and "性能規定:Performance-based", "法:regulation" and "building" hit 418.

It seems that to revise the building regulation is one of the national movements to refresh the structure of administration in USA, but that the case of BSL in Japan occupies an alone and distinguished position among the performance-based transformation. It seems to be in urgent need to enrich the administrative organizations.

ACKNOWLEDGEMENTS

The authors would like to thank fire research group in the Building Research Institute (BRI) for technical information on the performance evaluation methods. Opinions in this paper belong to individuals and do not necessarily reflect the official view.

REFERENCES

1. Pound, R., "An Introduction to the Philosophy of Law", p169, Yale University Press, 1921
2. Takagi T., "Transition of Building Standards Law and Performance-Based Fire Safety Design", Bulletin of Japan Association for Fire Safety Engineering, Vol. 50(1), pp. 59- 62, (in Japanese), 2000
3. Building Center of Japan, Total Fire Safety Design System of Buildings, 1989
4. Takeichi, N., "Building Regulation and Market ", Bulletin of Japan Association for Fire Safety Engineering, Vol. 49(6), pp. 1- 4, (in Japanese), 1999
5. Tanaka, T, Hokugo, A, Hagiwara, I, Harada, K, Ohmiya, Y., Koya, K., "A Case Study Using the Performance Based Fire Safety Design System in Japan", Proc. Int. Conf. on PBC & FSD, pp. 409- 420, 1997
6. Tanaka, T., Hagiwara, I., Harada, K., Ohmiya, Y., Mizuno, M., Yamaguchi, J., Tomatsu, T., "Performance- Based Fire Safety Design of a High-rise Office Building", Proc. 1998 Pacific Rim Conf. and 2nd Int. Conf. on PBC & FSD, pp. 563- 574, 1998
7. Shuitsu Yusa, Makoto Tsujimoto, "Outline of Reforming the Building Standards Law in Japan", presented at 15th US-Japan Panel on Natural Resources, Fire Research Panel, San Antonio, March 2000
8. Tsujimoto, M., Hagiwara, I., Harada, K., Takahashi, W., Takeichi, N., "Performance Evaluation Methods for Fire Safety Issues in the Building Standards Law of Japan", Bulletin of the Japan Association for Fire Science and Engineering, Vol. 49(1), pp. 7-15, (in Japanese), 1999
9. Harada, K., "Performance- Based Codes and Performance- Based Fire Safety Design", Fire Science & Technology, Vol. 19, No. 1, pp. 1～10, Science University of Tokyo, 1999

WORKSHOP-1