# NEW TREND OF FIRE SCIENCE AND FIRE PEROTECTION TECHNOLOGY

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## ABSTRACT

Firesafety design engineerings have been mainly derived from complicated rearrangement of descriptive specifications in codes or regulations through a great number of lessons from fire disasters.In this paper,the author refers to some recent developments in the field of building fire protection.At first,the author expresses his viewpoints concerning performance-based design codes,which have been popular throughout the world as a symbol of freedom from restiricted usage of building materials and components prescrived in regulation or bylaws,in spite of some conflicts between objects-oriented design method and industrial mass production.Secondly,the author introduces several innovative fire protection methods adopted for large or void spaces in building complex.Finally,the author forcasts a next development of firesafety science and technology,aimed at securing personal safety in hyperscale urban areas.

**KEY WORDS:**performance-based design,mass production of building materials,fire scenario,atrium,compartment,elderly people, smoke control,fireresistiveglass,automatic signing system for evacuees,virtual reality

## INTRODUCTION

Fire science and technology has its own mission of securing life-safety and mitigating property-loss with reasonable cost-benefit range by applying preferable engineering tools. In many countries,however,fire protection policy has been implemented according to the descriptive-based regulation or bylaw,which have quite a limited allowance against an alternative method for carring out firesafety design with various kinds of fire performance materials or equipments. In the other hand,the benefit of descriptive specification would be found in its deterministic expression,which enables the conclusion of exact contract between parties concerned,by using mass production materials or equipments,despite of its ambiguous attainment to firesafety. Japan has a great number of partial experiences on performance-based firesafety design for buiding or urban complex.Some examples are introduced in this paper.

## SOME ISSUES ABOUT PERFORMANCE-BASED DESIGN

Performance-based firesafety design would be carried out in compliance with the following procedure and also shown in **Fig 1**.

1) decide objectives and their risk-level for the concerned occupancy to be protected
2) define fire scenarios through characterizing potential fire hazards
3) select or develop appropriate modelling tools for fire phenomena
4) select candidates for suitable fire protection countermeasure
5) decide a reasonable specification through cost-performance analysis
6) obtain the third person's approval of the proposed design method with building construction materials and equipments

Objectives of firesafety is to reduce risk concerning loss of life and property. For example, the rate of life-loss caused by fire,traffic accident and disease are respectively $10^{-5}$,$10^{-4}$ and $10^{-3}$ persons per population in Japan. If the life-loss rate of a

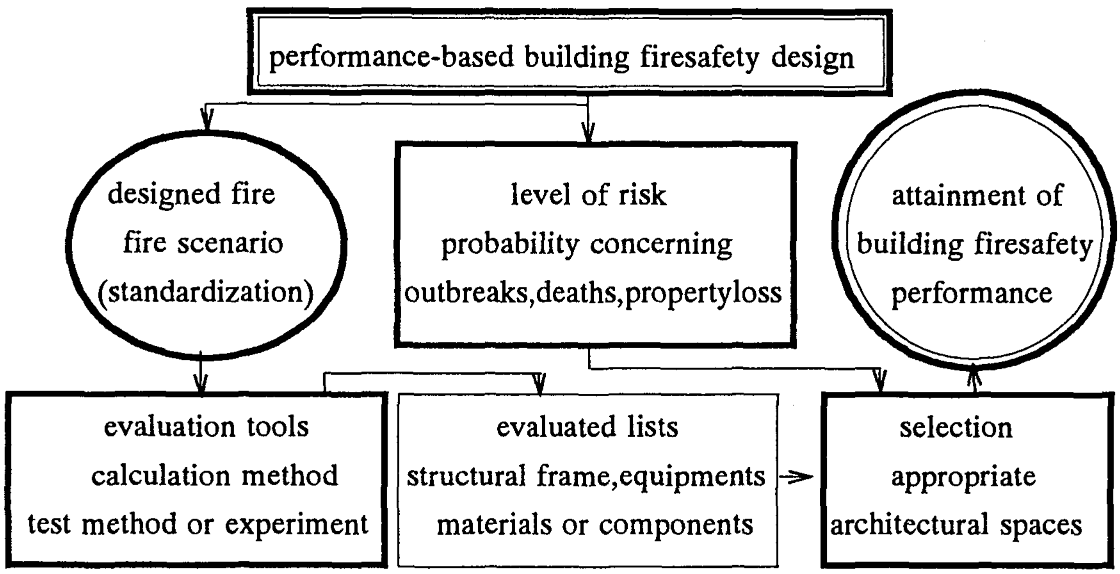


Fig. 1 Performance-based building firesafety design procedure

certain accident would be less than $10^{-6}$ value,the risk management might be recognized to rearch preferable level.According to this hypothesis, fire deaths should be reduced moreover down to hundred figures, because yearly fire fatalities in Japan have been approximately 1,200 persons so far[1].And fire costs have been increasing according to the addition of legal articles often revised by the lessons from a large numbers of fire tragedies.Performance-based design are expected to be effective for reduction of life-loss risk,rationalization of fire costs,promotion of world trade and economic activities,etc..Performance-based codes would be composed of the following packages.

1) guideline for the application of performance-based code packages
2) document on probabilty of fire outbreak and severity of fire origin
3) document on firesafety design method for establishing fire scenario
4) modelling tools for predicting: initial fire growth and time of flashover;heat,gas, and smoke release rate from compartment; peoples' evacuation and smoke movement in a building; compartment-to-compartment,or building-to-building fire; fire resistivity of wood, steel and reinforced concrete structure;the growth of group fire or conflagration

Some of them have been already popularized and the others are on the way of development or publication around the world[2],[3],[4],[5],[6],[7],[8].However,a great deal of works might remain before these packages become more serviceable.The below-mentioned are several articles to be solved for establishing performance-based firesafety design.

1) predict appropriate probability of fire outbreaks and their locations
2) prefer to calculate growth of fire by using data from basic and small scale tests
3) distinguish advantage in applying field or zone modelling for smoke movement
4) rationalize fire resistance design of structural frames
5) establish evaluation,inspection and insurance service systems(especially,in Japan)

## INNOVATIVE EXPERIENCES IN BUILDING FIRE PROTECTION DESIGN

Performance-based design engineering has been typically promoted for attaining firesafety in spacious areas such as arena,mall or atrium,which needs inherently to secure peoples' evacuation through predicting smoke movement. A great number of construction projects have been performed in Japan during from 1985 to 1995.Many engineering solutions have been developed for realizing firesafety.Some of them were beyond legal descriptive provisions concerning fire detection,fire extinguishment, compartmentation,smoke control,evacuation,fire protection and fire resistance.During the period,some new fire performance materials or equipments have been invented such as fire resistive steel,fire coverings for seismic-free apparatus,fire screen as alternative fire door,automatic fire escape signing system against smoke movement,and massive water spray system.

(1) Large-scale Buildings and Their Legal Approval Policies in Japan

The number of highrise buildings over 100m in height constructed during from 1985 to 1996 are shown in **Fig. 2**[9], including the Landmark Tower,the largest building complex at MM21 district in Yokoham whose height is 296m and total floor area is 388,201.72m$^2$ with about 74,000m$^2$ of entrance promnards and parking garage for 1,400 vehicles[10]. Some innovative fire technologies were also adopted for Kansai International Airport Project which were basically designed by Italian architect,Renzo Piano,with total floor areas 296,261m$^2$,spacious aerodynamic geometries in the roof structure,partial smoke or heat control (cabin or island concept) system for huge space [10].These projects have been performed so far in compliance with special building approval procedure authorized by the Ministry of Construction,Japanese government. A new trial building needs to conquer its illigality by applying appropriate packages for calculating fire phenomena,accompanied with several sorts of experiments.The general contents of document for legal approval are as follows.

1) profile of an proposed building; location,type of structure,scale,occupancy

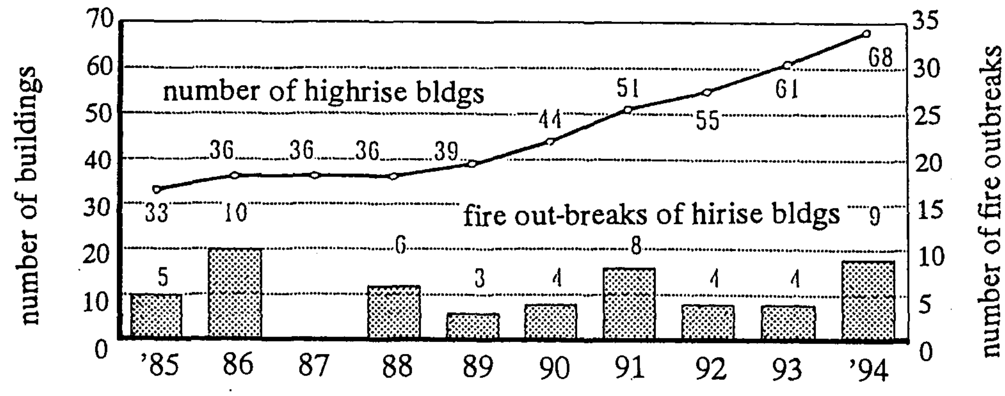


Fig. 2 Highrise buildings(>100m) constructed during from 1985 to 1994

2) basic concepts on fire protection policies; location of final escape floor, escape route, egress facilities, fire compartment,and semi-fire compartment.

3) site and road; entrance at final escape floor, connection between inside and surrounding road or vacant space

4) fire protection equipment; its kind and location

5) fire recognition and call; the kind and location of fire alarm, smoke or heat detection,and emergency call

6) evacuation;location and structure of egress facilities such as corridor,strait stair case,escape staircase,openings on the way of escape rout,emergency light,etc.

7) smoke exhaust equipment; exhausting method and structure of the equipment

8) emergency entrance and emergency elevator; location and structure

9) fire extingushing equipment; location and structure

10) fire control center, management system for fire protection equipments

11) building facilities management; management organization and its method

Almost architects want to keep adjascent rooms open to the atrium,which leads to a performance-based firesafety design.And its appropriate size has to be decided according to the results obtained both from calculation of smoke or heat dispersion speed and from peoples' final evacuation time. Smoke exhaustion from surrounding rooms might be useful to prevent its invasion to the atrium.Smoke control system,however, might belong to a quite sensitive technology. At the same time, another stride to develop new fire detecting or extinguishing equipments and fire performance materials would be indispensable for the creation of firesafety.**Table 1** shows the number of new technological trials approved during 1995[9].

Table 2 The number of technological trials approved during 1995

| main use | comprtmnt | | smoke | | escape | | elevator | | steel | | concrete | others | total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | area | atrium | pressure | exhaust | route | facility | smoke | seethrgh | cover | resistv | filled column | (sheet, timber) | |
| hotel | 2 | 3 | 0 | 1 | 0 | 0 | 1 | 1 | 2 | 3 | 0 | 0 | 13 |
| hospital | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 2 | 1 | 0 | 7 |
| apartment | 2 | 2 | 0 | 1 | 2 | 0 | 0 | 0 | 1 | 1 | 0 | 2 | 11 |
| office | 4 | 13 | 8 | 10 | 1 | 1 | 1 | 4 | 7 | 7 | 3 | 3 | 62 |
| store | 2 | 4 | 0 | 2 | 2 | 0 | 0 | 0 | 6 | 11 | 2 | 0 | 29 |
| complex | 12 | 17 | 8 | 12 | 5 | 2 | 1 | 12 | 15 | 12 | 1 | 5 | 102 |
| garage | 1 | 1 | 0 | 2 | 0 | 0 | 0 | 0 | 12 | 27 | 0 | 0 | 43 |
| other(big space)etc | 8 | 11 | 2 | 8 | 0 | 1 | 2 | 3 | 11 | 15 | 2 | 16 | 79 |
| total | 32 | 52 | 18 | 37 | 10 | 4 | 6 | 20 | 54 | 78 | 9 | 26 | 346 |

**note:number of buildings during 1994(136),during 1995 (160)**

(2) Some Examples of Approved Firesafety Designs

If building firesafety design would be carried out according to performance-based method, its engineering packages should be composed with the above-mentioned documents.However,performance-based design concept has been not fixed yet,and in Japan the following design procedure are generally adoptet for securing firesafety in a new trial building.The author would like to briefly introduce this procedure together with a few descriptions of engineering trials.

1) General;Firesafety design should be conducted according to an appropriate senario of fire growth, aimed at making no failure in peoples' egress and mitigating property-loss.The egress policy should be recognized successful, if all persons can escape into a vestible or staircase on the same floor.The proposed building should not collapse by the concerned fire. An adjacent building should not be caught in flame by fire of the proposed building.

2) Fire risk of heating source;If the received heat flux from the concerned heating origin is less than 12kW/m $^2$ for short time heating,10 kW/m $^2$ for regular time or 7 kW/m $^2$ for long time, the concerned heating origin should be recognized to have no risk against fire outbreak.

3) Determination of noncombustibility or ignitability of materials;. Noncombustibility should be determined by the recognized test method similar with ISO1182.Ignitability should be determined by 30 ～ 70 kW/m $^2$ radiation of the ISO 5659 test method for predicting flame-spread rate along the surface of interior finishing.

4) Upward flame-spread rating;At present,experimental results are adopted together with complementary calculation methods.

5) Flame height from fire origin;Calculation method is adopted together with some experiments.

6) Classification of standard heat flux;Standard heat flux should be classified according to use and occupancy followed by personal ability for escape and quality of fuels,which is classified to No.1 ～ No.3 fire origins (details omitted here).

7) Predicting time of flashover outbreak;Not settled.(Flashover phenomena might not be easy to predict its time of occurrence, in spite of the extreme importance to firesafety engineering.)

8) Behaviour of fully developed compartment fire;Endurance of fully developed fire would be able to calculate with burning rate controlled by ventilation or fuel.

9) Flame length emerged from openings of compartment;Flame length are estimated

through consideration of excessiveness of fuels in the compartment.
10) Temperature distribution and smoke movement;Several packages are prepared for estimating temperature or smoke hazards.

## NEXT CENTURY FOR FIRESAFETY DESIGN ENGINEERING

Development of performance-based design engineering will furthermore promote firesafety analysis on the viewpoint of cost-bebefit, risk management,world trade and ecomonic activities.In the field of fire science, researcher will be able to observe more substle phenomena by the sake of advanced computing or experimental apparatus.It is said that 21st century exists for further propulsion of human research,which will expect the condition of peoples' egress and fire management policy will be more explicit,especially for elderly and disabled peoples.Mutual functional requirements in building such as safety,comfort,durability,availability and serviceability will be harmonized furthermore, for each person to individually feel safe and comfortable in any urbanized situations.As far as building firesafety concerned,one of the symptons would be found in the Sendai Media Park Project by Japanese architect,Toyo-o,Ito as shown in **Fig. 3**[12],where each story has about 2,400 $m^2$ in floor area and 34 m in height.The special characteristics of this office building will be forcused on its complete transparency like a jellyfish,and its firesafety has been mainly secured by compartmentation of the surrounded staircases in irregular mesh columns by using heat resistive glass. Another symptom would

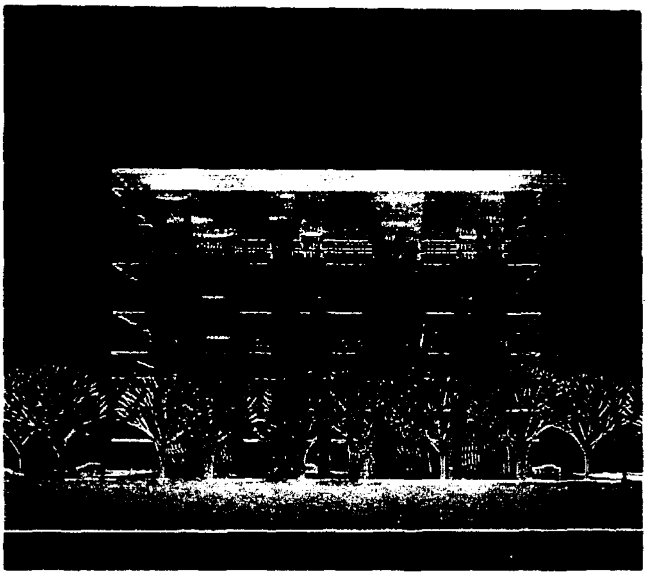

Fig. 3 Sendai Media Park,Japan by T.Ito

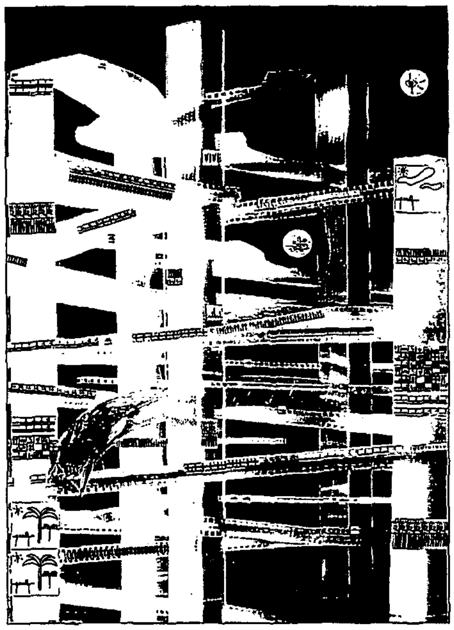

Fig. 4 Hyper highrise complex image

be found also in the Hyper Highrise Building Complex Project performed by Japanese construction community.This project is aimed at construction of super highrise complex of 1,000m in height,100 ha in total floor area and 1,000 years in availability as shown in **Fig.** 4[13],which needs furthermore firesafety technology based on another promotion of research such as access to fire dynamics in high level of wind speed and pressure difference and behaviour of peoples' evacuation by using a tool for virtual reality or cyber space.

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