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VOLUME 2

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NECESSITY OF DESIGN METHODOLOGY IN THE FRAMEWORK OF A PERFORMANCE BASED FIRE SAFETY DESIGN SYSTEM

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INTRODUCTION

Sometimes research people tend to esteem 'science' more than 'engineering'. The difference between the two may not matter for most fire researchers but may subconsciously affect the preference of their research targets. The primary goal of 'science' may be defined as to 'discover' the facts, truths or rules in the objects which exist in this world from the beginning. On the other hand, the main role of 'engineering', the word said to be derived from 'engine', has been considered to 'invent' something which 'benefits' our society. Hence, it follows that engineering creates something beneficial which does not exist in this world.

Moving to the subject fire modeling, the author consider that fire models belong more to engineering than to science and that they should find the area of developments more in that direction. In this paper, the author therefore would like to discuss how fire safety engineering tools in general, including computer fire models, can benefit our society, particularly building related community. A particular focus is placed on two layer zone fire models because of the authors expertise, although notable progress was of course made in other type of models, such as field models and detector response models.

PROGRESS IN FIRE MODELING

The notable fire models developed until 1993 are summarized in TABLE 1 according to type and year of publication. Although many more fire models have been developed to date, a thorough coverage is, needless to say, next to impossible here. The models shown in TABLE 1 are basically those cited in one of Refs.[1] - [8], which are papers for reviews or surveys of the state of arts of the fire models at those days. In other words, they are the models which , more or less, drew somebody else's attention.

(1) Dawn of Fire Models

Noticeably, a well mixed type (one layer) compartment fire model was published as early as in the late 1950s by Kawagoe and Sekine, BRI, Japan. It may be said that the means to predict the mass burning rate and the opening flow rates in compartment fires were established by this model. Despite that computers, or even hand calculators, are not available at that time, boundary wall temperatures were predicted using Shmit's method. This model was used until very recently with virtually no modification in the area of structural fire resistance in Japan perhaps because it was an excellent model. Only drawback of this model may be that so-called 'complete combustion ratio' (=0.6) was used probably to adjust the temperature predictions to experience. The universal validity of this parameter is questionable and this can be replaced with the fact that heat release rate in a ventilation limited fire is controlled by the air supply rate into the compartment. However, this must be a too harsh criticism. Considering the general conditions about fire research at that time, this model can be said an outstanding accomplishment..

Another important model appeared in this period is the one published in 1963 by Thomas et al. in conjunction with the investigations into roof smoke venting. The concept of a smoke layer and a fire plume were introduced in this model. It is suspected that this model gave a basic idea to the two layer zone models which thrived in later years.

(2) Smoke Movement Models

The next stage of fire modeling started with the onset of the computer era. The smoke movement model by Wakamatsu, BRI, Japan appeared as early as in 1968, before long when the use of computers began in some of the scientific area. This model was extensively used in the analyses of smoke movement in building fire accidents, such as Sennichimae Department Fire, and efficiency of smoke control systems, such as the stair pressurizations in the two office towers in Shinjuku, Tokyo. It may be said that this model convinced the fire research community in Japan the opening of a new epoch for fire research. In Canada, a similar model was developed by Tamura, NRC, Canada at nearly the same time. As the author believes, his model became the basis of ASCOS developed by Klote, NBS. USA,

(3) Two Layer Zone Models

A building fire involves a number of physical and chemical processes in coupling manners and its behavior is awfully affected by building environment. In conventional studies, only limited aspects of fires could be investigated in some simplified configurations because of the limitations of analytical methodologies, which must be a major reason for that fire researches had been somewhat slow for a significant time period. On the other hand, rapid progress of computers made it practicable to analyze complex fire behaviors as they are without neglecting many aspects.

It is the Home Fire Project in the USA that envisioned a promising progress in fire research area on the basis of the extensive computer capability and vigorously promoted the development of fire models. This project was conducted under the strong leadership of Professor Emmons, Harvard University. In his future scope there was such a model that is capable of predicting the transient fire environment of any kind, including burning, at any space in a building after an item has ignited in a room. He considered that a field type model was too heavy in terms of computing time despite of the enormous capability of the computers at that time, so that two layer zone models would be appropriate for such a purpose. It is suspected to be under the influence of his thoughts that many models were published almost simultaneously in the USA, by Rockett , Quintiere, NBS and Harvard University etc. In this sense, it can be said that Professor Emmons was the foster father of two layer zone models.

Ever since, the computer capability has been tremendously enhanced beyond our imagination. Still, Professor Emmons' decision seems to retain appropriateness. To borrow the words of Kokkala, VTT, it is the oxygen consumption calorimetry and the two layer zone models are the two major inventions that dramatically changed the way of fire research in this decade. The author has the same feeling, although wish to add the performance-based fire safety design method in near future. Thus, it turns out that Professor Emmons also triggered the rapid progress of fire research in recent years worldwide.

In Japan, Fire simulation workshop was initiated responding to the invitation of Professor Akita, University of Tokyo, about the same time as the Home Fire Project. Around ten or more members participated voluntarily from University of Tokyo, BRI, FRI etc. This small workshop had no particular mission nor financial support. Youth was the only asset, in fact most of the members were in their 20s, accustomed to lack of fund, incidentally. The members exchanged the ideas of each other's models with curiosity. Looking back, the author feel that this workshop, which continued

several years, played a valuable role in the early stage growth of fire modeling research in Japanese scene.

It is about such a time that UJNR Panel on Fire Research and Safety was initiated and active exchange of the fire research started between the USA and Japan. Since then, fire modeling has always been a central topic in the US - Japan joint meetings. Many two layer zone fire models were developed during this period in both countries, such as FIRST, CFAST, HARVARD III - VI, ASET in the USA, BRI2 etc. in Japan. UJNR Fire Panel affected on many of the model, directly or indirectly. It is well known that two layer zone models, of which the UJNR Fire Panel took the lead, have now propagated to many countries, stimulated their fire research and are being used for a number of practical applications such as to fire safety design of real buildings.

FUTURE DIRECTION OF FIRE MODELING

The progress of the two layer zone models was remarkable for a good while since they first appeared in the mid-1970s. They increased their predicting capabilities by incorporating new ideas and new findings. Coming to this point of time, however, it seems that the progress has somewhat slowed down. The author's impression is that this stagnation implies that the fire modeling has reached at the stage to have to think about what the objectives of prediction of fire behavior are.

(1) What Should Predict?

What a model should predict depends on the objective of the prediction. In the development of BRI2, including its preceding models, the consistent thinking was that it should be an engineering tool for fire safety designs of buildings rather than a scientific tool. Because of this, it did not deal with prediction of burning and tried to minimize the burden of data input. Modeling of burning behavior itself is difficult enough, but moreover it will require much detailed input data. This might be all right for scientific purposes but will be too much for most of design practices.

How detail and accurate a model should predict will also depend on the purpose. As long as usual building design practices are concerned, what the designer of a building would like to know based on the prediction will be such as whether or not exit width is enough for evacuating people within the available egress time, how much smoke extraction and air supply rates are required to clear the egress routes, whether or not the danger of breaking of the glass roof of the atrium exists and the sort of things. Since such assessments are normally made under a certain assumptions of the size, the location etc. of the fire source, a prediction in detail gives little reality so will not be paid for the extra work for detailed data inputting etc.

(2) Fire Models in the Framework of Performance-based Fire Safety Design

There is an impression that the priority area of fire research has shifted from fire modeling to performance-based fire safety design system. In fact, such a design system is considered to be vital to fire research as well as to building design practices. Many fire models will be able to find their objectives in this system.

What a fire model is to a performance-based design system looks like what a car is to a street system. However high ability a car may have, we will have no choice but cherish it in a garage unless the streets are smoothly paved. Likewise, however capable a fire model may be, we cannot but admire it for a while in a paper and forget before long if building designs have to comply to the existing prescriptive provisions.

Currently, several ideas exist on what the structure of the performance-based fire safety design system should be. One of them is 'Objective-based' type design system, which is most rational as long as the author believes. According to this system, a number of fire safety engineering tools, are needed for the verifications of compliance to the fire safety objectives. They are not necessarily computer fire models although indispensable, It follows that computer fire models hold a seat among these engineering tools. In a sense, this is natural since the purpose of a performance-based design system is not to use computer fire models but to provide a means for rational and effective fire safety designs, which is just like not only cars but also pedestrians, bicycles, motorcycles, street cars etc. use streets depending on the convenience.

PERFORMANCE-BASED FIRE SAFETY DESIGN METHODOLGY

(1) Problems in Using Fire Safety Engineering

Clearly, fire safety engineering tools, including computer fire models, and performance-based fire safety design methods are great contributions from the fire research community to the world of practice. But are they sufficient?

The current state of design practice is that building designers have established their own design methodologies to effectively plan buildings, harmonizing the requirements from building owners and the prescriptive safety provisions. However, a performance-based design system is such a drastic transition for nearly all of them that they currently have very little idea on how they can effectively design buildings based on the new framework. Without such design methodologies, performance-based design systems and fire safety engineering tools will be virtually useless.

Fire researchers may claim that such is the matter of education or training. However, fire researcher may be able to act as teachers of engineering tools but there is no teacher of design methodologies. The author noticed in one of the case study papers presented to an international symposium for performance-based fire safety design method such a sentence which says ' mechanical extraction at the rate of some 200 kg/s is sufficient to attain some 20m smoke clear height'. This is of course an extreme case, but in general fire researchers need to know that there are a lot of things which are practically impossible or too difficult albeit theoretically possible. In this regard, it may be said that the technical research center of the construction companies in Japan are doing good jobs, but even in such exceptionally lucky cases as to be able to have such a research center, the sizes of the staff are often too small for extensive and in-depth studies on the design methodologies. Evidently, fire researchers and practitioners need to have good contact with each other and jointly work for new methodologies. Such endeavors will not end up with mere well-fare services from the side of researchers. They will in return be paid off with a number of attractive research topics.

(2) Sprouts of Performance-based Fire Safety Design Methodologies

It may be said that, since the 5 year project 1981 - 1986, by BRI, MOC, a considering number of exercises for performance-based fire safety designs have been made through Article 38 of Building Standards Law. Thus, step by step, some engineers have got accustomed to the use of several fire safety engineering tools and accumulated some know-how to harmonize the requirements both from fire safety and building economy, that is design methodologies, for several cases of frequent appearance, such as atria smoke venting, lobby pressurization smoke control, unprotected car park steel structure. However, most of such methodologies still remain to be in-company know-how so their universal validity have not yet been proved.

Pressurization Smoke Control Workshop of Kinki branch of Architectural Institute of Japan attempted to work out a widely usable hand calculation methods for air supply rate in lobby

pressurization smoke control systems [9]. Another attempt was made by General Building Research Corporation to develop a smoke control design methodology for department stores with virtually no windows. However, perhaps, many more important issues are still untouched by fire research community.

CONCLUDING REMARKS

It is true that in the development of the fire models, some of the scientific knowledge on fire which existed at that time was used. But this does not mean that fire models depend only on the scientific knowledge, which was often insufficient to build a fire model. Some engineering dealings had to be invented in many cases and fire modeling practices identified the needed area of fire science.

Similar saying will be also true in the relationship between fire safety engineering tools and performance based design systems. The progress of fire models motivated the development of performance-based design systems, but in return the design system will draw demands for various engineering tools, and further on fire science.

It will be important and beneficial for fire researchers to more positively get involved in fire safety design methodologies to run smoothly performance-based design system, just like it is important to master how to drive a car in the streets.

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