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Fire safety engineering — Performance of structures in fire — Part 5: Example of a ~~multi-storey~~ timber building in Canada

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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 documentsdocument should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC- Directives, Part 2 (see www.iso.org/directiveswww.iso.org/directives).

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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.

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Introduction

This ~~ISO Technical Report (ISO/TR) in~~document provides an example of the application of ISO 24679-1 ~~*"Fire safety engineering — Performance of structures in fire – General"*~~. The procedure ~~in~~described this document is intended to follow the principles outlined in ISO 24679-1. It therefore preserves the numbering of subclauses in ISO 24679-1 ~~and so omits~~, omitting numbered subclauses for which there is no text or information ~~for~~relevant to this example.

~~This~~The example provided in this document is intended to illustrate the implementation of the steps of fire resistance assessment, as defined in ISO 24679-1, and to demonstrate how this ~~standard~~ISO 24679-1 can be applied to different building regulatory systems. It is not intended to demonstrate full ~~compliance~~conformance of a performance-based fire engineering design seeking approval. Therefore, only a limited number of fire design scenarios and structural assessments are presented.

Fire safety engineering — Performance of structures in fire — Part 5: Example of a ~~multi-storey~~ timber building in Canada

1 Scope

This document provides a fire engineering application relative to the fire resistance assessment of a multi-storey timber building according to the methodology given in ISO 24679-1. In an attempt to facilitate the understanding of the design process presented herein, this document follows the same step-by-step procedure as that given ~~within~~in ISO 24679-1.

The fire safety engineering approach is applied to a multi-storey timber building with respect to fire resistance and considers specific design fire scenarios, which impact the fire resistance of structural members.

A component-level (member analysis) approach to fire performance analysis is adopted in this worked example. Such an approach generally provides a more conservative design than a system-level (global structural) analysis or an analysis of parts of the structure where interaction between components can be assessed. An advantage of the component-level approach is that calculations can be done with the use of simple analytical models or spreadsheets. Advanced modelling using computational fluid dynamics is presented to replicate an actual office cubicle fire scenario and for assessing timber contribution to fire growth, intensity and duration, if any. The thermo-structural ~~behavior~~behaviour of the timber elements is assessed through advanced modelling using the finite element method.

The fire design scenarios chosen in this ~~TR~~document are only used for the evaluation of the structural fire resistance. They are not applicable for assessing, for example, smoke production, tenability conditions or other life safety conditions.

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 13943, *Fire safety — Vocabulary*

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

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

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 13943, ISO 23932-1 and ISO 24679-1 apply.

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

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

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

4 Design strategy for fire safety of structures

4.1 General design process for fire safety of structures

The built environment ~~of~~used in this example is a medium-rise office building. To accommodate tenant office functions, the building is separated into multiple compartments by floors and walls. Given that an office space typically consists of several office workstation or cubicles, it is likely that a fire will spread to neighbouring elements ~~to~~and eventually across the entire floor surface. As such, a fully-developed compartment fire is expected in each office suite of the building.

The structural elements are of glue-laminated timber beams and columns, where portions of the primary structural timber elements are left exposed for aesthetic purposes. The secondary structural elements are protected against fire using fire-resistance rated gypsum boards.

The fire development was studied using computational fluid dynamics (CFD) modelling, with specific considerations for capturing the potential fuel contribution from the structural timber elements. Time-temperature curves were produced, as well as relevant key events during the fire development (growth, flashover conditions, consumed fuel load, etc~~.~~.).

Simplified and advanced models have been used to define the thermal actions applied to the timber elements. The thermomechanical behaviour of the main structure of the office building, based on simplified and advanced methods, is carried out as a function of the actual thermal actions defined previously.

4.2 Practical design process for fire safety of structures

Refer to ISO 24679-1 for more information about the various steps and parameters to be considered when assessing the behaviour of structures subjected to fire exposure.

5 Quantification of the performance of structures in fire

5.1 Step 1: Scope of the project for fire safety of structures

5.1.1 Built-environment characteristics

The built environment consists of a 6-storey office building constructed with a timber structure. The floor area of each storey is approximately 960 m² for a total floor area of 5 760 m². Access to each floor is provided by two reinforced concrete exit stairs located at each end of a public corridor. An elevator shaft made of reinforced concrete is also provided and is located near the centre of the floor area. Figure 1 illustrates the structural framing of the building. Every floor has a clear interior floor/ceiling height of 3,0 m. These floor assemblies are required to form a fire separation with a fire-resistance rating not less than 1 hour. Load-bearing walls and columns are required to provide a fire-resistance rating not less than that required for the supported elements and assemblies.

According to the applicable national prescriptive provisions ~~[~~[4]~~]~~, a 6-storey office building using a timber structural system is required to be fully protected by an automatic sprinkler system ~~compliant with~~ conforming to NFPA 13 ~~*"Standard for the Installation of Sprinkler Systems"* and~~.[5] It is also required to have fire detection and fire alarm systems ~~[5]~~.

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The primary and secondary structural elements consist of glued-laminated timber beams and columns of the 20f-E and 12c-E Spruce-Pine (SP) stress grades [6], [7]. The floor structure is made of traditional visually-graded solid-sawn double tongue & -and- groove plank decking, of the Spruce-Pine-Fir (SPF) No.2 visually-graded lumber grade [8]. The plank decking is laid perpendicularly to the supporting secondary beams, which are spaced at every 2 m (centre to centre). All timber elements conform to the national lumber grading rules [9]. The structural engineering design, for ambient/normal conditions, conforms to the relevant design standard [8].

Concealed connections between the primary and secondary structural elements are used, in which metallic components such as self-tapping screws driven at 45° are fully embedded into the wood members to limit potential thermo-mechanical degradation from fire exposure. Figure 2 illustrates the floor structure and location of load-bearing elements. Figure 3 illustrates the detailing of the connections and their embedment into the load-bearing elements. The characteristics of the load-bearing elements assumed in this example are given in Table 1. It is noted that the The dimensions of the main elements are greater than required for structural purposes due to the embedment of the load-bearing elements and thus for providing; they need to be able to provide sufficient bearing lengths to the embedded main and secondary beams. The chosen elements considered for demonstrating the procedure of ISO 24679-1 procedure are a main beam, B1, located above the fire source and its supporting column, C2, towards the exterior wall.

a) Isometric view b) Front view

Figure 1 — Structural frame

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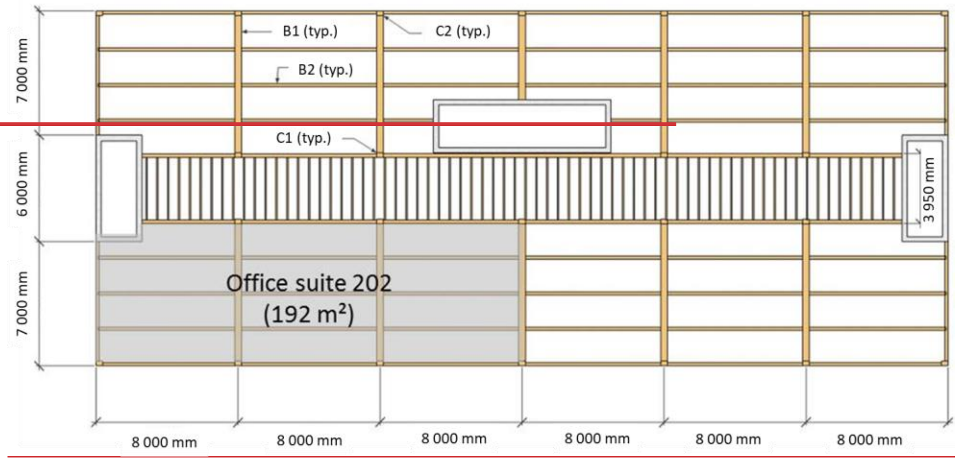

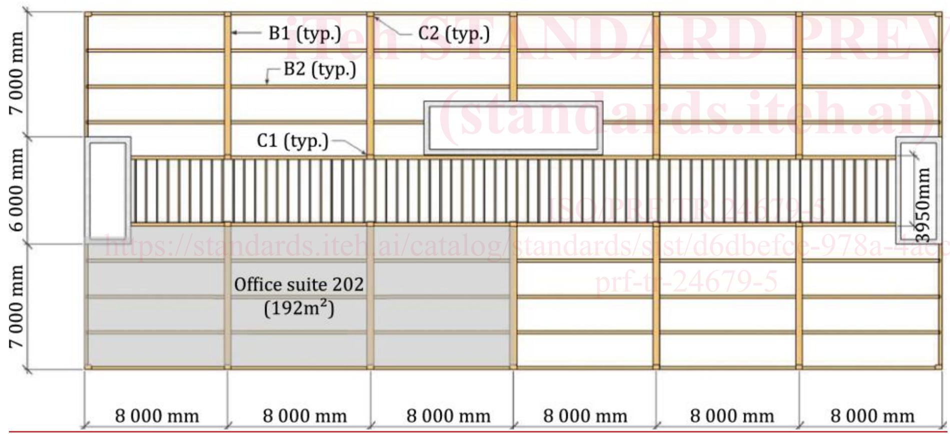

Figure 2 — Typical floor structural configuration

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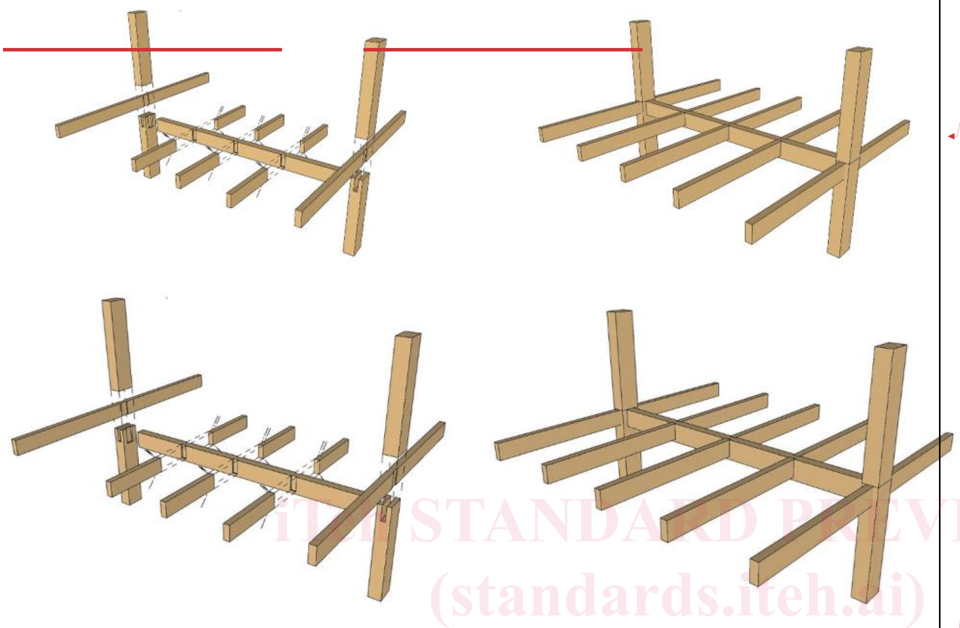

a) "Before" frame assembly

b) "After" frame assembly

Figure 3 — Detailing of the connections

Table 1 — Load-bearing elements characteristics — Preliminary design (ambient conditions)

Element	Type	Dimensions (mm)	Gypsum Boardboard
B1	Glulam 20f-E	265 × 532 at 8 000 mm c/c532[a]	None
B2	Glulam 20f-E	175 × 456 at 2 000 mm c/c456[b]	None
C1	Glulam 12c-E	418 × 365	None
C2	Glulam 12c-E	342 × 365	None
Decking	S-P-F No.2	89 × 133	1 × 16 mm Type X
Partitions	Wood studs	38 × 89[c]	2 × 13 mm Type X
Partitions	Wood studs	38 × 89 at[a] At 8 000 mm centre-to-centre (c/c). [b] At 2 000 mm c/c. [c] At 600 mm c/c.	2 × 13 mm Type X

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The dropped-ceiling assembly forms a cavity filled with ~~noncombustible~~non-combustible insulation for providing the required sound transmission class (Figure 4). The exposed ceiling consists of a single layer of 16 mm fire-rated gypsum board (e.g.~~,~~ Type X) ~~fasteners~~fastened to the secondary beams in conformance with national specifications [10, 11]. With this specific configuration, a limited portion of the primary beams and columns are left exposed and can thus ~~can~~ contribute to fire growth and severity.

Partitions made from wood stud walls are used to separate the office suites and the public corridor within the floor area. They are constructed using 38 mm ~~x~~× 89 mm wood studs spaced at 600 mm. Two (2) layers of 13 mm Type X gypsum board (i.e.~~,~~ fire-resistance rated gypsum boards) are installed on both sides of the studs, providing a 1 hour fire-resistance rating when tested by a standard fire-resistance test [12]. The inside cavities of the stud walls are filled with 89-mm thick ~~noncombustible~~non-combustible insulation in order to provide both the prescribed fire-resistance rating and the sound transmission class.

~~It is noted that according~~According to the applicable national prescriptive provisions, these partitions are not required to be constructed as a fire separation and are not required to provide a fire-resistance rating because the building is entirely protected by automatic sprinklers and the maximum travel distance from any part of the floor area to an exit is not more than 45 m. Assessment of the fire performance of the partitions is therefore beyond the scope of this document.

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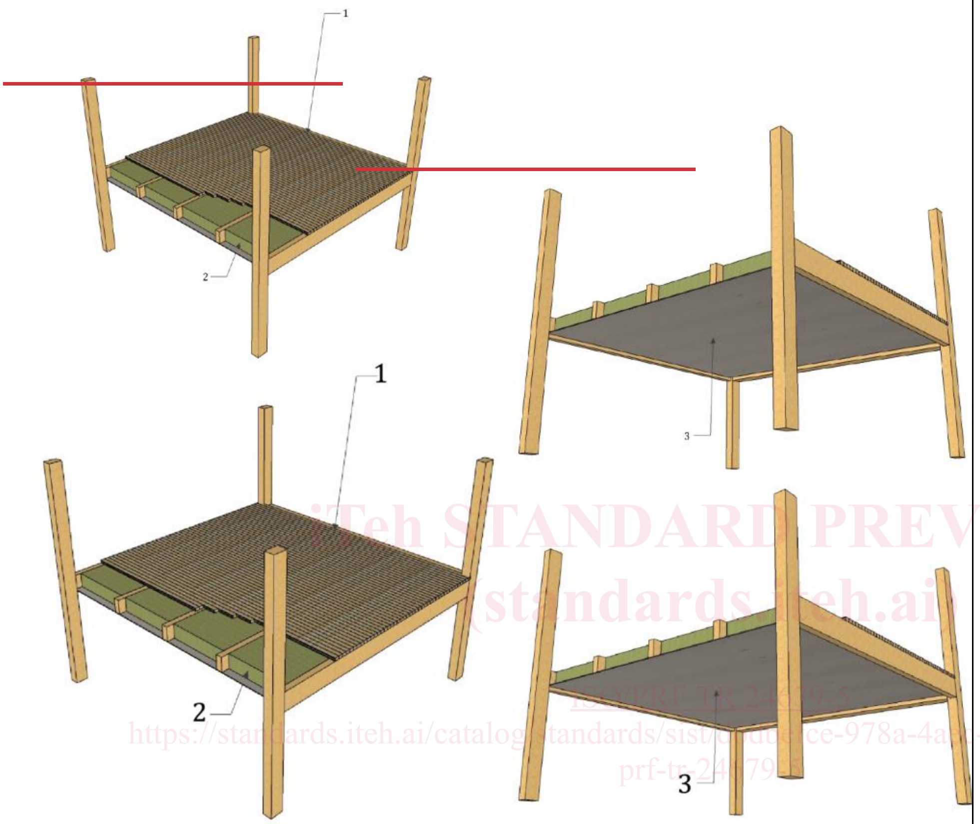

a) Isometric view   b) View of the ceiling

Key

1 89 ~~xmm ×~~ × 133 mm plank decking with double tongue ~~&~~ and groove

2 ~~Concealed~~concealed spaces filled with ~~noncombustible~~non-combustible insulation

3 16 mm ~~Type~~type X gypsum board

Figure 4 — Floor assembly

For the purpose of this document, the office suite to be analysed is located on the ~~2nd~~second floor and represents the compartment of fire origin. It is a 192 m² open-space office suite in which cubicles with computers, desks, chairs and filing cabinets are uniformly distributed across the floor area (Figure 5).

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