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Structural Fire Protection

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Structural Fire Protection

T. T. Lie, Editor

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ABSTRACT

This manual, *Structural Fire Protection: Manual of Practice (Manual and Report #78)*, is intended to provide a basis for the development of new standards for the calculation of the fire resistance of structural members. It provides information on current techniques and developments to improve fire safety in buildings. While it deals mainly with structural fire safety, related subjects are also discussed. The manual consists of two parts. The material in Part 1, which consists of three chapters, is mainly descriptive. Chapter 1 deals with various aspects related to structural fire protection, including building codes and the role of structural fire protection. Chapter 2 discusses the development of fire in enclosures and the effect of fire on the behavior of concrete, steel, and wood, including the properties of these materials at elevated temperatures. Chapter 3 describes methods for the calculation of the fire resistance of various structural members. Part 2, which consists of Chapters 4 and 5, deals with the development of fire and the calculation of fire resistance using mathematical models, respectively. It is hoped that, in addition to providing a basis for new standards, this manual will also be useful to architects, engineers, building officials and students in any branch concerned with structural fire safety.

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78	Structural Fire Protection

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PREFACE

Fire is the primary cause of loss of life and property in buildings in North America. Stimulated by conflagrations in many parts of the world, techniques to control or mitigate the effects of fire have been developed over the last two decades. Significant advances have been made in the development of knowledge of basic fire phenomena and fire dynamics in addition to the development of methods to protect buildings and their occupants against fire. Attention to techniques, materials, and details now enables the designer to confine a fire to only one part of a building, where a few years ago the entire building would have been lost. The ability to prevent spread of fire and to protect the building occupants does not automatically assure fire safety, however. Fire safety measures must be consciously incorporated into the design and construction processes from the preliminary planning to the completion of the construction.

While it is possible to improve considerably the fire safety design of buildings, there is a lack in attention on the part of architects and engineers to firesafety provisions (National Commission on Fire Prevention and Control 1973). One of the reasons cited is the insufficient availability of training in professional education and practice, leading to lack of or low levels of awareness of the principles and applications of fire protection in buildings. Whereas training is given in numerous institutions in many areas of building design, and many books and manuals are available in these areas, this is not the case in the area of fire.

The main objective of the Manual is to document selected data that over the years have been produced in the area of fire safety and to transfer this knowledge to the building design practitioner. Because the area of fire safety is very wide, mainly structural fire safety provisions and related subjects are discussed.

A considerable amount of research has been carried out in the area of structural fire protection in recent years. The use of numerical techniques has made it possible to develop mathematical models that simulate the behavior of various structural members in fire. A large number

of models that calculate the fire resistance of structural members now exists. Most of the models have been programmed for computer processing.

Much data on the thermal and mechanical properties of various building materials at elevated temperatures have also been produced in recent years. Knowledge of these properties, which are used as input data for the computer programs, is essential to be able to predict the behavior of structural members during exposure to fire. Methods for estimating the expected severity of building fires and temperature-time relations that characterize the severity of these fires have also been developed. At present much information exists for the determination of the required fire protection for various structural members.

In the Manual all the subjects mentioned above and several more are discussed. Although the Manual was written with the aim to provide a basis for the development of new standards for the calculation of fire resistance, it is hoped that it will also be used by architects, engineers, building officials, and students in any branch concerned with structural fire safety.

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ious chapters of the Manual are mentioned in the footnotes to each chapter.

Special thanks is extended to the Institute for Research in Construction (IRC), National Research Council of Canada, for the provision of considerable staff time during the writing of the manual. The typing and editing of the numerous drafts of the document were conducted by IRC's National Fire Laboratory, and the drawings prepared by IRC's Graphics Unit.

EXECUTIVE SUMMARY

The writing of the Manual was initiated by the Committee on Fire Protection in the Structural Division of the American Society of Civil Engineers. It was written with the aim of providing information on current techniques and developments to improve fire safety in buildings. It deals mainly with structural fire safety, although related subjects are also discussed.

The Manual consists of two parts: The objective of Part 1, consisting of Chapters 1–3, is to introduce the subject matter to the building design practitioner who has had no experience with fire other than in work with building codes. The material in this part is mainly descriptive.

In Chapter 1, various aspects related to structural fire protection are discussed, including building codes, their background and purpose, and the role structural fire protection plays in building fire safety.

Chapter 2 discusses the development of fire in enclosures and the effect of exposure to fire on common materials of construction, which includes concrete, steel, and wood. A large part of the chapter deals with the thermal and mechanical properties of these materials at elevated temperatures. In order to understand and eventually predict the performance of structural members in a fire, knowledge of the material properties that determine the behavior of a member at elevated temperatures is essential. A part of Chapter 2 deals with experimental evaluation of the fire resistance of structural members and describes the most common testing methods to determine the fire resistance of these members.

Chapter 3 provides methods that will enable the determination of the fire resistance of various building elements with the aid of simplified formulas and rules. Also, references are given in which fire resistance ratings, obtained from test results, can be found for a large number of building elements. In addition, extension rules are given that will enable the interpretation of test or calculated results for conditions that differ from those in the test or calculation. The materials considered in this chapter are concrete, steel, and wood, eventually in combination with

various other materials used as insulation, such as gypsum board and sprayed mineral fibre.

In Part 2, which consists of Chapters 4 and 5, the technical bases of the material in Part 1 is described. This will enable those interested to obtain more knowledge about the background of the material in Part 1.

Chapter 4 discusses various temperature-time relations for real world and for standard fires. Analytical expressions are given that describe characteristic temperature curves as a function of the significant parameters for various fire conditions commonly met with in practice. Expressions are also given for the standard fire curve used in North America and for the fire curve adopted by the International Organization for Standardization.

In Chapter 5, a large number of mathematical models for the calculation of fire resistance by numerical methods are described. Because mainly metric units were used in the literature dealing with these models, the same units were also used in this chapter. Most of the models have been programmed for computer processing.

Material related to test methods, codes, and standards are mainly based on North American practices. In several other areas, however, such as calculation methods, properties of materials and fire protection methods, the material is more general in scope.

The Manual is intended to provide a text that can be used as a basis for the development of new standards for the prediction of fire resistance by calculation. It has been reviewed by several members of the Committee on Fire Protection during the writing of the Manual and, subsequently, after completion of the writing by an independent Peer Review Committee, consisting of the members mentioned in the Acknowledgement in this Manual.

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