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TEMPERATURE ANALYSIS OF COMPARTMENT FIRES AND FIRE EXPOSED STRUCTURES

av

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This thesis comprises the following publications under the general heading "Temperature Analysis of Compartment Fires and Fire-Exposed Structures:

[a] Babrauskas, V. and Wickström, U., "Thermoplastic Pool Compartment Fires", Combustion and Flame, Vol. 34 (3), 1979 - see also "Thermoplastic Pool Compartment Fires", Report No. 79-1, Department of Structural Mechanics, Lund Institute of Technology, Lund, 1979.

[b] Wickström, U., "TASEF-2 - A Computer Program for Temperature Analysis of Structures Exposed to Fire", Report No. 79-2, Department of Structural Mechanics, Lund Institute of Technology, Lund, 1979.

[c] Wickström, U., "A Numerical Procedure for Calculating Temperature in Hollow Structures Exposed to Fire", Report No. 79-3, Department of Structural Mechanics, Lund Institute of Technology, Lund, 1979.

During many years the behaviour of structures exposed to fire has been studied by means of standard fire resistance tests. Structural elements have then been exposed to a fixed heating process in test furnaces, and the time to failure has been registered. In recent years, however, more rational design procedures have been introduced - as an alternative to the schematic procedure based on standard fire resistance tests - comprising the three main areas

- the fire development
- the heat transfer to structural elements
- the structural behaviour of elements at elevated temperature

This thesis deals with the first two items.

Only fully-developed or flashed-over fires with gas temperatures in the range of 600 to 1200^{o}C are of interest in structural design with respect to fire. Based on work by Kawagoe, Sekine, and Ödeen [1-3], Magnusson and Thelandersson [4,5] and later Babrauskas [6] numerically modelled flashed-over compartment fires. In applying the model for calculating time-temperature curves for design of structures with respect to fire, Magnusson and Thelandersson assumed that the rate of heat release inside the compartment was limited by the ventilation and that complete combustion of the fuel took place inside the compartment. Babrauskas included the rate of pyrolysis in the mass balance equation of the fire compartment; thus the influence of excess pyrolysis on the rate of heat release could be studied. Input to the model was rate of pyrolysis as a function of time. For most fuels, however, the rate pyrolysis is a function of rate of heat transfer to the fuel surface. The program has therefore been modified and plastic pool compartment fires have been analyzed in [a] according to this approach; the fuel is assumed to pyrolize radiatively only. The dominant variable is shown to be the ratio of ventilation parameter to fuel area. It is also found that with the assumptions made no solution to the heat balance equation exists in the fuel-controlled regime, i.e. well-stirred, flashed-over fires occur only at ventilation-controlled burning. Predicted results are compared to experimental data from small-scale fire tests where polyethylene and polymethylmethacrylate were used as fuel and showed reasonable good agreement.

A nonlinear heat flow equation must be solved to predict the distribution of temperature in a structure exposed to fire. Since analytical solutions of such equations exist only for idealized cases, numerical schemes that incorporate either the finite element or finite difference method have generally been employed to approximate heat conduction.

In [b] TASEF-2 (Temperature Analysis of Structures Exposed to Fire - Two Dimensional Version) a computer program based on the finite element method is described. Structures comprised of one or more materials and structures that enclose voids can be analyzed. Heat transferred by convection and radiation at the boundaries can be modelled. The explicit forward difference time integration scheme used in TASEF-2 facilitates consideration of latent heat in the calculation of temperature in materials such as humid concrete. The maximum length of the time increment that can be used without inducing numerical instability is discussed, and some procedures to avoid very short time steps are suggested. In the present version of the program two-dimensional rectangular elements are used; input of the geometry and generation of the finite element mesh have been automated.

In the report, the theoretical model and solution techniques are derived, the organization of the computer program is explained, and a commentary on practical aspects of using the program is made. Several examples are analyzed using TASEF-2 and calculated temperatures are in some cases compared to experimental results. The report contains fully annotated input instructions, and a listing of the program.

In [c] a procedure for analyzing two-dimensional heat exchange in structural voids is presented. The procedure has been so coded that it can be easily coupled to most algorithms used to predict heat conduction in solid structural elements. The surface surrounding a void is divided into a finite number of discrete zones, and radiation and convection conditions are accounted for. The accuracy of heat transfer calculations where the above procedure has been incorporated increases with the number of zones into which a void has been divided. In fact, calculations of radiation heat exchange will converge to an exact solution if a sufficiently large number of zones have been used to model a void.

References

[1] Kawagoe, K., "Fire Behaviour in Rooms", Building Research Institute, Report No. 27, Tokyo, 1958.

[2] Kawagoe, K. and Sekine, T., "Estimation of Fire Temperature-Time Curve in Rooms", Building Research Institute, Occasional Report No. 11, Tokyo, 1963.

[3] Ödeen, K., "Theoretical Study of Fire Characteristics in Enclosed Spaces", Division of Building Construction, Royal Institute of Technology, Bulletin No. 10, Stockholm 1963.

[4] Magnusson, S.E. and Thelandersson, S., "Temperature-Time Curves of Complete Process of Fire Development. Theoretical Study of Wood Fuel Fires in Enclosed Spaces", Acta Polytechnica Scandinavica, Ci 65, Stockholm, 1970.

[5] Magnusson, S.E. and Thelandersson, S., "Comments on Rate of Gas Flow and Rate of Burning for Fires in Enclosures", Bulletin 19, Division of Structural Mechanics and Concrete Construction, Lund Institute of Technology, Lund, 1971.

[6] Babrauskas, V., "COMPF, A Program for Calculating Post-Flashover Fire Temperatures", Report No. UCB FRG 75-2, Fire Research Group, Structural Engineering and Structural Mechanics, Department of Civil Engineering, University of California, Berkeley, 1975.

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