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THE SECOND GENERATION OF EUROCODE 5 – FIRE DESIGN

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ABSTRACT: The European Commission has a strong interest on the development of the Eurocodes to achieve a furthermore harmonization of the design rules in Europe by the revision process of all Eurocodes which was started 2015. The second generation of the Eurocodes is expected to be published starting from 2025. The main objectives of the revision are the improvement of the Ease-of-Use of the Eurocodes for practical users, the reduction of National Determined Parameters and their harmonization and the inclusion of the state-of-practice. After an intensive discussion within CEN/TC250 it was defined that the Eurocodes are addressed to competent civil, structural and geotechnical engineers, representing typically qualified professionals able to work autonomously in the relevant field.

This paper provides an overview to the second generation of the European design standard EN 1995-1-2 entitled Eurocode 5: Design of timber structures — Part 1-2: Structural fire design

KEYWORDS: Eurocode 5, Standardization, Fire design, Timber structures

1 - INTRODUCTION

After 10 years of revision work, the final draft of the new EN 1995-1-2 has been submitted to CEN Formal Vote, (April to July 2025). The revision work was performed by a Project Team (PT), which consisted of five members, and later by an extended Project Team (PT+), which consisted of authors of this paper. Basis for the revision work were extensive documents, reports and publications with the update state-of-the-art with regard to the structural fire behaviour and fire design of timber structures, e.g. the European Technical Guideline "Fire safety in timber buildings" [1] or the reports prepared in the frame of the recently concluded COST Action FP1404 [2-4]. The PT started its work in June 2018 and regularly reported to the Working Group WG4 of CEN/TC250/SC5, which is responsible for the EN 1995-1-2. Several drafts were prepared, reviewed by the WG4 and commented by the national standardisation bodies (NSB).

During the last three years, the PT prepared three drafts, which were reviewed by the WG4 and commented by the national standardisation bodies. The first draft (May 2019, 75 pages) received 265 comments, the second draft (Mai 2020, 134 pages) 624 comments and the third draft (November 2020, 138 pages) 364 comments. The final draft of EN 1995-1-2 was submitted end of August 2021 and received 396 comments. Formal Enquiry of the document was held from September 2023 to January 2024 and received 856 comments.

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2 - STRUCTURE OF EN 1995-1-2

The structure of the new EN 1995-1-2 follows the harmonised logic of all fire parts of the Eurocodes. The structure and also the first four chapters for all fire parts of the Eurocodes are written by TC250 "Horizontal Group Fire". This has resulted in a harmonized structure, which contributes to user-friendliness. Table 1 provides an overview of the structure of the draft standard and a comparison with the currently valid EN 1995-1-2:2004. The principle of a three-stage possibility of verification levels with different levels of complexity and accuracy, which is already known from other Eurocodes, is now also fully established for timber construction. Thus, in the future there are

• tabulated design data (Chapter 6),

• simplified design methods (Chapter 7), and

• advanced design methods (Chapter 8).

In addition to the principles for simplified design models already known in the current EN 1995-1-2 and the basics for numerical simulation models, Chapter 6 in the new EN 1995-1-2 lists for the first time proven construction structures or predefined characteristic values such as the protective effect (t_{prot}) of panels or for the zero strength layer (d_0) dependent on the lay-up of the cross-section for cross-laminated timber. In this way the user is given a very simple and efficient way of verifying the fire resistance. Despite the increased scope of regulations and the expansion of the scope of application, the structure adapted in this way will enable simple application.

3 - EUROPEAN CHARRING MODEL

Charring has extensively been dealt with and the current model -in the future referenced as the European Charring Model- has been generalised considering the different phases of protection and the corresponding modification factors for one-dimensional charring in a more systematic way. Further, the charring model clearly distinguishes two cases with respect to bonded structures, i.e. bond line integrity in fire maintained or not maintained. See Figure 1. Supplementary guidance for the assessment of the bond line integrity in fire has been included in the new Annex B.

3.1 Bond line integrity

To evaluate the performance characteristic of the bonding in case of fire, two test methods are introduced in Annex B. Consequently examination is possible of the surface bonding of timber layers and the finger-jointing in the flanges of web beams.

Table 1 Comparison of the content and structure between the current EN 1995-1-2 and the revision

EN 1995-1-2:2004		EN 1995-1-2:2025	
1	General	1	Scope
-		2	Normative references
-		3	Terms, definitions and symbols
2	Basis of design	4	Basis of design
3	Material properties	5	Material properties
4	Design procedures for mechanical resistance	6	Tabulated design data
5	Design procedures for wall and floor assemblies	7	Simplified design methods
-		8	Advanced design methods
6	Connections	9	Connections
7	Detailing	10	Detailing
Annex A: Parametric fire exposure		Annex A: Design of timber structures exposed to physically based design fires	
Annex B: Advanced calculation methods		Annex B: Assessment of the bond line integrity in fire	
Annex C: Load-bearing floor joists and wall studs in assemblies whose cavities are completely filled with insulation		Annex C: Determination of the basic charring rate	
Annex D: Charring of members in wall and floor assemblies with void cavities		Annex D: Assessment of Protection Level (PL) of the cavity insulation	
Annex E: Analysis of the separating function of wall and floor assemblies		Annex E: Assessment of external flaming	
Annex F: Guidance for users of this Eurocode Part		Annex F: Assessment of the failure time of fire protection systems	
-		Annex G: Implementation rules for the Separating Function Method	
-		Annex I: Design model for timber frame assemblies with I-shaped linear timber members	
-		Annex T: Determination of temperature in timber members	

For face bonds, the charring rate of a tested CLT or glulam specimen are compared to a solid wood reference in 120 minutes standard fire test in a horizontal position. The bond line integrity is assessed as maintained if the charring rate of the tested specimen does not differ more than 5% from the charring rate of solid wood reference.

For the assessment of finger-joints in the flanges of I-joists in case of fire, a test method was introduced in Annex B with small test specimens that are exposed to constant exterior heat flux. The test method was correlated to fire tests and was developed as part of the Forest Value research project FIRENWOOD. Based on the test results, the finger joints are divided into three performance classes, which should be taken into account for the fire design.

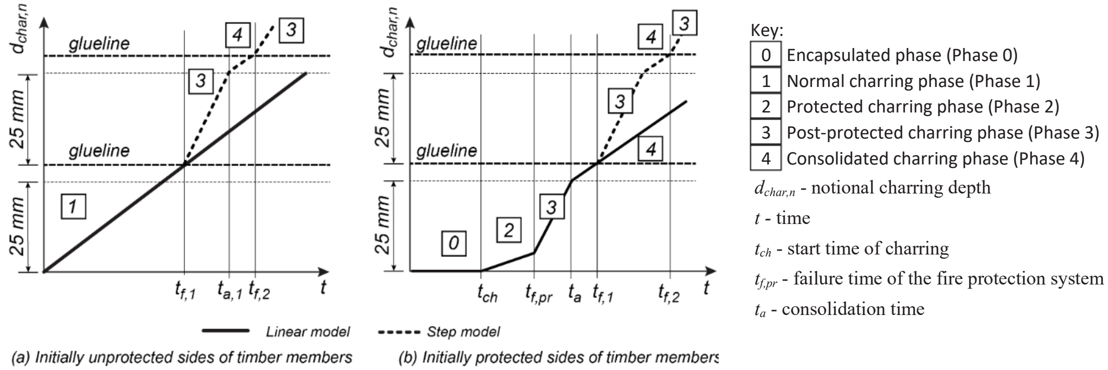

Figure 1 Charring phases for timber members according to the European charring model.

3.2 Time limits of charring phases

Time limits between phases for initially protected timber members are defined by start time of charring t_{ch}, failure time (or fall-off time) of the fire protection system $t_{\mathrm{f,pr}}$ and consolidation time t_a. For structures with bond line integrity not maintained, the fall-off time of charred layers $t_{\mathrm{f,i}}$ is considered. The start time of charring t_{ch} will be derived according to Separating Function Method. The fall-off time $t_{\mathrm{f,pr}}$ is one of the most important parameters influencing the fire resistance of initially protected timber structures, especially concerning timber members with small cross-section. In the new Eurocode the failure times (defined as fall-off times) of different panels, including gypsum plasterboard Type A and F and gypsum fibreboards are given with simplified equations based on a large data base of fire tests. Furthermore, for other fire protection systems, the failure times can be determined according to EN 13381-7. Annex F of the new code gives possibility to evaluate failure times observed in the full-scale fire tests according to EN 1363-1, EN 1364 and EN 1365, respectively.

The temperature increase behind gypsum plasterboards backed by insulation occurs faster and the fall-off of the board occurs earlier compared to the situation when backed by wooden surface (e.g. CLT). This is due to decreased heat transfer and also distance between fasteners. Fall-off time of the boards covering void cavities is also delayed if compared with insulated cavities of timber frame assemblies.

The protective properties of clay and lime plaster have been investigated experimentally and numerically. The fall-off time of clay plaster depends on the fixation as well as the adhesion between clay and the fastening system. Fixation of clay plaster onto CLT can be excellent and, therefore, clay plaster offers good protection to the timber structure.

3.3 Basic and notional design charring rate

Notional design charring rates in different phases and for different types of members will be calculated using applicable modification factors.

$$\beta_n = \prod k_i \cdot \beta_0 \qquad (1)$$

β_n	is the notional design charring rate within one charring phase, in mm/min;
β_0	is the basic design charring rate, in mm/min;
$\prod k_i$	is the product of applicable modification factors for charring.

In EN 1995-1-2:2025 the basic design charring rates β_0 are given for European softwood (Table B.2 in EN 14081-1), some hardwood species (beech, oak, ash) and also panels made of LVL, OSB, fibre boards, particle boards and plywood. Compared to EN 1995-1-2:2004 the basic design charring rates of some wood based boards are decreased based on further studies.

The basic design charring rates for engineered wood (glulam, CLT) should be chosen according to the wood species that lamellae are made of. The basic design charring rates for species and wood-based boards not listed in the EN 1995-1-2 should be determined using the assessment method given in Annex C of the code.

Different modification factors are applied in different design situations, taking into account presence and sizes of gaps, effect of corner roundings, effect of protection etc.

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Table2. Basic design charring rates

Timber species, products	β_0 [mm/min]
Softwood	0,65
Beech	0,7
Ash	0,6
Oak	0,5
Particleboard, fibreboard	0,72*
OSB	0,95
Plywood	1,0

* changed

4 - EFFECTIVE CROSS SECTION METHOD

The Effective Cross-section Method has extensively been revised and its use extended to all common structural timber members, including cross-laminated timber (CLT), timber frame assemblies and timber-concrete-composite elements (TCC).

The current Reduced Properties Method has not been further updated and is removed in the 2nd generation of Eurocode 5.

According to the effective cross-section method the initial cross-section of a timber member is reduced by a notional charring depth and by the zero-strength layer depth from the respective sides. Strength properties of the effective cross-section will not be reduced for the fire situation. The heating effect is taken into account by the zero-strength layer depth. Timber members are considered as linear or plane members. Linear members, for example, are beams and columns that can have charring on adjacent sides. Charring from different sides is considered as two-dimensional. Plane members always have one-dimensional charring. Exposure from 2 opposite sides is considered as two one-dimensional charring scenarios. Examples of plane members can be wall or floor elements made of timber.

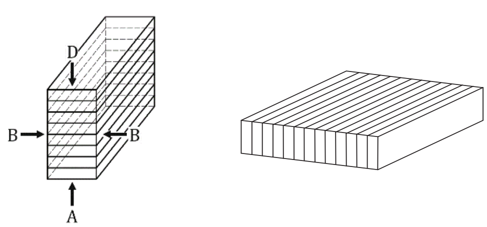
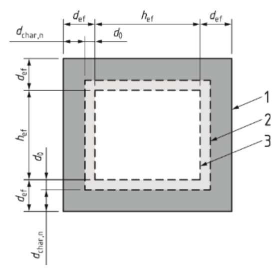


Figure 2: Example of linear member (left) and plane member (right).

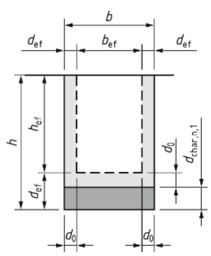
Many fire test results from the last decades show that the zero strength layer depth 7 mm given in the current Eurocode 5 often leads to unconservative results in the design. In the 2nd generation of Eurocode 5, the zero-strength layer depths are increased to 10 mm for bending and tension members and 14 mm for compression members.



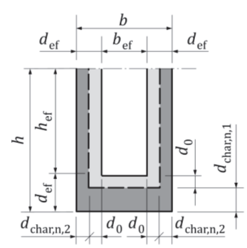
Key:
1 fire exposed side(s) or fire exposed perimeter
2 border-line of the residual cross-section
3 border-line of the effective cross-section

d_{ef} - effective charring depth
$d_{char,n}$ - notional charring depth
d_0 - zero-strength layer depth
b_{ef} - width of the effective cross-section'
h_{ef} - depth of the effective cross-section

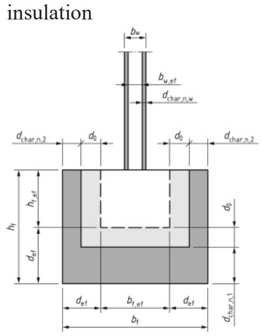
Figure 3: Example of the effective cross-section. Fire exposure from 4 sides.



Members of timber frame assemblies with PL1 insulation



Members of timber frame assemblies with PL2, PL3 insulations



Lower flange of the I-joist

Figure 4: Example of the effective cross-section of the members of timber frame assemblies.

Calculation of the effective cross-section is given for cross-laminated timber, taking into account the load-bearing and non-load bearing layers.

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The current Annexes C (timber frame assemblies with filled cavities) and D (timber frame assemblies with void cavities) have been extensively improved and moved to the main part of EN 1995-1-2. The revised content is normative. The design model for timber frame assemblies with filled cavities is based on the Effective Cross-section Method and allows considering the performance of different types of insulation (mineral wool, cellulose, wood fibre, etc.). The performance of the insulation can be evaluated with model-scale fire tests According to Annex D and assessed in three different protection level (PL1, PL2, PL3). For some common insulation materials the PL class can be chosen without further testing.

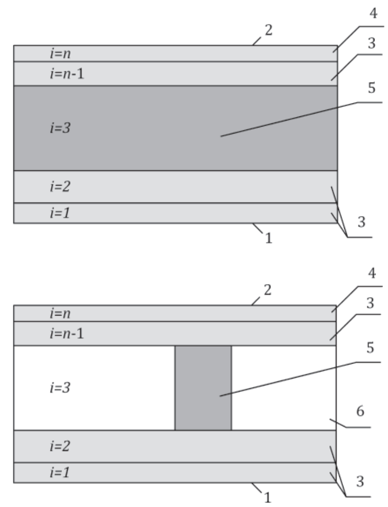
Annex I of the new EN 1995-1-2 gives a fire design model for walls and floors with the I-joists. The charring of flanges and web are considered.

5 - SEPARATING FUNCTION METHOD

The current Annex E (Component additive method) for the verification of the separating function has extensively been improved and moved to the main part of the EN 1995-1-2:2025. The revised content is normative and the design method for separating function has been extended to 120 minutes fire resistance.

Heat paths through the timber members or other materials as panels and insulations maybe calculated by taking the contribution of each layer into account starting from the fire exposed side. Layers can be combined and changed easily. The total insulation time of an assembly is the sum of contributions of all layers. Generic values for protection times are given for wood-based products, gypsum boards, clay and lime plasters, mineral wool and cellulose based insulation materials and as well as cement based screed. The method is open to include new materials or products using the procedure in the new Annex G.•

The Separating Function Method will be also used to calculate the start time of charring behind a multi-layered fire protection systems.



Key:
1 Fire exposed side
2 Unexposed side
3 Panels as protective layers
4 Panel as insulating layer (last layer n)
5 Timber member as protective layer
6 Cavity (insulation or void) as protective layer

Figure 5: Definition of layers for the Separating Function Method.

6 - CONNECTIONS

Calculation methods for connections are extended and enhanced. Improved rules for the fire design of connections up to 120 minutes fire resistance are given based on extensive experimental and numerical analysis, allowing bolts, dowels, nails or screws. The chapter contain tabulated design data and simplified design methods for connections. Minimum fire resistances of connections designed for ambient conditions are given based on the 1st generation of Eurocode 5.

Geometric requirements for a specific fire resistance time for timber-to-timber connections and steel-to-timber connections with dowels are given as tabulated values. The values are based on simulations on connections calibrated to fire tests.

An exponential reduction method for connections with dowels or bolts, nails or screws is proposed. The model is based on simulations on connections and calibrated to fire tests.

Rules for protected connections with timber side members are given allowing the design of the fire protection system. If the failure of the fire protection system occurs at least 20 minutes after the start of charring of the protected connection behind the fire protection system, the fire protection system should be

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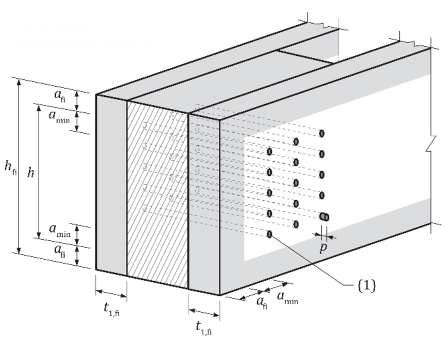
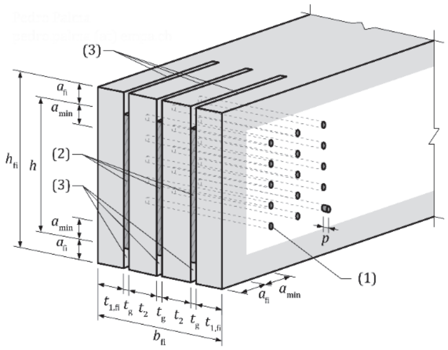
designed only for the difference between the required fire resistance and the fire resistance of the connection without protection. Otherwise, the fire protection system should be designed for an increased difference between the required fire resistance and the fire resistance of the connection without protection, to take into account the increased charring after the failure of the fire protection system. In the most unfavourable case, the difference is increased by 20 minutes.



a) Timber-to-timber connection



b) Steel-to-timber connection

Figure 6: Examples of connections.

7 - DETAILING

Detailing rules shall always be satisfied when simplified design methods or tabulated design parameters are used.

The rules for detailing were extended and enhanced compared to current version of EN 1995-1-2. The rules for panels and insulation (minimum dimensions, maximum spacings between fasteners of panels, fixation of cavity insulation, etc), rules for joints in and between elements and to other adjacent components as well as rules for penetrations and openings are given.

8 - TABULATED DESIGN DATA

Tabulated data are given for typical fire protections system (start times of charring and failure times of protection systems) consisting of gypsum boards and wood-based boards. Tabulated data for the effective cross-section of common CLT setups are provided.

More tabulated data can be added by National Annexes.

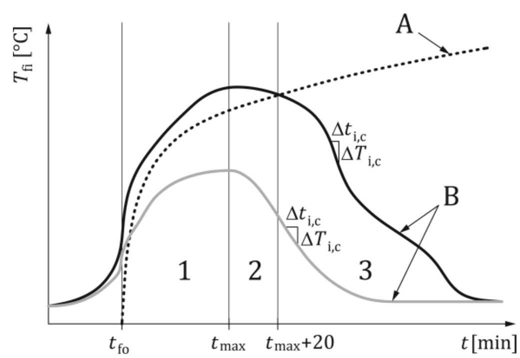
9 - ADVANCED DESIGN METHODS

Advanced design methods may be used in association with any thermal action, provided the material properties are known for the relevant temperature history. Advanced design methods include separate calculation models for the determination of the development and distribution of the temperature within structural members (thermal response model) and the mechanical behaviour of the structure or of any part of it (mechanical response model). Thermal and mechanical properties at elevated temperatures for wood and wood-based materials, gypsum boards and mineral wool are given for advanced analysis.

10 - DESIGN FOR PHYSICALLY BASED FIRES

For the design of timber structures exposed to physically based design fires, improved rules and design methods have been developed and given in the new Annex A.

Design methods for any temperature-time curve including parametric fires are given. According to the new Eurocode, timber structures can be designed until burnout including the contribution of structural fire load to the total fire load. The calculation of structural fire load is performed in accordance with Annex H of a new EN 1991-1-2.



Key:

t_{fo}	time of flashover
t_{max}	time of maximum compartment temperature
$\Delta t_{i,c}$	time difference in the cooling phase (evaluation step i)
$\Delta T_{i,c}$	temperature difference in the cooling phase (evaluation step i)
1	heating phase

Figure 7: Compartment fire temperature: definition of phases for physically based fires.

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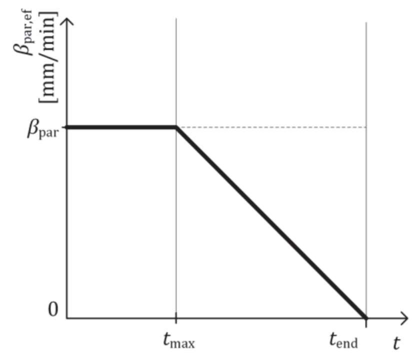

Key:

β_{par} is the charring rate of unprotected structural timber members under parametric fire exposure;

t is the time, in min;

t_{max} is the time at which maximum temperature according to EN 1991-1-2, Annex A is reached;

t_{end} is the time at which the parametric time temperature reaches 20°C.

Figure 8: Charring rate for parametric fire.

The standardized methods for physical based fires create new possibilities for design of fire resistance of large and tall timber buildings for a full fire scenario including the decay phase of fire.

11 - SUMMARY

It is expected that the second generation of design standard EN 1995-1-2:2025 will fill most gaps of the current EN 1995-1-2:2004 and will allow a safe and economic design of timber structures in fire.

The scope of the standard has been growing due to the necessary consideration of new products made of wood, the demand for more accurate design and the increase of available design approaches. Despite this, a central focus was on maintaining and even increasing the ease-of use through restructuring, homogenisation and simplified methods. Nevertheless, similar to the changeover to the first generation of EN 1995-1-2, an additional learning and training process will be necessary, which should start before the final publication.

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