TECHNICAL REPORT

ISO/TR 24679-8

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Fire safety engineering — Performance of structures in fire —

Part 8: Example of a probabilistic assessment of a concrete building

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

Partie 8: Exemple d'évaluation probabiliste d'un bâtiment en béton

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Foreword

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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).

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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*.

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

This document provides an example of the application of ISO 24679-1. The procedure in this document is intended to follow the principles outlined in ISO 24679-1. The clauses of ISO 24679-1 which are considered relevant to this document are identified and the clause titles are kept the same and in the same order.

The purpose of this document is to demonstrate the application of the steps outlined in ISO 24679-1 for fire safety engineering, performance of structures in fire, applying probabilistic methods.

The analysis shows how the achievement of the fire safety objectives, with respect to structural fire resistance, can be demonstrated through probabilistic analysis. The building is based on a demonstration case for Eurocode 2[2] and is thus conformant with the design requirements of EN 1992-1-2[5]. For this type of building, a probabilistic analysis would generally not be performed. However, probabilistic analysis can demonstrate the achievement of the fire safety objectives for situations which are not conformant with standard design guidance.

This document only presents an example application of a probabilistic analysis. More advanced applications considering system behaviour and stochastic fire exposure are possible. These more advanced procedures will generally result in an improved understanding of the reasonably foreseeable structural behaviour in case of fire, and can, for example, be used for an in-depth analysis of the post-fire structural performance.

Probabilistic methods make engineering assumptions more explicit. This pushes the engineer to question their competence and promotes an in-depth communication with stakeholders on the intended structural performance in case of fire.

Fire safety engineering — Performance of structures in fire —

Part 8: Example of a probabilistic assessment of a concrete building

1 Scope

This document provides an example of a probabilistic assessment of a concrete building by revisiting the structural fire analysis of the concrete building presented in ISO/TR 24679-6, using probabilistic approaches. Specifically, the most heavily-loaded concrete column is analysed probabilistically, using the evaluation in ISO/TR 24679-6 as a starting point.

This report only addresses the fire safety objectives related to the structural performance. The analysis within this document therefore forms only part of the overall building fire safety strategy.

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 24679-1, *Fire safety engineering — Performance of structures in fire — Part 1: General*

3 Terms, definitions and symbols

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 24679-1 apply.

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

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

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

3.2 Symbols

e average eccentricity

E load effect

E_d design value of E

E_k characteristic load

f out-of-straightness

f_{ck} characteristic concrete compressive strength

f_{yk} characteristic steel yield strength

G dead load

G_F dead load façade

G_k characteristic value of the permanent load effect

K_E model uncertainty for the load effect

K_R model uncertainty for the resistance effect

L column height

$N_{ED,fi}$ design load

p_s reliability (i.e. probability of failure in the case of a given fire exposure)

p_f failure probability

$p_{f,t}$ target maximum failure probability

P axial load

P_{max} load bearing capacity of the column

$P_{max,num}$ numerical evaluation of P_{max}

P_{Gk} characteristic permanent load

P_{Qk} characteristic imposed load

P_T total axial load

Q dominant live load effect

Q_k characteristic value of the imposed load effect

R resistance effect

R_d design value of R

R_k characteristic resistance

V coefficient of variation

V_E coefficient of variation for the load effect

V_R coefficient of variation for the resistance effect

Z limit state function

β reliability index

β_t target reliability index

γ_0 safety factor

γ_E load factor

γ_R resistance factor

ε surface emissivity of the member

μ mean value

μ_E mean value for the load effect

μ_R mean value for the resistance effect

σ standard deviation

σ_E standard deviation for the load effect

σ_R standard deviation for the resistance effect

Φ out-of-plumbness; the standard normal cumulative distribution function

χ load ratio (characteristic live load effect relative to total characteristic load effect)

Ψ combination factor for the live load effect

Ψ_{fi} fire design variable action combination factor

Ø reinforcement bar diameter

4 Design strategy for fire safety of structure

The built environment of this example is an office building, as considered in ISO/TR 24679-6. The structural elements are composed of concrete.

For the concrete columns, the tabulated fire resistance, under standard thermal action (ISO 834) in accordance with EN 1992-1-2 is 90 min, while the calculated fire resistance using simplified calculation methods is 180 min, as specified in Eurocode 2.[2]

The safety level (i.e. probability of failure) associated with a tabulated or calculated standard fire resistance is not known. Consequently, there is a possibility that the structure does not behave as expected during fire exposure, notably because:

— the expectations did not account for the failure probability;

— the real fire conditions and structural behaviour do not match the concept of fire resistance under standard fire exposure.

These shortcomings can be reduced by:

— conducting a detailed analysis taking into account potential fire scenarios and structural behaviour for the building system in question, as applied in ISO/TR 24679-6, where the fire was defined taking into account Reference [3]; or

— conducting a probabilistic assessment of the failure probability for an isolated structural element exposed to a standard fire, as applied further; or

— a combination of both of the previous bullet points, for example, a full probabilistic analysis of a structural system, taking into account uncertainties in the fire development and structural response. This level of analysis can be very computationally expensive.

In the following clauses, a probabilistic assessment is carried out for the example concrete building (specifically, for the most loaded concrete column), demonstrating confidence in the achievement of the fire safety objectives.

5 Quantification of the performance of structures in fire

5.1 STEP 1: Scope of the project for fire safety of structure

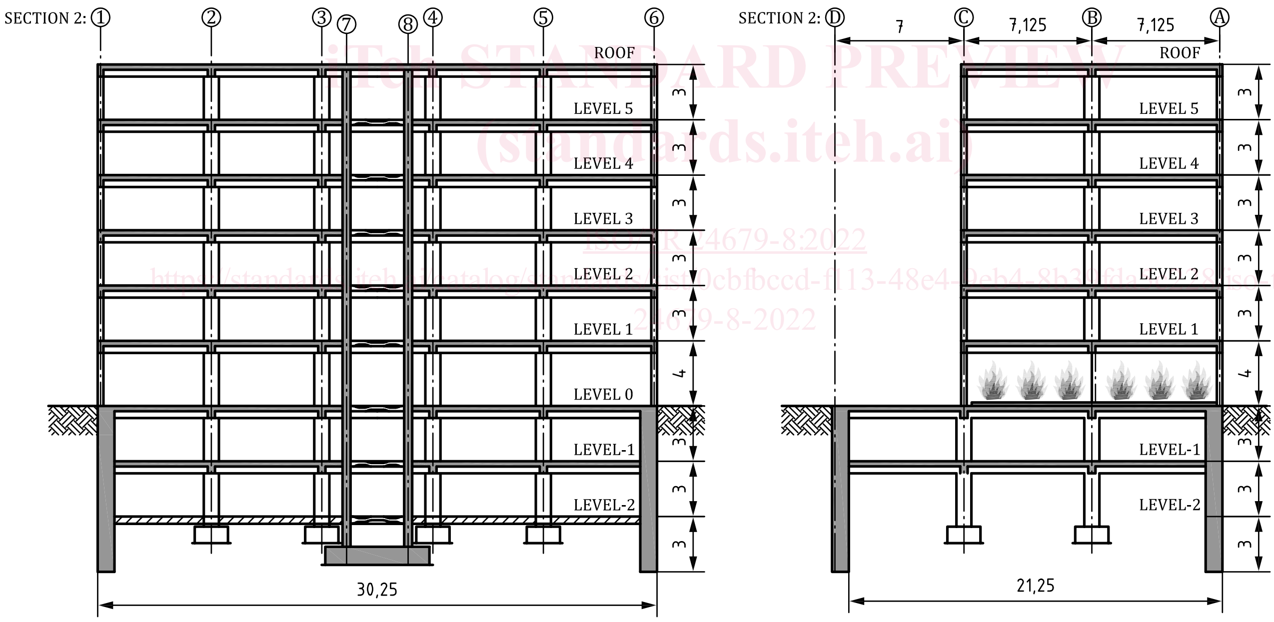
5.1.1 Built-environment characteristics

The concrete building considered is the same as that studied in ISO/TR 24679-6. The building characteristics are re-introduced in this subclause.

The building studied is an open-plan office building without any interior vertical compartmentations, with a glazed façade all around the perimeter. It has a floor area of approximately 420 m^2 and total gross area of 3 360 m^2. The building is divided into two basement levels, a ground floor and five floors above ground which are open to the public. The building is 30,25 m long × 14,25 m wide × 25 m high. The ground floor has a height of 4 m, whereas the upper storeys have a height of 3 m. Elevators and stair cases are placed in the central core.

The length is divided into five structural bays and the width into two bays. Each bay measures 6 m × 7,125 m as shown in Figure 1. The building frame is composed of reinforced continuous concrete beams and columns, supporting concrete floor slabs which are 180 mm thick; the exterior walls are 200 mm thick; the columns are 500 mm × 500 mm wide, and the beams are 400 mm deep × 250 mm wide.

Dimensions in metres



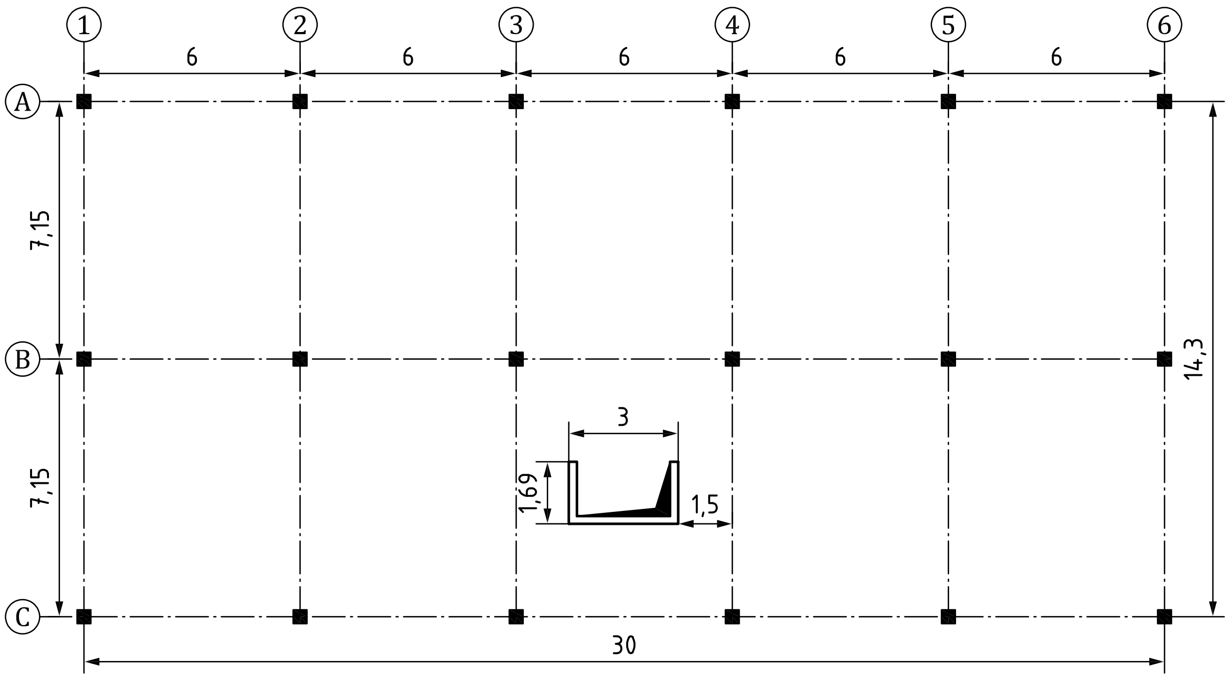


Figure 1 — Plan and elevation of the structure

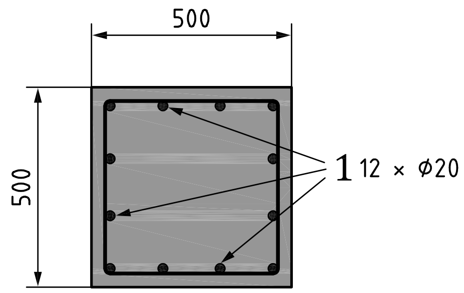
The structure includes three kinds of structural members: reinforced concrete columns, beams and slabs. The cross-section of the column is equal to 0,25 m^2 and is presented in Figure 2 (Key element 1, longitudinal reinforcement).

For the first floor, the height of the column is equal to 4 m whereas the upper storeys have a column height of 3 m. The materials are:

— Concrete: C30/37 (Note: 30 and 37 are the characteristic cylinder and cube compressive strengths respectively in MPa);

— Steel: hot rolled, Grade 500, Class B.

Dimensions in millimetres



Key

1 longitudinal reinforcement

Figure 2 — Column cross-section

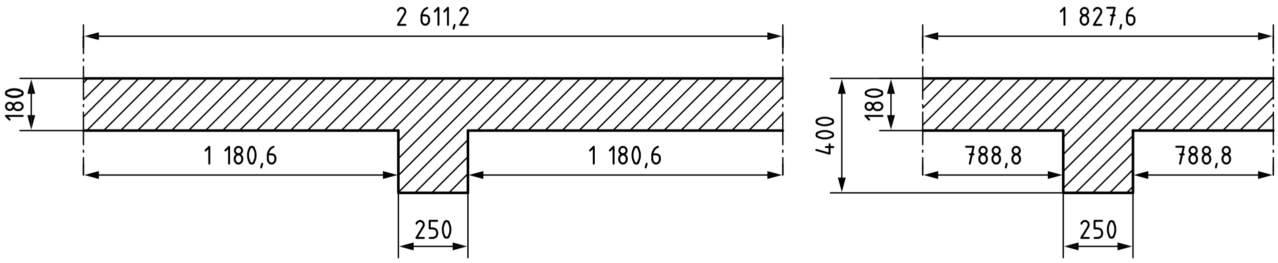
The reinforcement in the column and the axis distance are presented in Table 1.

Table 1 — Column reinforcements and the axis distance of reinforcements.

Column	Ø mm	Axis distance mm
Longitudinal reinforcement	12 Ø 20	52
Stirrups	Ø 12/200	36

In Figure 3, the cross-sections of the beams are illustrated, and in Figure 4 the concrete slab and reinforcement is presented (180 mm thick). As the analysis further focuses on the most-loaded concrete column, no further details regarding the beams and slabs are given here.

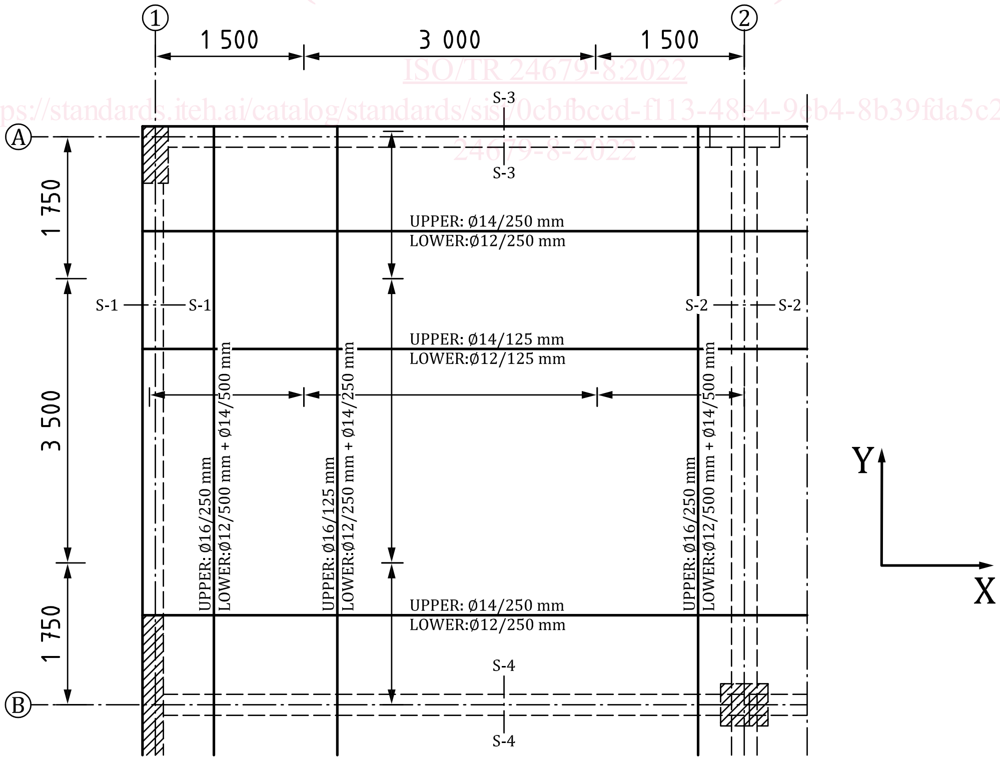
Dimensions in millimetres



a) Cross-section at mid-span **b) Cross-section at intermediate support**

Figure 3 — Continuous beam cross-section

Dimensions in millimetres



NOTE The terms "UPPER" and "LOWER" in this figure refer to the upper side and lower side measurements, respectively.

Figure 4 — Reinforcement distribution in the slab