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Fire safety engineering — Performance of structures in fire

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

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Foreword

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International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

In other circumstances, particularly when there is an urgent market requirement for such documents, a technical committee may decide to publish other types of normative document:

— an ISO Publicly Available Specification (ISO/PAS) represents an agreement between technical experts in an ISO working group and is accepted for publication if it is approved by more than 50 % of the members of the parent committee casting a vote;

— an ISO Technical Specification (ISO/TS) represents an agreement between the members of a technical committee and is accepted for publication if it is approved by 2/3 of the members of the committee casting a vote.

An ISO/PAS or ISO/TS is reviewed after three years in order to decide whether it will be confirmed for a further three years, revised to become an International Standard, or withdrawn. If the ISO/PAS or ISO/TS is confirmed, it is reviewed again after a further three years, at which time it must either be transformed into an International Standard or be withdrawn.

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.

ISO/TS 24679 was prepared by Technical Committee ISO/TC 92, *Fire safety*, Subcommittee SC 4, *Fire safety engineering*.

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 regulation, 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.

Standard fire tests apply to fires with an inexhaustible fuel supply, where no distinction is made between enclosure size and ventilation, and which do not take into account realistic structural loads, the redistribution of load or conditions of structural restraint. Such an assessment method is only able to provide a comparative rating of the construction products but cannot furnish all the information required to make a fire safety analysis of a given built environment (e.g. smoke leakage, other types of fire, treatment of a full structure).

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 load conditions; and

— include the cooling phase of the fire.

This Technical Specification provides a methodology for applying an engineering approach to the assessment of fire performance of structures in real fires. In such an approach, the solutions are based on principles of reason, judgement, science, engineering and practicability. A rational 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.

This Technical Specification is intended for use by fire safety practitioners who employ performance-based design methods. Examples of users include fire safety engineers and structural engineers as well as authorities having jurisdiction, such as authority officials, fire service personnel and code developers. It is expected that users of this Technical Specification are appropriately qualified and competent in the fields of fire safety and structural engineering. It is particularly important that the users understand the limitations of any methodology used.

In addition to the standard clauses (Clauses 1, 2, 3 and Bibliography), this Technical Specification includes the following clauses:

— Clause 4 provides generic ways of describing design strategies for the fire safety of structures;

— Clause 5 presents the quantification of the performance of structures in fire, which includes guidance on the steps and engineering methods used to predict the thermal and mechanical responses of structural and separating elements exposed to fire and thereby evaluate the potential for fire spread and structural failure. Also included is a description of the factors that should be taken into consideration in the assessment and quantification process, namely fire spread paths and material properties at elevated temperatures;

— Clause 6 gives guidance on the use of the different quantification methods.

Fire safety engineering — Performance of structures in fire

1 Scope

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

This Technical Specification, which follows the principles outlined in ISO 23932, 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 referenced documents are indispensable for the application 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 23932, *Fire safety engineering — General principles*

3 Terms and definitions

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

3.1
building element
integral part of a built environment

NOTE 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
structural element
building element that is designed to carry loads besides its own weight

3.4
mechanical actions
defined force impacts 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 carry loads 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 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 actions
description of the variation of temperatures or heat fluxes as a function of time in an enclosure

NOTE 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 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 recently 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 enables better simulation 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 conventional fire 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:

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

— heat transfer, by conduction, through non-load-bearing separating elements, when the thermal properties of the component materials are known.

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 conventional 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 could 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 could 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 being made increasingly possible to either use advanced calculation or develop simplified calculation to deal with the behaviour of structure in real-fire situations.

This Technical Specification 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;
- considering design fire scenarios that could 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;
- 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 for the fire safety of structures. More details are provided in Clause 5 on quantification.

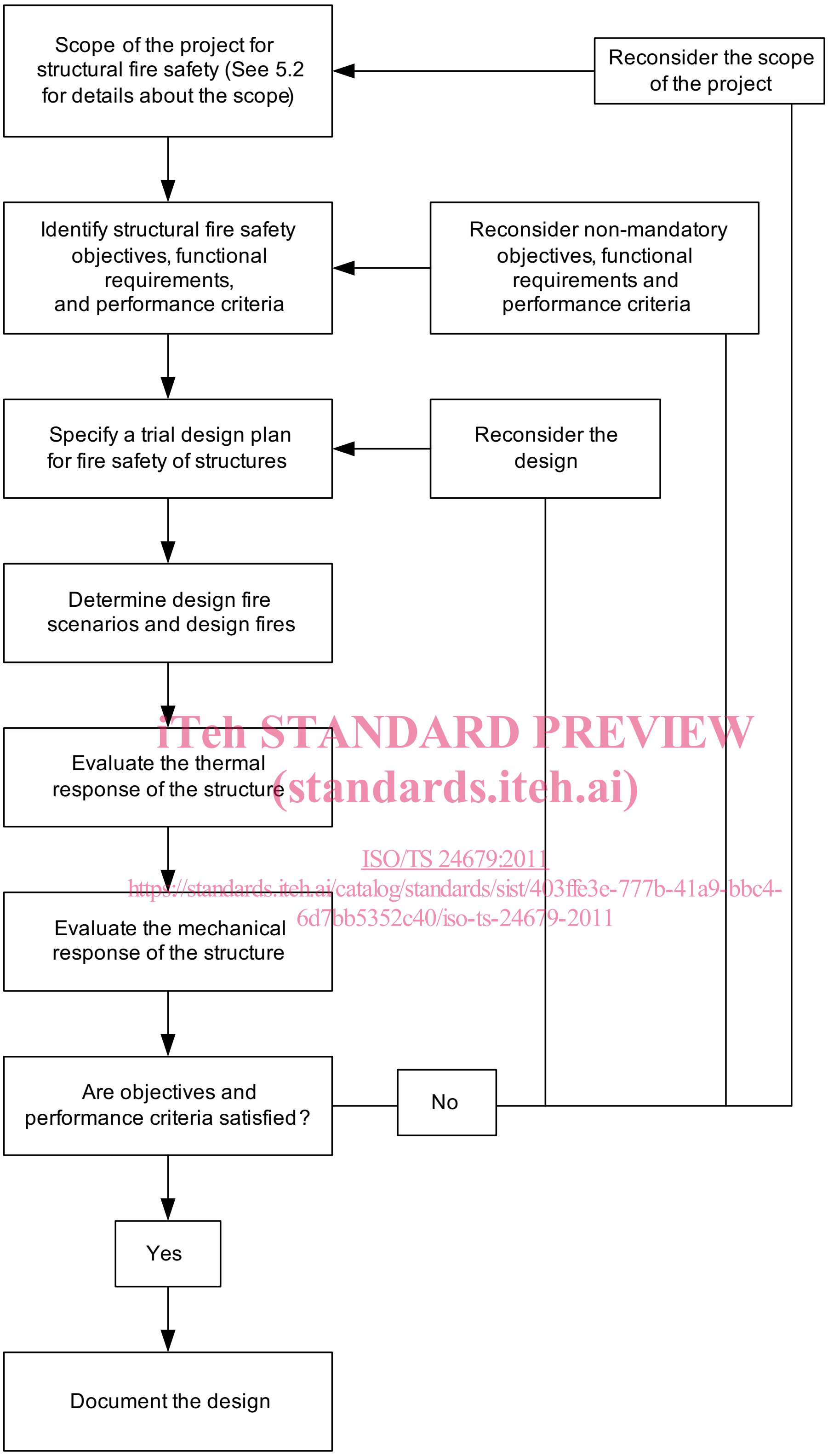

Figure 1 — Fire safety of structures — Design process

4.2 Objectives and functional requirements for fire safety of structures

Conducting a rational fire safety design of structures requires the establishment of fire safety objectives and functional requirements.

The fire safety objectives usually address life safety, conservation of property, continuity of operations, preservation of heritage, and protection of the environment (singly or in combination).

The functional requirements for providing fire safety of structures, usually stated in terms of compartmentation, integrity and stability of the structure, are outlined as follows:

a) Compartmentation for the prevention or limitation of fire spread

1) Prevent or limit fire spread within the built environment. As a result of the fire dynamics, but also due to pressure, thermomechanical deformation and heat transfer through components of the structure, fire (flames and smoke) can spread to other enclosures within the built environment, endangering life safety and adversely affecting the value of the built environment and its contents. In this case, a built environment is divided into fire enclosures (concept of compartmentation) with barriers (usually floors or walls), which contain the fire in the enclosure in which the fire originated.

2) Prevent or limit fire spread to other built environments and outside the built environment. Enclosure boundary walls, floors and roofs may contribute to such fire spread, either as a secondary fuel source for fire located on the outside of the built environment, where adjacent built environments and the natural environment are exposed, or through enclosure failure, creating a path for an interior fire to vent to the outside, again exposing adjacent built environments and the natural environment. The hazard is greater in presence of materials that can sustain more intense fires or more toxic or corrosive pyrolytic products, for example in the case of a warehouse containing hazardous materials or a chemical processing facility that uses or produces hazardous materials. Consequently, enclosure boundary walls, floors and roofs should provide sufficient fire performance to resist secondary ignition and to contain an interior fire. Another strategy consists in placing the built environment at sufficient distance from any potential exposure to prevent any significant risk of fire spread.

3) Maintain the integrity of the separating elements of the built environment. This provision aims to increase the time available for escape, protect escape routes, facilitate firefighter access during rescue operations, limit the area of possible loss, reduce the impact of fire on the structure and its contents, separate different occupancies, isolate hazards, and contain releases of hazardous materials (during a fire and even after the fire).

b) Integrity and stability of the structure for the prevention or limitation of structural failure

1) Prevent or limit structural failure. For various reasons, including thermal deformation (expansion and contraction) and reduction of strength and stiffness resulting from heating exposed components of the structure, collapse may occur in one of two ways: through failure of heated portions of the structure or through failure involving non-heated portions of the structure. Collapse due to either mechanism creates a dangerous situation with respect to life safety (if anyone remains inside the building) and property protection. Even in the absence of collapse, deformation may still affect exit paths, endangering life safety, and may cause considerable property damage. Therefore, structural elements should have sufficient structural fire performance (in terms of both integrity and stability) to prevent or delay failure. Prevention of collapse and/or limitation of deformation is essential for load-bearing structural members and for load-bearing barriers, which also provide containment. The main load-bearing structural elements, and secondary elements, which support or provide stability to barriers or main members, shall be given structural fire performance.

2) Maintain the integrity and/or limit the deformation of the structural elements of the built environment.

For the above-stated objectives and functional requirements for fire safety of structures, the time needed to achieve the objectives may be defined by the interested and affected parties as the time to complete burnout, the time to complete evacuation or the time for the fire department to respond to and start controlling a fire. These are some examples and the interested and affected parties may specify other times.

In satisfying the functional requirements, consideration should be given to the existence of active and passive fire control systems and their effectiveness.

4.3 Performance criteria for fire safety of structures

Performance criteria are used to determine whether the objectives and functional requirements for the fire safety of structures have been satisfied.

Some candidate criteria for the fire performance of structures may be inferred from existing criteria employed in standard fire resistance tests in accordance with ISO 834-1. However, such criteria are generally expressed in prescriptive terms for a single element rather than in performance terms of a single element or the whole structure. In addition, although these performance criteria may still be useful, it is necessary to question their relevance and the way in which they are measured.

To allow for a more realistic assessment when using fire safety engineering design and analysis, performance criteria should not be stated as fixed values, in accordance with ISO 834-1, but should be expressed in terms of the fire safety and protection of people, property and contents, and the environment, and should take into account the interaction between the different elements within the structure.

Existing and new (relevant or more representative) performance criteria may be separated into categories:

a) to limit the harm or damage due to fire spreading, using compartmentation (through separating elements and structural elements);

b) to limit the harm or damage due to the collapse of structural elements (for partial or total collapse).

The criteria relating to these two groups are presented in 4.3.1 and 4.3.2.

4.3.1 Performance criteria to limit fire spread (compartmentation)

The existing performance criteria relate to those found in ISO 834-1 and are as follows:

— Insulation criteria: in the form of a limited temperature rise of 140 °C on average, reaching a maximum of 180 °C, on the unexposed side of separating (load-bearing and non-load-bearing) elements. These limiting values are generally a very conservative means of assessing the risk of fire spread.

— Integrity criteria: assessed by igniting a cotton pad or through gaps formed through separating (load-bearing and non-load-bearing) elements. Neither the cotton pad test nor the gap test provides sufficient quantitative data.

The new (relevant) performance criteria are concerned with setting limit values so that enclosure boundaries meet the objectives and functional requirements for the fire safety of structures.

— A criterion for limiting heat transfer through separating (load-bearing and non-load-bearing) elements (or the surface temperature of the boundaries of adjacent enclosures), and thermal radiation emanating from these elements, in order to avoid any ignition of combustible material on the unexposed side of separating (load-bearing and non-load-bearing) elements, taking into account their relative location (penetrating materials, lining materials or any combustible materials in the adjacent enclosure), the kind of materials, and injury to occupants. Such a criterion could be measured in terms of heat flux or temperature of the unexposed side.

— A criterion for limiting the spread of hot fire gases through separating (load-bearing and non-load-bearing) elements in order to avoid both ignition of combustible materials on the other side of separating (load-bearing and non-load-bearing) elements and injury to occupants. Such a criterion could be measured in terms of leakage rate.

