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Fire resistance tests — Guidelines for computational structural fire design

*Essais de résistance au feu — Lignes directrices sur la conception
statistique des feux de structures*



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ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2. www.iso.org/directives

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The committee responsible for this document is ISO/TC 92, *Fire safety*, Subcommittee SC 2, *Fire containment*.

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Introduction

In recent years significant advances have been made in the scientific community in understanding the behaviour of fire in building structures and as a result there is an increasing activity in the development of computer models that are capable of describing and predicting many of the different aspects of fire safety engineering.

As a result of this research, design codes have been prepared that enable practising engineers to undertake this type of analysis which can be applied to comply with prescriptive requirements as specified in National Building Regulations, or, to develop performance based fire safety strategies and often involving complex computational analysis.

In particular, analytical procedures and computer models have been developed in the areas of:

- reaction of materials to fire;
- fire growth in a compartment;
- fully developed compartment fire;
- fire spread between buildings;
- fire behaviour of load-bearing and separating elements and building structures;
- smoke filling in enclosures and smoke movement in escape routes and multi-story buildings;
- interaction of sprinklers and fire, including sprinkler and fire venting interaction;
- process of escape; and
- systems approach to the overall fire safety of a building, in its most general form comprising fire development models interacting with human response models.

This progress in fire research has led to consequent changes in the field of codes, specifications, and recommendations for fire engineering. Some characteristic trends in these changes are:

- improved relationship between standard tests and real fire scenarios;
- increased use of fire safety engineering principles to meet functional requirements and performance based criteria;
- development of new test methods, that are, as far as possible, material-independent and related to well-defined phenomena and properties;
- increase in the application of reliability-based analytical design;
- extended use of integrated assessments; and
- introduction of goal-oriented systems of analysis of total, active and passive fire protection for a building.

One of the most rapidly developing trends relates to the structural fire engineering design of load-bearing and separating structures. An analytical determination of the fire resistance of structural elements is being accepted more widely by the Approving Authorities in many countries as an alternative to the internationally prescriptive based approaches based on the results of the standard fire resistance test and connected classification.

A significant contribution to the analysis of building structures in fire has been made by the development of the European Structural Eurocodes which enable practising engineers to follow agreed design procedures for application in individual member states. During the mid 1990s, these Codes which covered; Fire Actions and individual structural materials (Concrete, Steel, Composite Steel and Concrete, Timber, Masonry, Aluminium) were published as ENV's (or pre-standards). These Codes had the status of Draft for Development, and were supplemented with National Applications Documents (NAD's), which

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permitted member states to ascribe certain factors to many of the calculations and input variables in order to align with National experience.

During the last five years, considerable progress has been made in converting these pre-standards into full European Design Codes for application in the European Community member states. The Codes are now divided into two separate parts:

- **Normative** - in which members states are obliged to follow.
- **Informative** - usually consisting of a series of Annexes in which acceptance is voluntary by individual member states.

In addition, there is still provision to apply individual National Determined Parameters (NDP's) to align more closely with National experience. The interaction of the Eurocodes are summarized in [Figure 1](#).

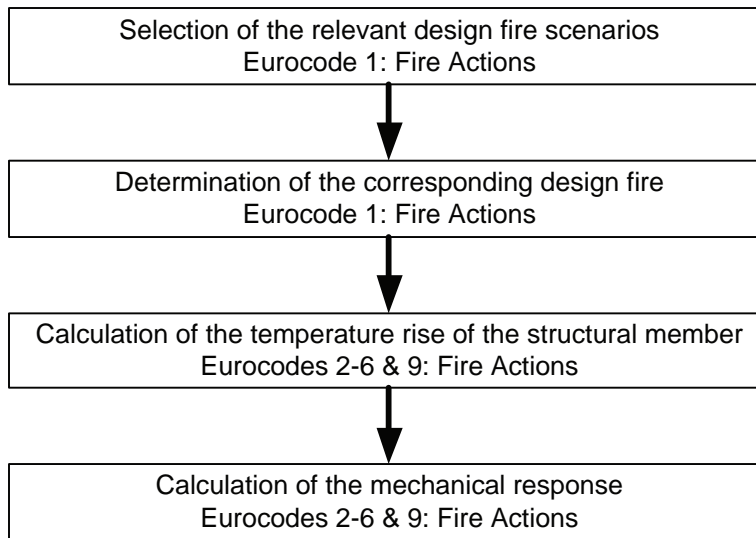


Figure 1 — Interaction of the Structural Eurocodes

The structural Fire Engineering design models have been reviewed in Reference [1] and essentially they can be presented in a simple form as three succinct design steps shown in [Figure 2](#):

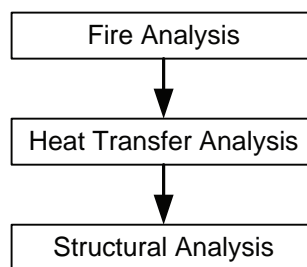


Figure 2 — Three stages to structural fire design

This report examines each of the above under separate headings. In each case, internationally applied methods for a structural fire engineering design are discussed.

For fire models or thermal actions the report considers:

Furnace tests:

- according to ISO 834: cellulosic, hydrocarbon, external and smouldering curves.
- tunnel heating curves according to RWS and the French National curve.

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Natural fires:

- single zone or parametric fires in so far as they may be used in a standardised way to provide characteristic occupancy related standard tests. This also includes time equivalent relationships for quantifying real fires into an equivalent period of heating in the standard ISO 834 test.

For heat transfer models the report considers:

- Heat transfer for uniform temperature distribution
- Non-uniform temperature distribution for
 - one dimension
 - two dimensions
 - three dimensions

For structural models the report considers:

- Single member analysis
 - Sub-frame assembly analysis (sub-frames and assembly of members)
 - Global structural analysis in which load redistribution occurs.

The report also considers **Combination Models** for thermal and structural analysis and the performance of structural glass, plastics and resins.

In addressing structural models relevant thermo-physical and mechanical properties are presented for each loadbearing material. While these are presented for use in calculating the thermal response under standard furnace heating conditions for the most part the same properties will invariably be appropriate for natural fires.

This Technical Report is one of a series of Technical Reports being developed that provide guidance on important aspects of calculation methods for fire resistance of structures. Related documents include

- ISO/TR 15655, *Fire resistance — Tests for thermo-physical and mechanical properties of structural materials at elevated temperatures for fire engineering design*,
- ISO/TR 15656, *Fire resistance — Guidelines for evaluating the predictive capability of calculation models for structural fire behaviour*, and
- ISO/TR 15658, *Fire resistance tests — Guidelines for the design and conduct of non-furnace-based large-scale tests and simulation*.

Other documents, which have been produced in ISO/TC92/SC2, provide data and information on the determination of fire resistance. In particular, these include

- ISO 834 (all parts), *Fire resistance tests — Elements of Building Construction*,
- ISO/TR 12470, *Fire resistance tests — Guidance on the application and extension of results*,
- ISO/TR 12471, *Computational structural fire design — Review of calculation models, fire tests for determining input material data and needs for further development*, and
- ISO/TR 10158:1991¹⁾, *Principles and rationale underlying calculation methods in relation to fire resistance of structural elements*.

1) Withdrawn.