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Comments by the Author of the Introductory Report

Remarques de l'auteur du rapport introductif

Bemerkungen des Verfassers des Einführungsberichtes

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Thermal Effects of Fire in Building

The Introductry Report of Subtheme III (a) "Thermal Effects of Fires in Buildings" written by us has been issued in 1975.

Four Preliminary Reports have been presented to the Subtheme III (a) and issued before the Congress.

In the first paper "Théorie des Equivalences" by Mr.E.Absi and M.Borensztein, CEBTP, France, the calculation method to predict the temperature-time field and the thermal stress in a concrete structural element are described and some calculation results are shown.

In the second paper "Détermination par la method des éléments fines des evolutions de temperature pour les structure soumises à l'incendie" by Mr.J.C.Dotreppe and M.Hogge, Universite de Liege, Belgique, the detail of a calculation method to predict the temperature-time field in a structural element is described and an experimental result is compared with the calculated one.

In the third paper "Application of a Limit State Concept to the Performance of a Structure under Fire Conditions" by Mr.H.L. Malhotra, Fire Research Station, U.K., a new concept considered some limit state to the performance of a structure, based on the semi-probablistic approach is described.

In the fourth paper "A Differentiated Approach to Structural Fire Engineering Design" by professor O. Pettersson, Lund University, Sweden, a pure engineering design method for fire resistance of building structure which has been legally available in Sweden is described.

These four papers are connected each other and I will explain as one story mixing with our introductry report.

As Mr.Malhotra describes in his paper, "the standard temperature-time curve" for the standard fire test of building structural elements was established, and the simple relationship between the fire load density and the necessary duration of fire exposure along the standard temperature-time curve was derived by Dr.S.H.Ingberg about 60 years ago.

Then the concept of the fire resistance design for building structure was established.

That concept was to subdivide the building effectivelly into "fire resisting compartments," and the building regulations and codes designated the fire duration required, depending on the occupancies and the height or the size of building and also the fire resisting capacity of structural element was determined by the results of the full scale standard fire test.

In many countries except Sweden and France, this traditional design method has been still used legally and the International Standard Fire Test Method by ISO has recently been agreed.

Over the last fifteen years the fire research has been advanced remarkably, and the people intend to use the engineering method for fire resisting design apart from the traditional way.

The first country in which a new engineering method was permitted to use legally was Sweden. Professor Pettersson describes in his paper that it is necessary to define the following four items to establish an engineering design system.

a) the fire load characteristics,
b) the gas temperature-time curve of the fire compartment as a function of the fire load density, the ventilation characteristics of the fire compartment,
c) the temperature time field, and
d) the structural behaviour and minimum load bearing capacity of the fire exposed structure for a complete process of fire development.

Our introductry report has been described along these items. Now I explain some detail of each one.

a) The survey of the fire load of several occupancies has been done in several countries. But the fire load characteristics is slightly different for each country, because the structure and the use of building are different. Therefore it is necessary to determine the fire load density in each country, whatever the survey of fire load takes much labour and time.

The explanation of fire load density has many ways, depending on the purpose, as follows,

$\dfrac{\text{equivalent weight of wood (Kg)}}{\text{unit floor area (m}^2\text{)}}$ (traditional)

$\dfrac{\text{potential heat content (Mj)}}{\text{unit floor area (m}^2\text{)}}$ (ISO)

$\dfrac{\text{effective heat content (Mj)}}{\text{unit interior surface area (m}^2\text{)}}$ (Sweden)

$\dfrac{\text{effective heat content (Mj)}}{\text{unit window area (m}^2\text{)}}$

b) The gas temperature-time curve of a given compartment can be predicted roughly by the calculation of heat balance equation inside compartment, in which the heat release of fire load inside compartment.

In Sweden the calculated gas temperature time curve of a given compartment is taken as the heat load to the fire exposed structure, ignored "the standard temperature-time curve."

In Japan and other countries, the equivalent fire duration along the standard temperature-time curve, which temperature time area over the critical temperature of steel is same as the calculated one, is wanted to use as the heat load.

The result of the international corporative study of CIB W-14, in which eight laboratories were joined to test the model compartment fires, concluded that an experimental formula ($t_f = kL/\sqrt{A_W A_T}$) as shown in Malhotra's paper could be available to use for the estimation of fire duration alon the standard temperature time curve.

c) The temperature rise of steel member protected by the fire cover is not only depend on the thickness and the thermal properties of fire cover but also the heat capacity of steel member itself. It is not rational to determine only the thickness of covering material as usual designation in the codes and regulation.

In Sweden the thickness of fire cover is determined by the calculation of the heat conduction of each element exposed by each thermal load. Therefore a lot of tables and figures have been prepared, some of which are shown in Pettersson's paper.
In France the calculation method is applied legally in the concrete structural design since December 1975, which method is described in Adam's paper in subtheme III (c).

Because the theory of heat conduction has already been established, a lot of studies has been made for the prediction of temperature time field of structural elements exposed by fire.

In preliminary reports in this subtheme, Mr.Absi and Borensztein describe the calculation method used by the theory of equivalences and show some calculated results of concrete structural elements briefly. And Mr.Dotreppe and Hogge describe the detail of calculation method using the finite element one and compare an experimental result obtained from the heating of a block of concrete 18cm X 18cm with the calculated one.

In fact, in the calculation of heat balance equation in a compartment, the calculation of temperature time field of enclosed structual element is necessary. If a big computer could be used, the temperature time field could be calculated in the same time so that it is not necessary to divide b) and c).

Instead the theoretical calculation can be possible to any section of structual elements, the effect of spalling of concrete and of cracks of materials are rather difficult to insert the calculation and also the thermal properties of materials under the high temperature and the mechanism of moisture migration inside material under the high temperature are not well known, which are the problems to be solved.

d) The structual behaviour and the load bearing capacity of the fire exposed structure are the main themes of IABSE and especially in subtheme III (b) and III (c). In this subtheme III (a), Mr.Absi and Borensztein describe the calculation method of the thermal stress and the deformation used by the theory of equivalences, but the discussion of these problems is left to III (b)and(c).

For the systematize of the engineering design method based on from a) to b), many ways can be chosen. Now we look at the Swedish system as an example.

At the first, the rate of burning and the rate of heat release in a given compartment are calculated from the fire load density, the size and the geometry of compartment and the ventilation characteristics. Then the gas temperature time curve is calculated which is assumed as the heat load.

Input this heat load to the structural element, the temperature-time field inside it is calculated.

From this temperature-time field and the restraint forces, moments, thermal stress and the reduction of mechanical properties in the structual element, the load carring capacity Rd is calculated.

Leaving these calculated results, the load effect at fire condition Sd is calculated separately.

If Sd is greater than Rd, the proposed structure is modified and recalculation is made until to obtain the satisfaction of Sd<Rd.

In Japan, tall apartment buildings of a big project was designed their fire resistance used by a similar engineering method, but it was specially permitted, not available to use any building.

Finally, the new concept of the limit state approach in fire by Mr.Malhotra is introduced. He divides the limit state into two, one is the limit state of stability which means the structural load carring capacity under fire based on the probablistic approach and another is the limit state of integrity which means the capacities of barrier of the compartmentation.

A similar probablistic analysis for steel structure is presented by Dr.S.E.Magnusson in subtheme III (b).

These studies based on the probablistic approach are only started, but the re-consideration of fire safety will become an important research subject in the fire engineering field because it would be the important basic concept of engineering design.