History of Fire Safety Engineering

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To prevent the repetition of failures, the mistakes on fire safety procedures in the past made in Japan is explained from the viewpoint of safety engineering. For example, it was imaged that, to reduce the fire risk dramatically, to change the structural material of the building from wood to noncombustible one would be enough. But the life risk by fire in buildings didn’t change so much in Japan after that change.

Material and Fire, Compartmentation, Fire Resistance and Smoke Control are discussed.

1. Material and Fire

Speaking about fires in Japan, the big city fires in Tokyo in Edo era(1600-1868) are representative. Figure 1 shows an area crowded by 3-stories wooden houses at the end of 19 Century. Tokyo in Edo era(1600-1868) had experienced big fires 89 times, which the length of burned area is over 1.6km. It is easy to explain the reason of big fires. It is because the houses were made of thin woods and they were distributed easy to burn away. In Europe, houses are also made of wood, but not so easy to burn. Because columns and beams are thick and the wall is stuffed with stones or bricks. I’m very surprised when I heard some researcher from Italy saying that the target of fire research in his country was not the human life safety but to protect the cultural property.

In this period, some counter measures were proposed, for example, to widen the street, to increase the number of firemen, and to change the roofing to tile. But only one measure, that was to provide every space with hydrant is apparently proved to decrease the scale of fire from the statistics (1600-2000). (Fig.2) Also there are remarkable differences in the scale of fires before and after the Great Earthquake(1923) and the air attack in World War Ⅱ. The reason is assumed to be the street-widening and the change of frame of structures. But there is no accurate statistic data concerned these two factors, so it is impossible to certificate.

It must be mentioned that pressurized water and proper number of firemen is very effective in the area filled with combustibles.

Next, since Meiji era (1968-) many buildings were built up by reinforced concrete. But the risk of fire in each building was not so reduced by changing the frame of structure from combustible to incombustible, except the probability of city fire (large scale urban fires).

It is clear that the probability of outbreak of fire is not influenced by the frame of structure and that the size of fires in the room does not decrease as many combustibles are carried in it according to Japanese custom.

According to this fact, the regulation to restrict the combustibility of lining of wall and ceiling was introduced to the Building Standard Law, but as shown in Fig.3 the restriction of wall lining have had slight effect because many combustible furniture is fitted up. It is very difficult to restrict the materials used in the building to reduce the probability of outbreak of fire and the damage.

2. Compartmentation

Fig.4 is the typical landscape of European cities (Paris, 2005). The wall of fixed thickness called Party Wall separates each building. And it is prohibited to make an opening to this wall. Its function is to limit the fire within the compartment and to protect the adjacent building. The act regarding Party Wall started in 1189, but it became popular after the London Great Fire (1666). It is worthy of attention that this basic measure took 500 years to become popular.

Expanding this measure, the Compartmentation which limits the growth of fire by separating the building into fixed value of floor area (1500m^2 in Japan) with fire wall became a worldwide method. But this measure was introduced to Japan incorrectly in some points. The first failure was the selection of the steel plate, which was used to protect the window from city fires at that time and has no heat insulation, as a fire door inside the building. The second was to introduce the limitation of floor area by the way of dividing the building vertically as shown in Fig.4. In Japan, the openings such as doors or windows are big compared to Europe and doors are kept always open because of the climate in Summer. So the stairs easily become the path of smoke and the compartmentation loses its effect.

3. Fire Resistance

As mentioned in section 2, if the structure of the building is combustible, the building will collapse at the early stage of fire. It may be the reason that a church or a castle is made of stone and houses are made of wood.

After the Industrial Revolution, iron had become the material for structure of building. And the building made of iron and glass such as Crystal Palace (1851, Fig.5), was considered to be free from fire damage. But many structures made of iron collapsed by the city fires around 1900. Even now, it is difficult to predict precisely the fire resistance of structure, because the prediction needs the heat release rate of fire and how it transfers to the structure. The accidents in World Trade Center and Windsor Building show its difficulty.

4. Smoke Control

Overcoming the weak points mentioned above, the reinforced concrete and steel with fire resistive protection became the mainstream of structure of building. As the result, the risk of the building collapse was reduced, but the life risk of the occupants was not. After the flash over, the hot smoke with high concentration of CO (carbon monoxide) tends to spread rapidly in the building, mainly to upper floors. This is the basic weak point of high-rise buildings, resulted from the efforts to get an efficient occupancy of urban lands in the cities. The smoke spread (heat convection) occurs faster than heat transfer, and the occupants easily lose the ability to evacuate. It becomes the last important theme of high-rise building: how to control the smoke movement.

The best way to prevent the smoke spreading around the building is by shutting it in the compartment like shutting of the flame spread. But it is very difficult to stop the smoke spread by closing the openings like doors if compared to the flame spread, because the occupants usually want to move between compartments freely and dislike to close the openings. (Excluding the combustible materials at some fixed distances can stop flame spread.) To control the smoke movement in a staircase where the buoyancy of smoke effects is strong, is the last important problem of fire safety engineering.

The final purpose of smoke control is to assure the life safety of the occupants. And to reach it, the assessment methods to predict the fire scale, the smoke movement and the evacuation of occupants considering the character of them are necessary. Fig.6 shows the schematization of performance-based fire safety design in Japan nowadays, using these assessment methods.

After all, the mistakes in the past teach us that it is most important not to misread the scale of fire and what will happen in the building.

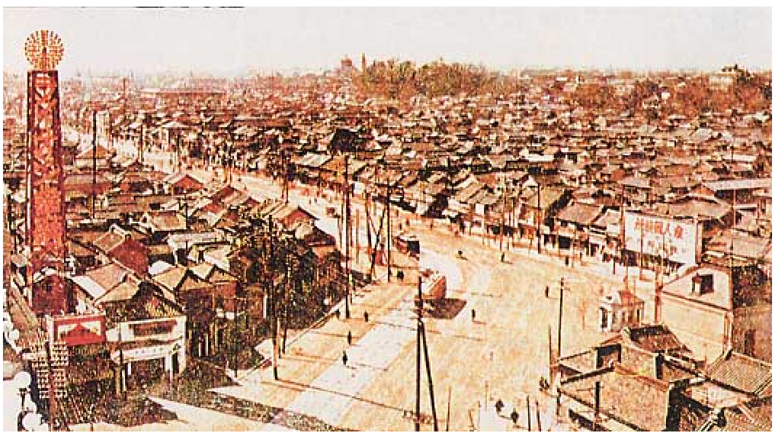
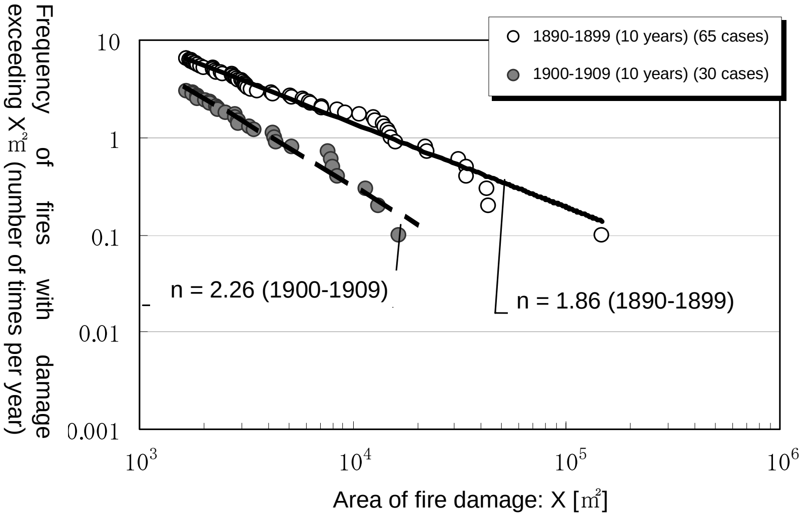
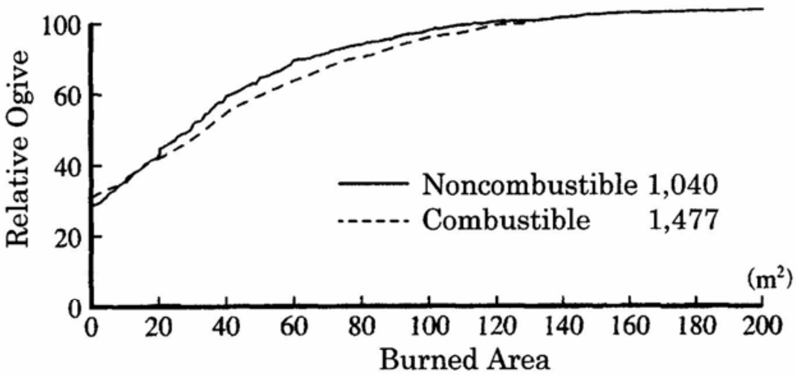


Fig.1 A view of Kanda district from Ueno Park, Tokyo

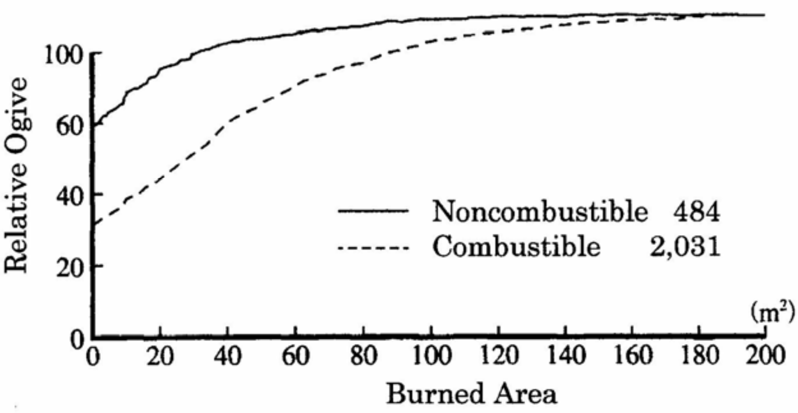


Size and frequency of fires before and after installing fire hydrants

Fig.2



a. Lining of Wall and Burned Area



b. Lining of Ceiling and Burned Area

Fig.3 Lining and Burned Area

Fig.4 Party Wall (Paris, from Pompidou Center, 2005)

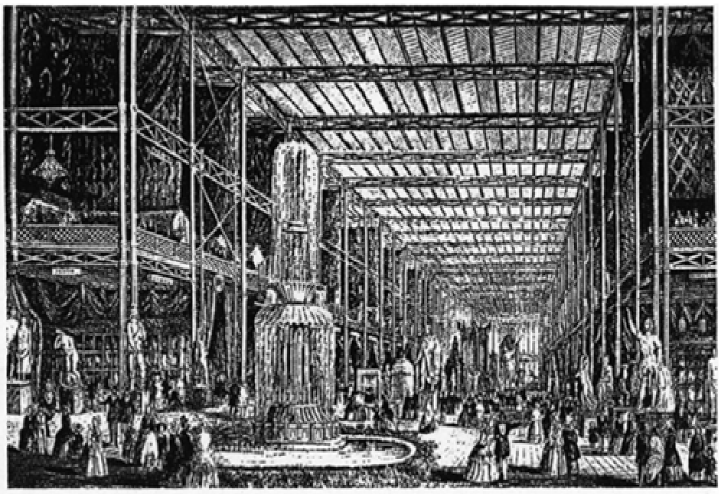


写真 5 -310 ハイド・パークに完成したクリスタル・パレス，内部：ロンドン(1851)

Fig.5 Cristal Palace (London, 1851)

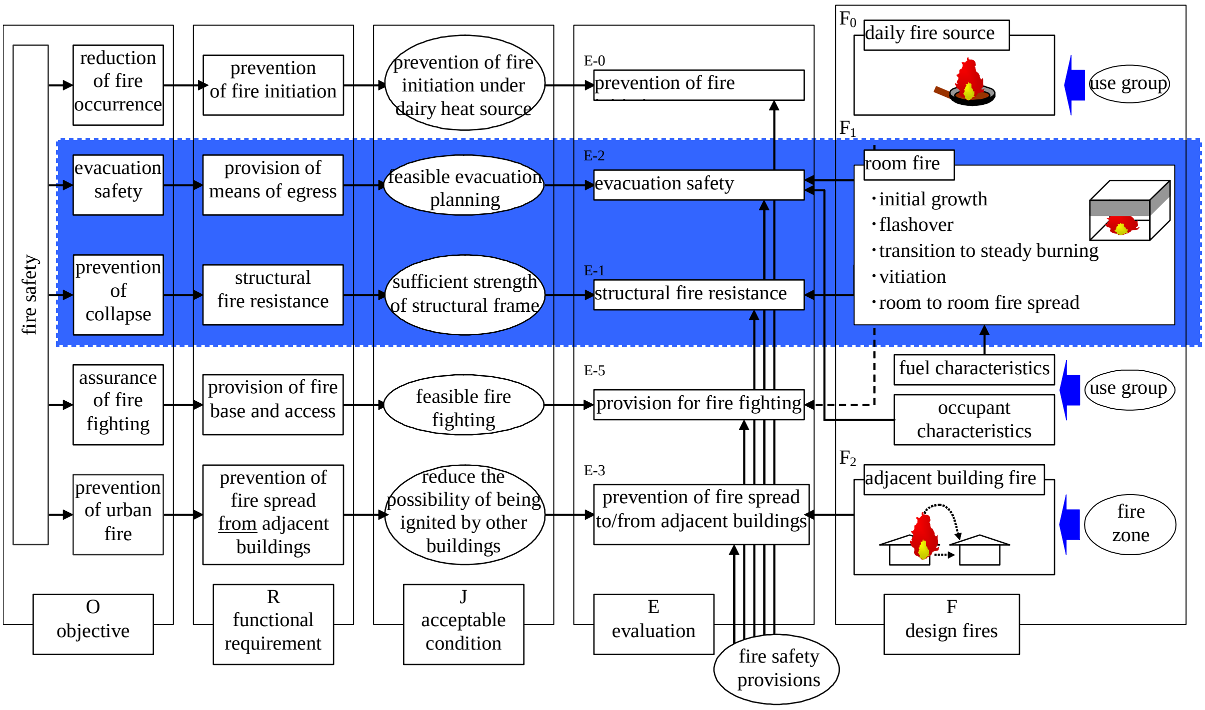


Fig.6 Schematization of performance-based fire safety design and performance evaluation system (hatched box)