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Fire safety engineering — Performance of structures in fire —

Part 1: General

Ingénierie de la sécurité incendie — Performances des structures en situation d'incendie —

Partie 1: Généralités

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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 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 92, *Fire safety*, Subcommittee SC 4, *Fire safety engineering*.

This first edition of ISO 24679-1 cancels and replaces ISO/TS 24679:2011, which has been technically revised.

The main changes compared to the previous edition are as follows:

— The document has been updated to properly structure as a normative document.

A list of all parts in the ISO 24679 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Fire is an extreme loading condition for structures, which can lead to significant effects on people, property and the environment. Part of the fire safety design of a built environment arises out of the need to provide design strategies that minimize the occurrence and spread of fire and its impact on life, property and the environment. Fire safety of structures is one important component of an overall fire safety design strategy. The role of fire safety of structures is to ensure that elements of a structure, (separating and structural elements) within a built environment, are capable of preventing or delaying fire spread and structural failure, so that the fire safety objectives, such as safety of life (for occupants and firefighters), conservation of property, continuity of operations, preservation of heritage and protection of the environment, are not compromised.

Traditionally, most designs for the fire safety of structures have been based on prescriptive requirements set by building regulations, building codes and associated standards. In prescriptive regulations, this is also known as *fire resistance*. The evaluation of fire resistance of construction elements is mainly determined by fire tests that involve:

— a single fire represented by a standard time-temperature curve (such as that given in ISO 834-1); and

— isolated elements or assemblies with defined boundary conditions and sizes.

In standard fire resistance tests, the thermal fire action continues to increase for the duration of the test according to standardized time-temperature fire curves. These thermal actions do not take into account the real conditions such as real fuel load, enclosure size, ventilation conditions, thermal properties of enclosure boundaries, active fire protection systems and firefighting actions. At the same time, from a mechanical point of view, these tests do not take into account the realistic boundary conditions and, consequently, the mechanical loads are not realistic. For example, possible redistribution of loads to other elements in a structure is not evaluated, since only single elements are tested. In addition, most test furnace facilities cannot take into account of the effect of restraint conditions that the tested element may undergo within a structure in real situation.

Such an assessment method is only able to provide a comparative rating of the construction products and cannot provide all the information required to perform a structural fire analysis of a given built environment.

With the recent advances in fire safety engineering and the opportunity for designers to take advantage of an engineering approach when evaluating the performance of structures in fire, it is becoming necessary to:

— refine the philosophy covered by the fire safety of structures, in the case of real fires, with respect to the whole structure;

— move beyond the sole consideration of individual elements and include the behaviour of the entire structural system;

— consider realistic thermal and mechanical load conditions; and

— include the cooling phase of the fire.

In the approach used in this document, solutions are based on engineering principles founded on a quantification of fire development, heat transfer and thermo-mechanical behaviour, on experts' judgement and on practicability.

An engineering approach offers many benefits, including:

— the provisions for better and more reliable fire safety in the built environment;

— potential cost-effective fire safety measures, and more options with regard to the choice of these measures; and

— better communication with other professionals involved in the design, construction process and approval process.

ISO 24679-1 is intended for use by fire safety practitioners who employ performance-based design methods. It is expected that users of this document be appropriately qualified and competent in the fields of fire safety and structural engineering. It is particularly important that users understand the limitations of any methodology used.

Each ISO standard supporting the global fire safety engineering analysis and information system includes language in the introduction to tie this document to the steps in the fire safety engineering design process outlined in ISO 23932-1.

ISO 23932-1 provides a performance-based methodology for engineers to assess the level of fire safety for new or existing built environments. Fire safety is evaluated through an engineered approach based on the quantification of the behaviour of fire and based on knowledge of the consequences of such behaviour on life safety, property and the environment.

ISO 24679-1 "Performance of structures in fire" standard form part of compliance with ISO 23932-1, and all the requirements of ISO 23932-1 (see Figure 1) apply to any application of this International Standard. For example, section "Selection of engineering methods and preliminary report" of ISO 23932-1 describes the procedure to select engineering methods used to assess the fire behaviour of structure, and section "Scenario-based evaluation of trial design" of ISO 23932-1 describes the procedure of quantification of the performance of structures in fire.

Fire safety engineering — Performance of structures in fire —

Part 1: General

1 Scope

This document provides a methodology for assessing the performance of structures in the built environment when exposed to a real fire.

This document, which follows the principles outlined in ISO 23932-1, provides a performance-based methodology for engineers to assess the level of fire safety of new or existing structures.

NOTE The fire safety of structures is evaluated through an engineering approach based on the quantification of the behaviour of a structure for the purpose of meeting fire safety objectives and can cover the entire time history of a real fire (including the cooling phase), and its consequences related to fire safety objectives such as life safety, property protection and/or environmental protection.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 834-1:1999, *Fire-resistance tests — Elements of building construction — Part 1: General requirements*

ISO 13943, *Fire safety — Vocabulary*

ISO/TR 16576, *Fire safety engineering — Examples of fire safety objectives, functional requirements and safety criteria*

ISO/TS 16733-2, *Fire safety engineering — Selection of design fire scenarios and design fires — Part 2: Design fires*

ISO 23932-1, *Fire safety engineering — General principles – Part 1: General*

3 Terms and definitions

For the purpose of this document, the terms and definitions given in ISO 13943, ISO 23932-1 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at https://www.iso.org/obp

3.1
building element
integral part of a built environment

Note 1 to entry: This includes floors, walls, beams, columns, doors, and penetrations, but does not include contents.

3.2
function
role and actions assigned to, or required or expected of, various parts of a structure to achieve a specified objective or task

3.3
load-bearing element
building element that is designed to resist mechanical actions

3.4
mechanical action
defined force impact on other elements due to strain or stress redistribution within a structure, or part of a structure, in fire

3.5
non-load-bearing element
building element that is not designed to resist mechanical actions besides its own weight

3.6
reliability
ability of a structure or structural element to fulfil the specific requirements, including working life, for which it has been designed

3.7
structure
assembly of materials forming a construction for occupancy or use to serve a specific purpose

Note 1 to entry: This includes, but is not limited to, buildings, open platforms, bridges, roof assemblies over open storage or process areas, tents, air-supported structures, and grand stands.

3.8
structural fire performance
extent to which a structure or structural element fulfils the specific requirements, including working life, for which it has been designed, when exposed to fire for a given time

3.9
thermal action
description of the variation of temperatures or heat fluxes as a function of time in an enclosure

Note 1 to entry: These temperatures or heat fluxes depend on fire load density, fuel arrangement, geometry of and openings within the enclosure.

4 Design strategy for fire safety of structures

4.1 General design process for fire safety of structures

Although many countries are still delivering fire safety design of structures based on prescriptive requirements and standardized tests, there has been a move towards using calculation methods to estimate the performance of structures in fires. This is due to an enhanced understanding of the behaviour of structures in fire and improved knowledge of thermal and mechanical responses of structures at elevated temperatures. This understanding and knowledge enable a better evaluation of what would happen in a built environment during real fires. However, many of the calculation methods are still at a stage where they replace standard fire tests, or are used to extend the results of these standard tests, in a bid to overcome the drawbacks of testing. Most of the existing calculation methods are simple models applicable to isolated elements and assemblies and cover mainly:

— heat transfer through load-bearing elements or non-load-bearing separating elements, when the thermal properties of the component materials and boundaries conditions are known;

— load-bearing fire performance for common construction materials such as steel, concrete and timber.

These simple calculation methods, just like the standard tests, are only able to provide data for ranking the various elements based on their ability to resist a standard fire. Although they do make accounting for some more specific parameters easier, they do not provide the necessary tools for assessing the performance of a structure in various possible real-fire scenarios, such as localized or fully-developed fires, including the cooling phase that can lead to certain failure mechanisms. For this reason, the current design approach for fire safety of a structure and its elements is still based on crude assumptions, which may lead to limited flexibility in design as well as very little or no opportunity for accurate optimization of fire safety measures in a built environment.

However, it is increasingly possible to either use advanced calculation methods or develop simplified calculation methods to deal with the behaviour of structure in real fire situations.

This document provides a methodology for applying an engineering approach to the assessment of fire performance of structures in real fires. An engineering approach for the design of fire safety of structures includes:

— defining the built-environment characteristics, including geometry, actions, materials, etc.;

— identifying clear objectives for the fire safety of structures;

— identifying performance criteria for elements of construction in the context of the objectives for fire safety of structures;

— defining a trial design plan for fire safety of structures;

— considering design fire scenarios that can develop in the built environment and challenge the structure and the enclosure boundaries;

— assessing the fire performance of the built environment (load-bearing and non-load-bearing) elements and the structure as a whole system; and

— examining the fire performance of the structure against the identified objectives and established performance criteria by taking into account realistic design fire scenarios.

Figure 1 is a flow chart showing the overall design process of fire safety engineering according to ISO 23932-1, while the details concerning fire safety of structures are provided in Clause 5 (see Table 1 and Figure 2) of this document.

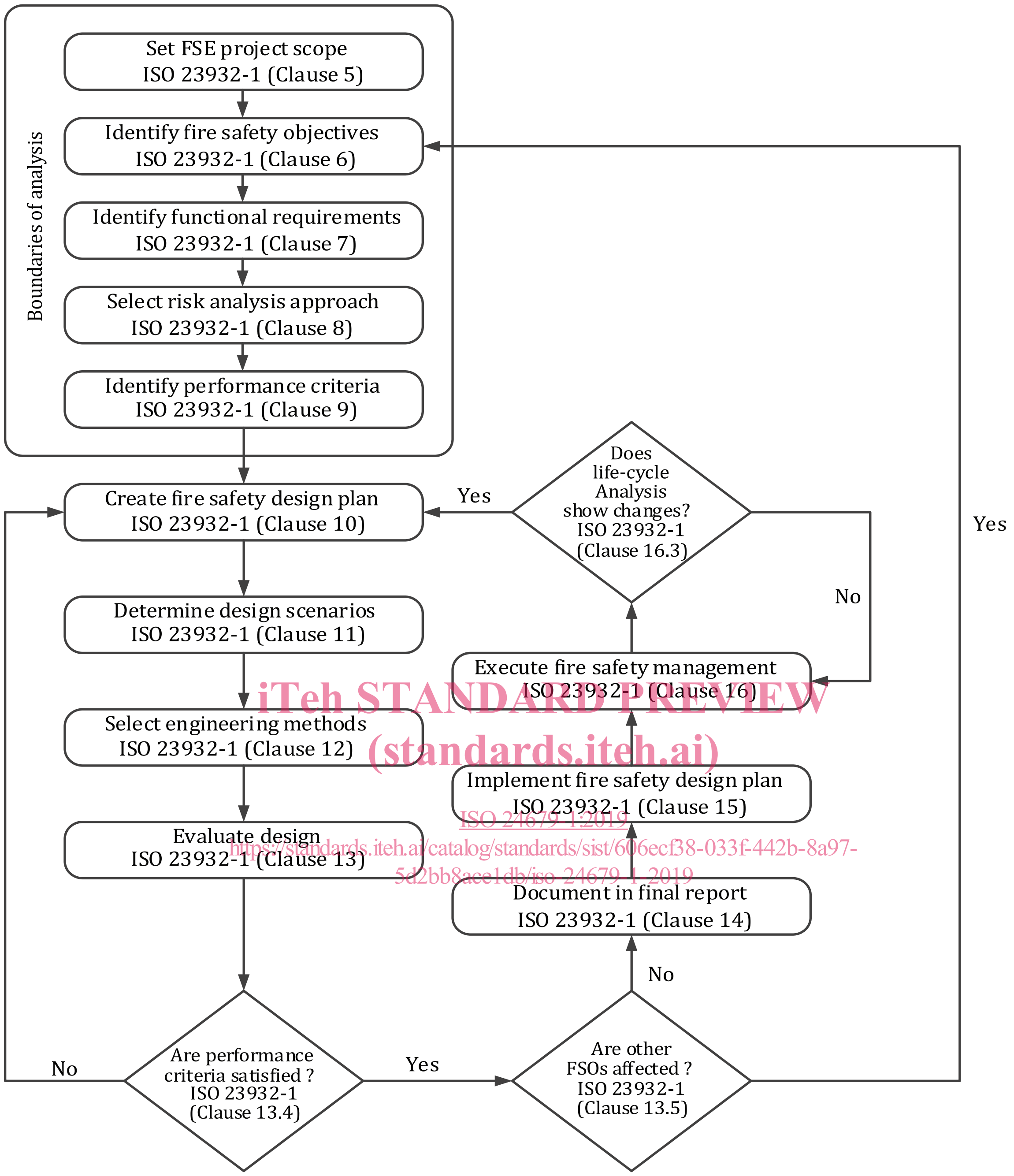

Figure 1 — Fire safety engineering — Design process according to ISO 23932-1

4.2 Practical design process guidance for fire safety of structures

Table 1 identifies the various steps and parameters to be considered when assessing the behaviour of structures subjected to fire exposure. The details of these steps are explained in Clause 5.

Figure 2 shows a flow chart detailing the methodology of the following four steps:

1) Determination of design fire scenarios and design fires;

2) Evaluation of thermal response of the structure;

3) Evaluation of the mechanical response of the structure; and

4) Assessment of responses against the fire safety objectives (Steps 4 to 7 of Table 1).

This flow chart helps to provide a detailed understanding of a rational approach to the fire safety of structures exposed to real fires. As illustrated in Figure 2, inputs are determined from Steps 1, 2 and 3 of Table 1 and outputs obtained for the assessment of Step 8 in Table 1.

If the fire safety objectives are not satisfied (see Figure 2, Step 7) with the first suggested strategy by the trial design plan (Step 3), then Steps 4 to 7 shall be repeated using a different strategy proposed at Step 3. This procedure shall be repeated until a solution that satisfies the fire safety objectives is found. If the found solution is not viable for the stakeholder, it is necessary to go back to Steps 1 and 2 in order to modify the scope of the project, and if possible, the fire safety objectives.

Table 1 — Steps of practical design process

Step No.	To consider	To determine or identify	Input	Factors of influence
1	Scope of the project for fire safety of structures	— Context and purpose of the design and/or the different parts — Mechanical actions, including initial structural loads on the elements of the structure or loads induced by the fire such as pressures — Fuel loads in compartments	— Built-environment characteristics: — Geometry — Lining materials — Openings — Quantity of fuel load — Dead and live loads — Active and passive fire protection systems	— Interested and affected parties — Structural systems to be analysed
2	Identifying objectives, functional requirements and performance criteria for fire safety of structures	— Objectives relating to: — Safety of life — Conservation of property — Continuity of operations — Preservation of heritage — Protection of the environment — Functional requirements relating to: — Limiting or preventing fire spread — Limiting or preventing structural failure — Performance criteria to fulfil the objectives and functional requirements	— Statements in codes, standards and guidance documents	— Type of occupancy of built environment to be designed — Interested and affected parties including code officials, owners, and fire safety professionals — Existence of active and passive fire systems and effectiveness of these systems — Escape time approach — Target reliability

Table 1 *(continued)*

Step No.	To consider	To determine or identify	Input	Factors of influence
3	Trial design plan for fire safety of structures	— Strategy for fire safety of structures — Design elements and functions to be considered for the fire safety of structures include structural stability, integrity, containment and compartmentation	— Objectives, functional requirements and performance criteria — Type and method of analysis	— Type of occupancy of built environment to be designed — Interested and affected parties — Fire protection system
4	Design fire scenarios and design fires (fire development)	— Thermal actions on the elements of the structure: — Heat release rates — Temperatures — Heat fluxes	— Fuel loads and distribution in compartments — Compartment characteristics (e.g., ventilation)	— Fire severity — Fire duration
				— Pressure in the fire enclosures
			— Reliability and response time of suppression systems	— Effectiveness of suppression systems — Fire safety management plan and procedures
			— Fire department response and intervention time	— Firefighting effectiveness
			— Criteria for fire spread: — Ignition by flames and/or smoke — Integrity — Thermal insulation — Others	— Effectiveness of fire separation — Paths of fire spread (openings and/or breaching of boundaries) — Temperatures and pressures in enclosures
				— Method of analysis chosen (e.g., deterministic fire analysis or probabilistic analysis)
5	Thermal response of the structure	— Temperatures in elements of the structure	— Temperatures in every enclosure — Heat transfer data for thermal response of the elements of the structure — Thermal properties of the elements of the structure	— Effectiveness of fire separation — Paths of fire spread (openings and/or breaching of boundaries) — Effects of temperatures and pressures in enclosures