Det igangværende revisionsarbejde - Eurocode for trækonstruktioner

Webinar 27. oktober 2023

DS DANSK STANDARD

Program

Vi er tre her i dag på webinaret:

Jørgen Munch-Andersen, BUILD/Aalborg Universitet

Finn Larsen, fra WSP Danmark A/S

Erling Richard Trudsø, Dansk Standard

De to herrer sidder i dag som hhv. forperson og medlem i S-1995 Eurocodes trækonstruktioner og har arbejdets indenfor trækonstruktionsområdet i rigtigt mange år.

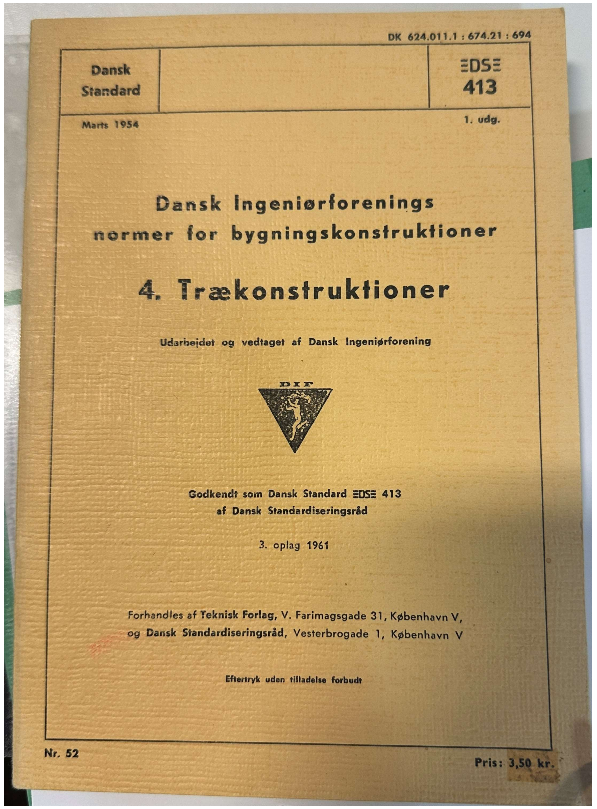
Jeg har også selv arbejdet med træområdet og bl.a. været europæisk sekretær for CEN/TC 124 Timber structures (produktsiden).

Program

- Introduktion til baggrunden for Eurocode og den igangværende revision
- Overordnede ændringer i prEN 1995-1-2 (brand)
- Den fremadrettede proces og mulighed for kommentering
- Spørgsmål
- Tak for i dag

Forhistorien

Lidt om de tidligere sæt af danske konstruktionsnormer



DK 624.011.1 : 674.21 : 694

Dansk Standard

DS 413

Marts 1954

1. udg.

Dansk Ingeniørforenings normer for bygningskonstruktioner

4. Trækonstruktioner

Udarbejdet og vedtaget af Dansk Ingeniørforening

Godkendt som Dansk Standard DS 413 af Dansk Standardiseringsråd

3. oplag 1961

Forhandles af Teknisk Forlag, V. Farimagsgade 31, København V, og Dansk Standardiseringsråd, Vesterbrogade 1, København V

Eftertryk uden tilladelse forbudt

Nr. 52

Pris: 3,50 kr.

DANSK STANDARD

Det første skridt mod europæiske standarder

DS-Information

DS/ENV 1995-1-2

1. udgave

Godkendt: 1995-01-10

Eurocode 5:
Trækonstruktioner
Del 1-2: Generelle regler
Brandteknisk dimensionering

Eurocode 5: Design of timber structures –
Part 1-2: General rules – Structural fire design

DS/EN 1995-1-2:2007

Den nugældende eurocode for træ

Dansk standard

DS/EN 1995-1-2 + AC

2. udgave

2007-06-11

**Eurocode 5: Trækonstruktioner –
Del 1-2: Generelt – Brandteknisk dimensionering**

Eurocode 5: Design of timber structures –
Part 1-2: General – Structural fire design

DS/EN 1995-1-2 DK NA

Det tilhørende DK NA

- Eurocodes skal altid benyttes sammen med gældende DK NA – forudsat at der er udarbejdet et sådant.
- Et national anneks kobler anvendelsen af en eurocode til det pågældende lands byggelovgivning.
- Gældende DK NA kan downloades fra Dansk Standards hjemmeside.
- https://www.ds.dk/da/fagomraader/byggeri-og-anlaeg/eurocodes/nationale-annekser/gaeldende

Revisionen af eurocodes

De i alt knapt 70 dele af eurocodes har siden 2010 været under revision efter opdrag fra EU Kommissionen.

Revisionsarbejdet er blevet forberedt i en antal project teams og dernæst flyttet videre til en mængde arbejdsgrupper under de respektive eurocodes materialeområder.

Der vil omkring 2026-2027 være blevet udgivet ca. 8.000 sider, dækkende samtlige nuværende konstruktionstyper og materialer plus nogle få nye.

Nogle vigtige datoer

Kommentering af forslagene til nye eurocodes

Der er indtil primo december mulighed for at fremsende kommentarer til de foreliggende forslag til nye 2. generations eurocodes for træ.

Temaet i dag er som allerede nævnt branddimensionering af trækonstruktioner (prEN 1995-1-2), men der er samme kommenteringsfrist på prEN 1995-1-1 (generel del), prEN 1995-1-3 (udførelse) samt prEN 1995-2 (broer).

Såfremt vi har væsentlige kommentarer – og det har vi – så er det vigtigt, at vi fremsender disse til det europæiske sekretariat for eurocodes revisionen inden deadline.

Der skal anvendes en særlig skabelon og man kan ikke nøjes med at skrive, at man er utilfreds med et givent afsnit.

Man skal også komme med velformuleret ændringsforslag.

Og alt skal skrives på engelsk!

DANSK STANDARD

Revision af Eurocode 5 Del 1-2

Webinar DS 27 okt. 2023

Jørgen Munch-Andersen, BUILD
Finn Larsen, WSP

Baseret på slides fra webinar afholdt af Svenskt Trä og SIS, udarbejdet af Alar Just og Daniel Brandon, RISE

Originale slides er på engelsk, vores tilføjelser på dansk

Uppdateringar i Eurokod 5 Del 1-2

Alar Just
Daniel Brandon

Svensk Trä
SIS
Online 28.9.2023

EN 1995-1-2:2025

1. Scope
2. Normative references
3. Terms, definitions and symbols
4. Basis of design
5. Material properties
6. Tabulated design data
7. Simplified design methods
8. Advanced design methods
9. Connections
10. Detailing

Annexes

Common part for all EN 199x-1-2

Start of charring, failure time of protection, charring rate

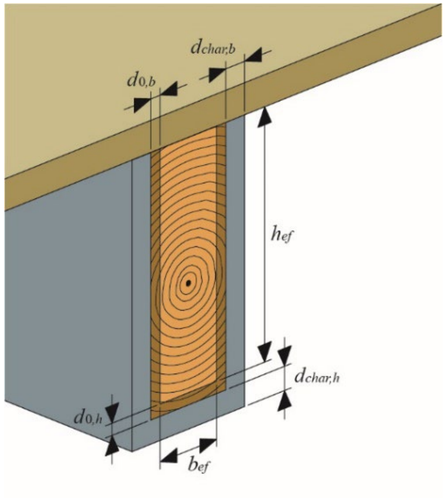
Specific rules
Zero-strength layer

Requirements for detailing

Opdateringen af EC5-1-2 er en videreudvikling af

Restbæreevne (R)

1. Bestem t_{ch} og t_f for eventuel beklædning
   - t_{ch} er tiden hvor forkulningen starter
   - t_f er tiden hvor beklædningen falder ned
     ($t_f > t_{ch}$ kun for brandgips)
2. Bestem indbrændingshastighed β og indbrændingdybden
   $d_{char} = \beta\, t$



3. Bestem tykkelsen d_0 af styrkeløst lag
4. Resttværsnit ved 3-sidet brand
   - højde $h_{ef} = h – (d_{char} + d_0)$
   - bredde $b_{ef} = b – 2(d_{char} + d_0)$
5. Kontroller bæreevne af resttværsnit som ulykkeslast, dvs. styrke øget med ca 100 % og last reduceret med 30-50 %

Brandmodstandstid (EI) for vægge og dæk

Krav:

- E - Sidste pladelag skal være sammenhængende
- I - Temperatur på ikke-eksponeret side må højst øges med 140 K

Beregningsmetode:

- Bidrag for hvert lag adderes (lag = beklædning, isolering)

$$t_{ins} = \sum_{i=1}^{i=n-1} t_{prot,i} + t_{ins,n}$$

i: lag no fra eksponeret side

n: sidste lag

Annexes (normative or informative)

Annex A Design of timber structures exposed to physically based design fires

Annex B Evaluation of the bond line integrity in fire

Annex C Determination of the basic design charring rate

Annex D Assessment of Protection Level (PL) of the cavity insulation

Annex E External flaming

Annex F Assessment of the failure time of fire protection systems

Annex G Implementation rules for Separating Function Method

Annex I Design model for timber frame assemblies with I-shaped timber member

Annex M Material properties

EN 1995-1-2:2025

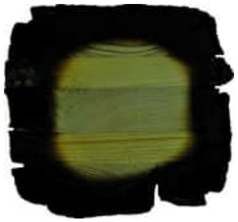
- **4.5 (8)**
- Fire resistance calculated according to design methods given in this document may be used for the classification according to EN 13501-2.

Materials and products

Table 5.2 — Protection level PL for cavity insulation materials

Protection level PL	Insulation material	Requirement
PL1	Stone wool	$\rho \geq 26$ kg/m^3
PL2	Glass wool	$\rho \geq 14$ kg/m^3
	Wood fibre	$\rho \geq 50$ kg/m^3
	Loose-fill cellulose fibre	$\rho \geq 50$ kg/m^3
	Loose-fill wood fibre	$\rho \geq 35$ kg/m^3
PL3	XPS, EPS, PUR, PIR	-
	Not assessed insulation materials	-
where ρ is the density, in kg/m^3.		

Test method to determine Protection Level PL is given in Annex D



Basic design charring rates

Nu kun 1-dim

	β_0 [mm/min]
a) Timber member made of softwood(1) (3) (4)	0,65
b) Timber member made of hardwood(1)	
Beech(5)	0.70
Beech(5) LVL	0,65
Ash(6)	0,60
Oak(7)	0,50
c) Panel(2)	
Solid wood panelling and cladding, solid wood panel with only one layer	0,65
LVL panel(3)	0,65
Particleboard, fibreboard	0,72
OSB, solid wood panel with multiple layers	0,9
Plywood	1,0

- **Annex C** – a method for the evaluation of the basic design charring rate
- NDP for other species/densities allowed

Charring depth

(3) If the timber member undergoes charring in different charring phases the European charring model shall be individually applied for the individual charring phases (see Figure 5.1 and Figure 5.2).

(4) The notional charring depth $d_{char,n}$ (see Figure 5.3) should be calculated as follows:

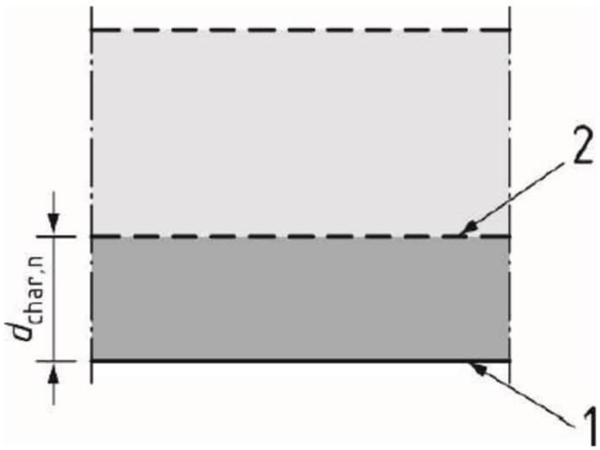
$$d_{char,n} = \Sigma_{Phases}(\beta_n \cdot t) \tag{5.1}$$

where

$d_{char,n}$	is the notional charring depth in mm;
β_n	is the notional design charring rate within one charring phase in mm/min (see 5.4.2.2);
t	is the time for the charring phase considered in min (see 5.4.2.1).

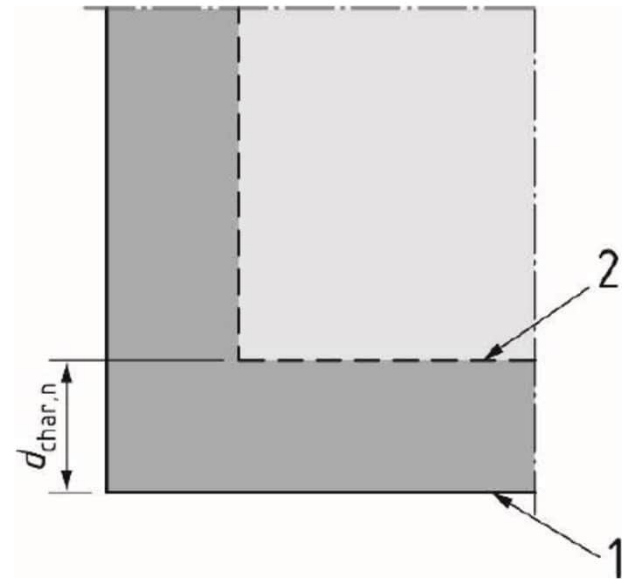
Charring depth

Plane members



a) One-dimensional charring

Linear members



b) Two-dimensional charring.

Hjørneafrundings-
faktor = 0,70/0,65

Notional design charring rate

$$\beta_n = \prod_{k_i} k_i \cdot \beta_0$$

Table 5.1 – Modification factors for charring

Modification factor	Designation	Reference
k_{gd}	grain direction factor	5.4.2.2 (4)
k_g	gap factor	5.4.2.2 (6)
k_h	thickness factor	5.4.2.2 (8)
k_n	conversion factor	5.4.2.2 (5), 7.2.2 (2)
$k_{s,n,1}$	combined section and conversion factor for the fire exposed side	5.4.2.2 (7); 7.2.4 (12)
$k_{s,n,2}$	combined section and conversion factor for the lateral side	5.4.2.2 (7); 7.2.4 (12)
k_ρ	density factor	5.4.2.2 (9)
k_2	protection factor for Phase 2	5.4.2.2 (10)-(12)
k_3	post-protection factor for Phase 3	5.4.2.2 (13)
$k_{3,1}$	post-protection factor for the fire exposed side for Phase 3	7.2.4 Table 7.6
$k_{3,2}$	post-protection factor for lateral side for Phase 3	7.2.4 Table 7.6
k_4	consolidation factor for Phase 4	5.4.2.2 (14)

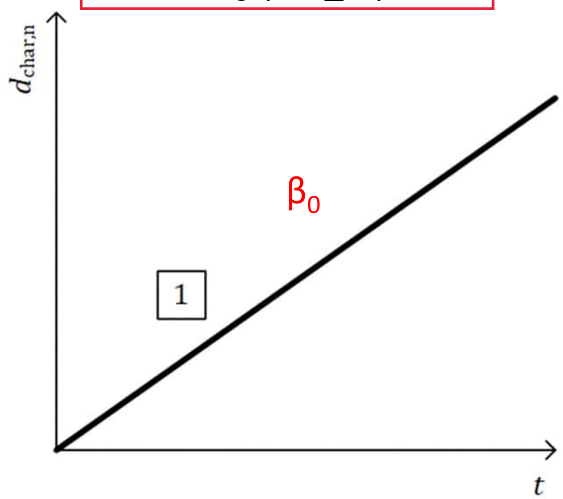
Revnefaktor for fx CLT. Er 1 op til 2 mm revner, men kan blive
noget større ved udtørring af CLT fra typisk 12 % til 6 % fugt.

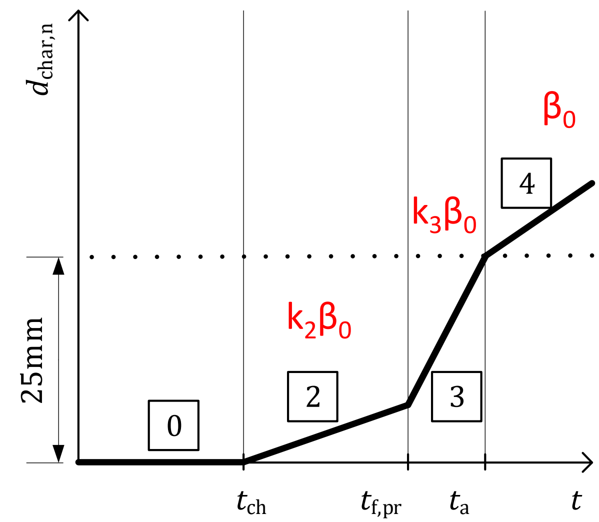
t_ch er tid for start af forkulning

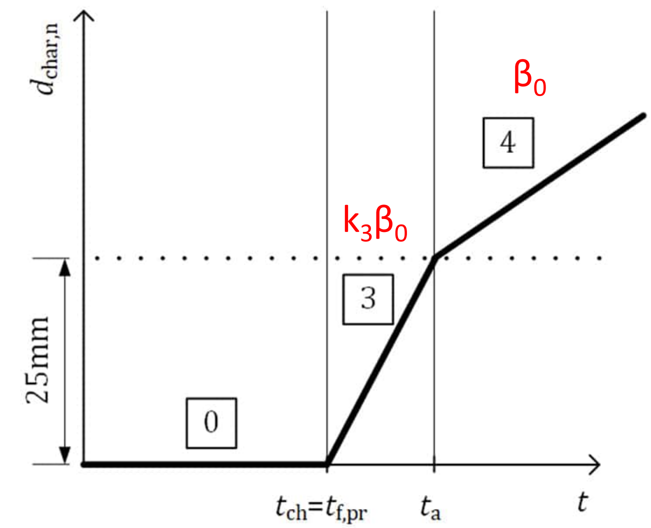
t_f er tid for nedfald af beklædning (>= t_ch)

European Charring Model

Når kullaget bliver 25 mm reduceres indbrændingen til beta_0







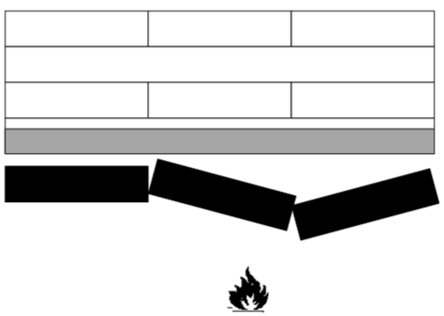
- Normal charring phase (Phase 1)

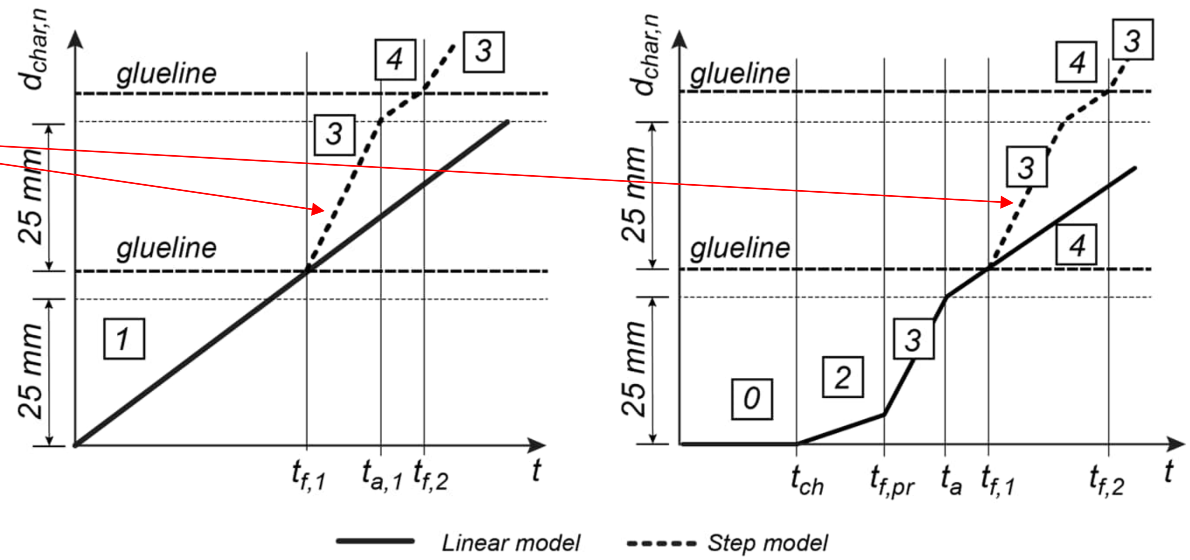
$$\beta_n = \prod k_i \cdot \beta_0$$

- Encapsulated phase (Phase 0)
- Protected charring phase (Phase 2)
- Post-protected charring phase (Phase 3)
- Consolidated charring phase (Phase 4)

Influence of bond line integrity

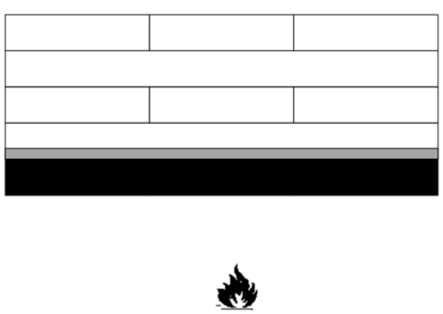
Bond line integrity is not maintained





(a) Initially unprotected sides of timber members *(b) Initially protected sides of timber members*

Bond line integrity is maintained



Adhesives

5.5.2 Bond line integrity of face bonds

(1) For structural members with face bonds the bond line integrity in fire for the required time of fire resistance t_{req} shall be considered in the design.

NOTE The bond line integrity in fire can depend on the particular member, e.g. layup of the cross-section, thickness of the lamellae, etc.

(2) The European charring model given in 5.4.2 should be used to satisfy 5.5.2(1) when the bond line integrity in fire is maintained (see Figure 5.1) or not maintained (see Figure 5.2).

(3) Unless other rules are given in this document, the bond line integrity in fire of face bonds shall be verified using the test method given in Annex B.

(4) The bond line integrity in fire may be assumed as maintained for the following adhesives:

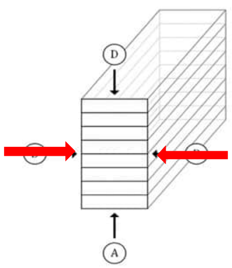
— phenolic Type I adhesives according to EN 301

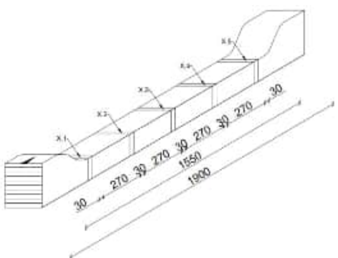
— phenolic adhesives for structural LVL according to EN 14374 and plywood according to EN 636

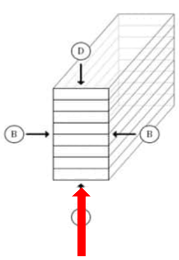
FIRENWOOD

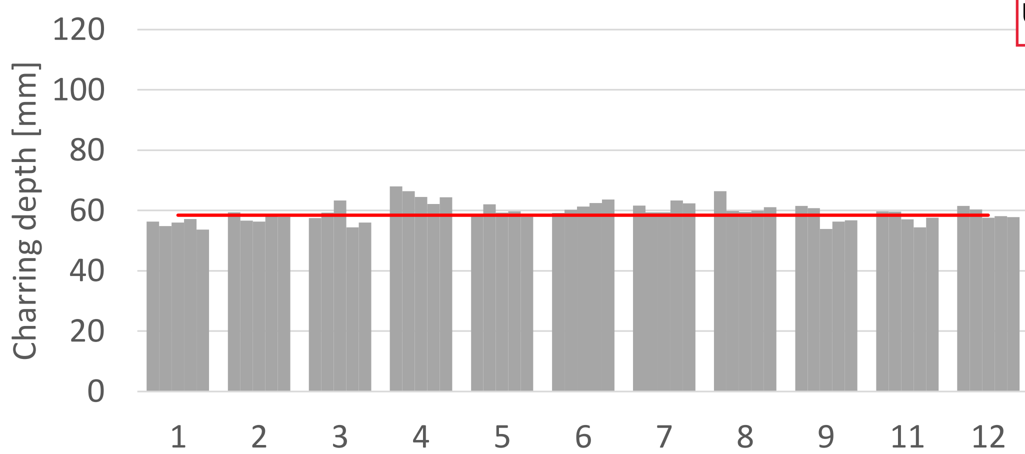
Glulam beams

Limtræ vil delaminere under brand for mange typer lim. Især når eksponeret på undersiden.

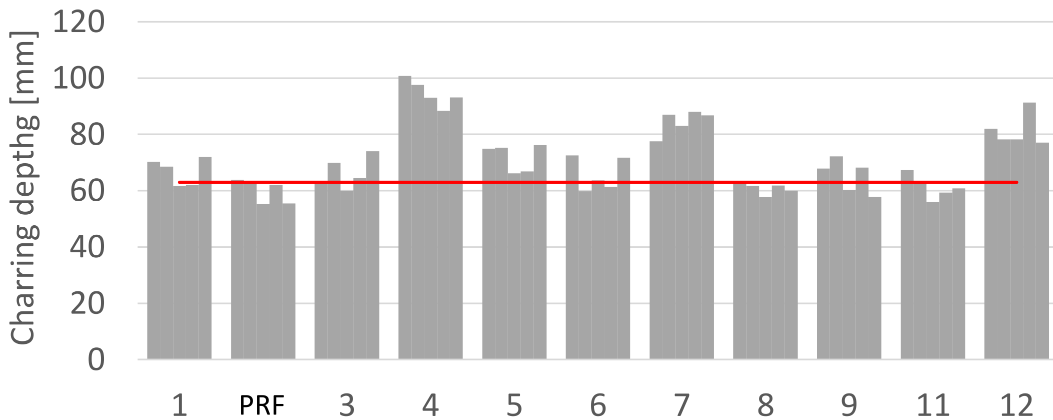






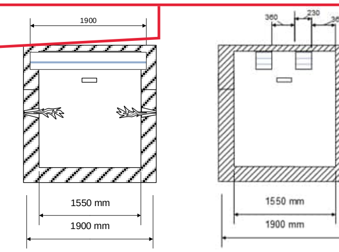


0,65 mm/min



Som beta_n inkl hjørneafrunding i nuværende EC

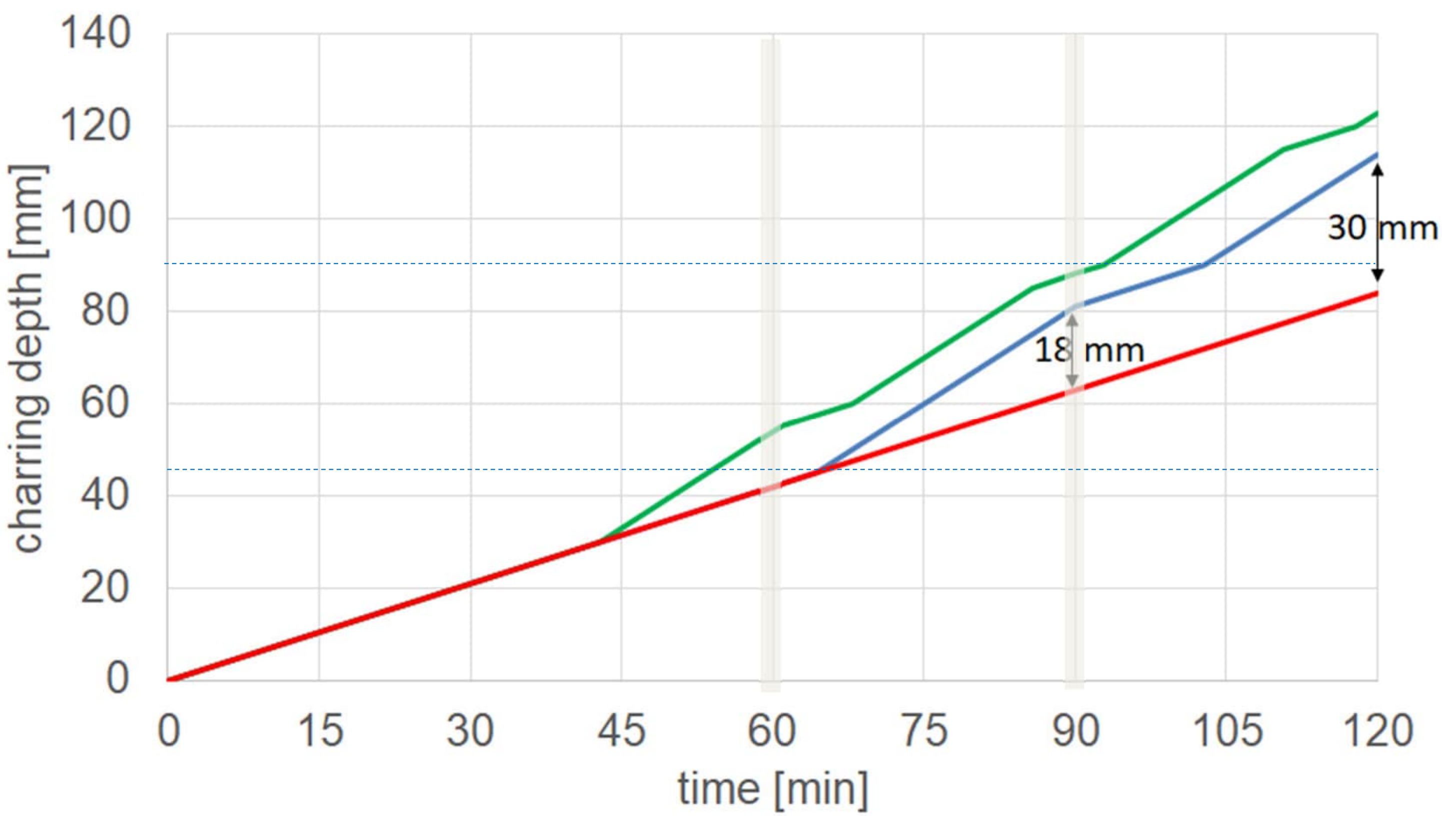
0,7 mm/min



Reference = 'brun lim'

90 min

Linear model vs step model



Stor lameltykkelse er godt. Med 45 mm er indbrænding efter 1 time uafhængig af limtype

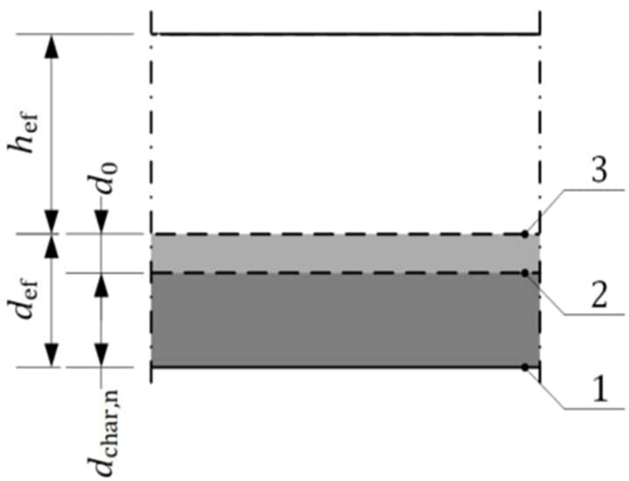
Step model 30 mm

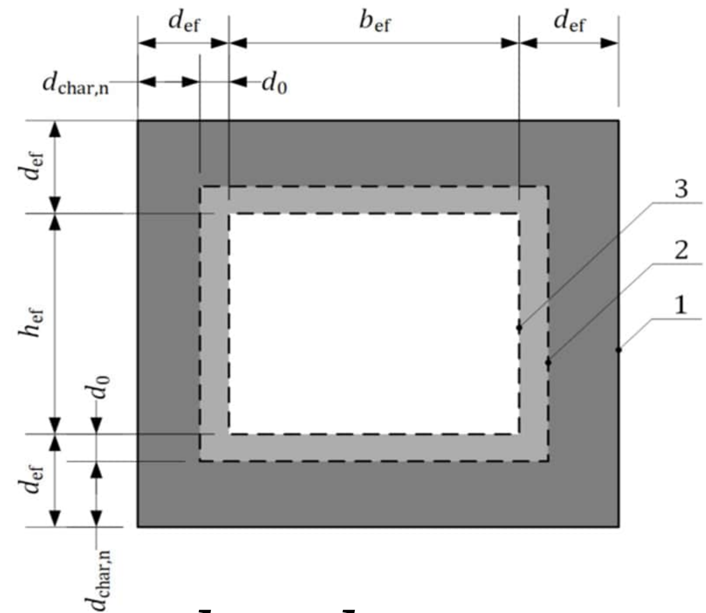
Step model 45 mm

Linear model for massiv træ eller 'brun lim', 30, 45 mm

Effective cross-section

NB: Styrkereduktionsmetoden er udgået





1 Fire exposed side
2 Residual cross-section
3 Effective cross-section

d_0 is the zero-strength layer depth
$d_{char,n}$ is the notional charring depth
d_{ef} is the effective charring depth
k_{side} is the number of respective sides exposed to fire

$$d_{ef} = d_{char,n} + d_{\vartheta}$$

$$b_{ef} = b - k_{side} \cdot d_{ef}$$

$$h_{ef} = h - k_{side} \cdot d_{ef}$$

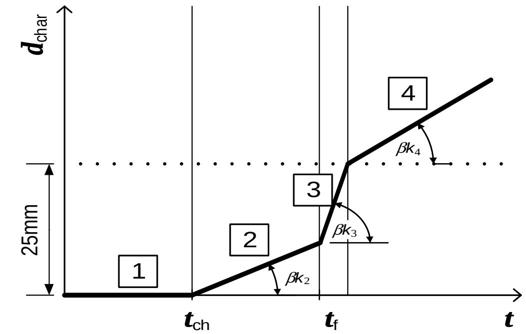
4.5 Design values of material properties

(Uændret)

$$X_{d,fi} = k_{fi} \cdot X_k \;/\; \gamma_{M,fi}$$

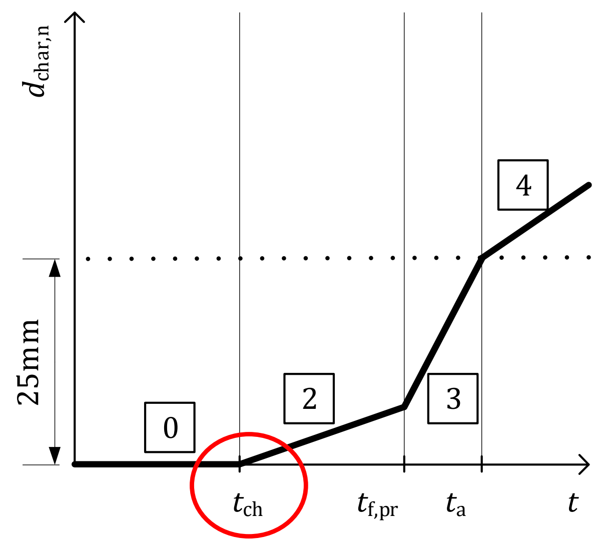
Solid timber	1,25
Glued-laminated timber, cross-laminated timber	1,15
Wood-based panels	1,15
LVL	1,10
Connections with laterally loaded fasteners with side members of wood and wood-based panels	1,15
Connections with laterally loaded fasteners with side members of steel	1,05
Connections with axially loaded fasteners	1,05

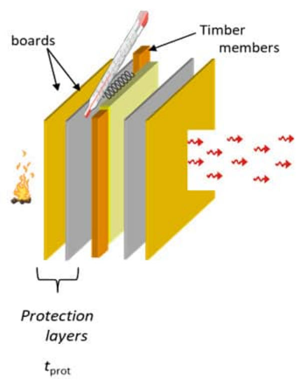
Protection materials



Start time of charring

- According to Separating Function Method
- For other products shall be determined by tests according to EN 13381-7.
- The start time of charring t_{ch} for **floors** (ie ceilings) should be calculated as minimum of failure time $t_{f,pr}$ or start time of charring.





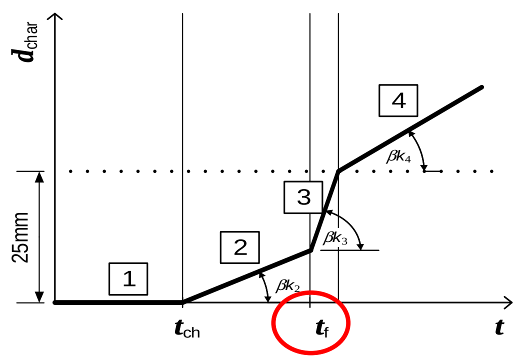
$$t_{\text{ch}} = \Sigma\, t_{\text{prot, cladding}}$$

Floors:

$$t_{ch} = \min \begin{cases} \sum t_{prot} \\ t_{f,pr} \end{cases}$$

Failure times of gypsum boards

20% fractile values from database of full scale test results



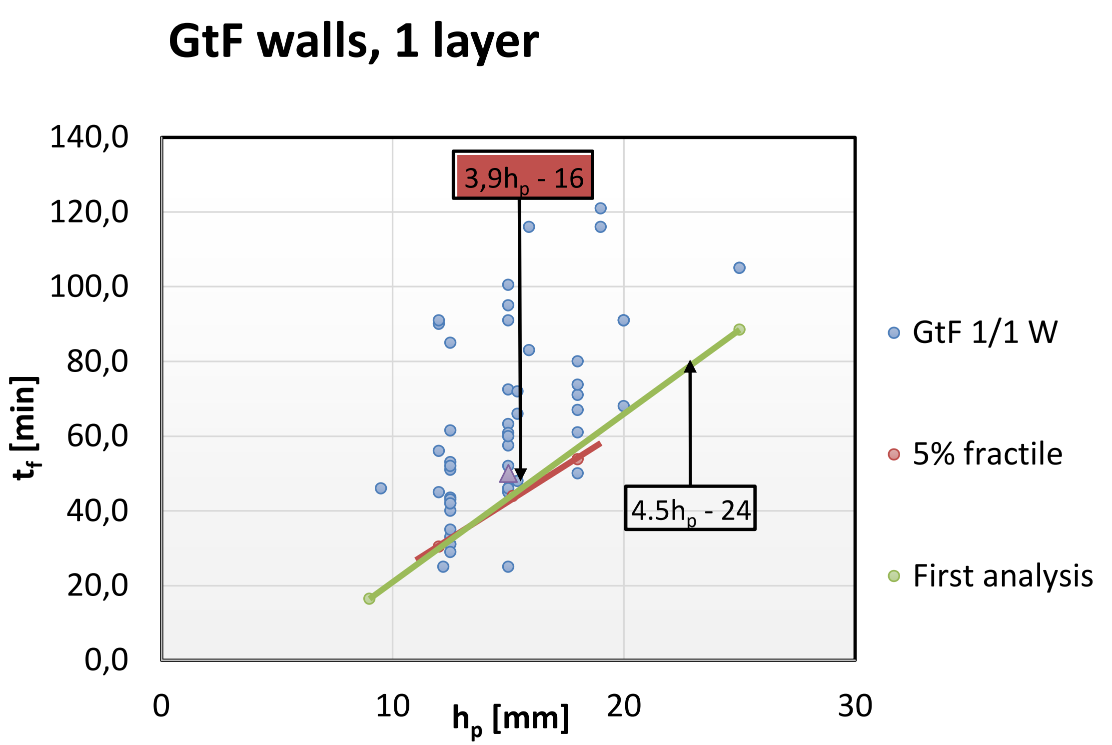
For other materials:
EN 13381-7
Alternative Annex F (EN 1363 etc)

Table 5.6 – Failure time of gypsum panels

Panels		Vertical		Horizontal	
		t_f [min]	h_p [mm]	t_f [min]	h_p [mm]
Gypsum plasterboards	Type F, one layer	$t_f = 4{,}6 \cdot h_p - 25$ (5.10)	$9 \leq h_p \leq 18$	$t_f = 1{,}3 \cdot h_p + 9$ (5.11)	$9 \leq h_p \leq 18$
	Type F, two layers or Type F + A(*)	$t_f = 4{,}4 \cdot h_p - 50$ (5.12)	$25 \leq h_p \leq 36$	$t_f = 1{,}5 \cdot h_p + 15$ (5.13)	$25 \leq h_p \leq 36$
	Type A, one layer	$t_f = 2{,}1 \cdot h_p - 6$ (5.14)	$9 \leq h_p \leq 18$	$t_f = 2{,}1 \cdot h_p - 9$ (5.15)	$9 \leq h_p \leq 18$
	Type A, two layers	$t_f = 1{,}8 \cdot h_p - 4$ (5.16)	$25 \leq h_p \leq 36$	$t_f = 1{,}7 \cdot h_p - 13$ (5.17)	$25 \leq h_p \leq 36$
Gypsum fibreboards, one layer		$t_f = 3{,}8 \cdot h_p - 21$ (5.18)	$9 \leq h_p \leq 18$	$t_f = 1{,}3 \cdot h_p + 7$ (5.19)	$9 \leq h_p \leq 18$
Gypsum fibreboards, two layers		$t_f = 3{,}7 \cdot h_p - 42$ (5.20)	$25 \leq h_p \leq 36$	$t_f = 1{,}3 \cdot h_p + 14$ (5.21)	$25 \leq h_p \leq 36$
where:					
h_p	is the is the thickness of the single panel or the total thickness of multiple panels of the same material, in mm				

(*) Type F directly exposed to fire.

Failure times



Database analysis by Kraudok (2020)

(7) For fire protection systems with horizontal orientation (e.g. floors) and exposed to fire from above, the values according to Table 5.6 for vertical application may be used.

(8) For linear timber members (e.g. beams and columns, see 7.2.2) the values according to Table 5.6 for the vertical orientation may be used and the values may be increased by 10 %.

(9) For timber frame assemblies with void cavities the values according to Table 5.6 may be increased by 10 %.

(10) The failure time t_f according to Table 5.6 may be increased by 10 % when the fire protection system is applied to plane timber members (see 7.2.3), which are vertically oriented (e.g. walls).

(11) The failure time t_f according to Table 5.6 may be increased by 20 % when the fire protection system is applied to plane timber members (see 7.2.3), which are horizontally oriented (e.g. ceilings).

Tabulated design data

Table 6.2 — Start time of charring t_{ch} and failure time of the fire protection systems $t_{f,pr}$ on horizontal timber frame assemblies or plane timber members exposed to fire from below

Panels	Thickness of the fire protection system h_p [mm] [a]		Layers backed by insulation [b]		Layers backed by panel	
	layer 1 h_1	layer 2 h_2	Start of charring t_{ch} [min]	Failure time $t_{f,pr}$ [min]	Start of charring t_{ch} [min	Failure time $t_{f,pr}$ [min]
Gypsum plasterboard Type A	12,5	-	17	17	20	20
	15	-	22	22	27	27
	18	-	29	29	34	34
	12,5	12,5	28	29	35	35
	15	15	36	39	45	45
	18	18	47	48	58	58
Gypsum plasterboard Type F	12,5	-	17	25	24	30
	15	-	22	28	30	34
	18	-	28	32	37	39
	12,5	12,5	39	52	49	63
	15	15	50	60	60	72
	18	18	63	69	75	83

Tabulated design data

Table 6.4 — Fire protection systems satisfying the required fire resistance of 60 minutes of the timber members (R, EI, REI)

Layer 1	Layer 2
Solid wood panel (SWP) with tongue and groove and $h_i \geq 53$ mm	not required
Solid wood panel (SWP) with tongue and groove and $h_i \geq 27$ mm	Solid wood panel (SWP) with tongue and groove and $h_i \geq 27$ mm [a]
Gypsum plasterboards Type F with filled or tight butt joint and $h_i \geq 18$ mm	Gypsum plasterboards Type F with filled or tight butt joint and $h_i \geq 18$ mm
Gypsum fibreboard (GF) with filled or tight butt joint and $h_i \geq 18$ mm	Gypsum fibreboard (GF) with filled or tight butt joint and $h_i \geq 18$ mm
Floor screed (cement, gypsum, anhydride) with $h_i \geq 60$ mm	not required
Floor screed (cement, gypsum, anhydride) with $h_i \geq 45$ mm	Mineral wool insulation with PL1 and $h_i \geq 15$ mm

h_i is the thickness of the layer *i*

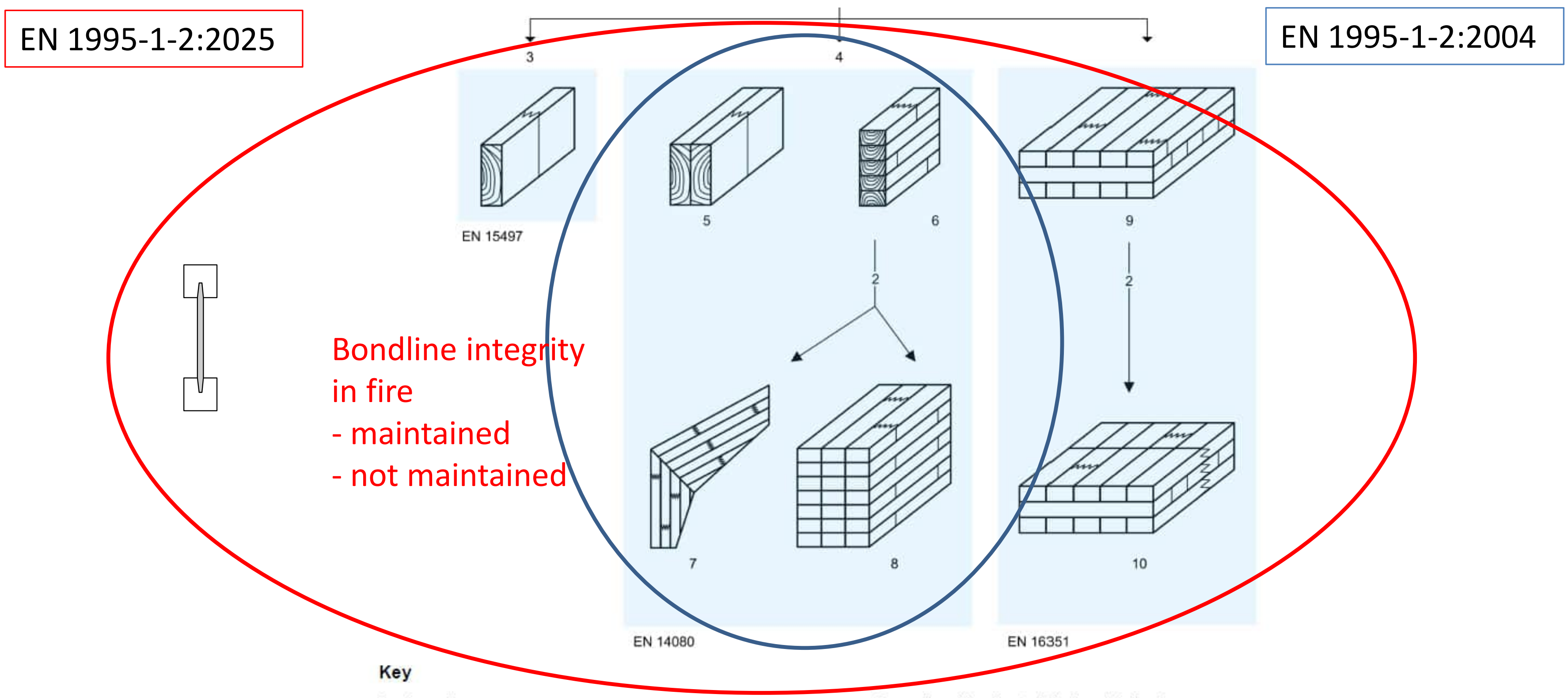
[a] The two layers mounted with the longitudinal direction perpendicular to each other.

Tabulated design data

Table 6.5 — Values of the depth of the effective cross-section h_{ef} in mm for initially unprotected floors made of CLT with bond line integrity maintained

# of layers	Layup [mm]	Total thickness [mm]	h_{ef} [mm]		
			30 min	60 min	90 min
3	20-20-20	60	18	9	-
3	40-40-40	120	94	38	38
5	20-20-20-20-20	100	58	49	18
5	40-20-20-20-40	140	114	78	70
5	40-20-40-20-40	160	134	98	90
5	40-30-40-30-40	180	154	108	108
5	40-40-40-40-40	200	174	118	118

Design models



Key

1 boards

2 is a component for

3 structural finger jointed timber

4 glued laminated products

5 glued solid timber

6 glued laminated timber (glulam)

7 glulam with large finger joints

8 block glued glulam

9 cross laminated timber (X-Lam)

10 cross laminated timber (X-Lam) with large finger joints

7.2.2 Design of linear members

det vil sige søjler og tryk

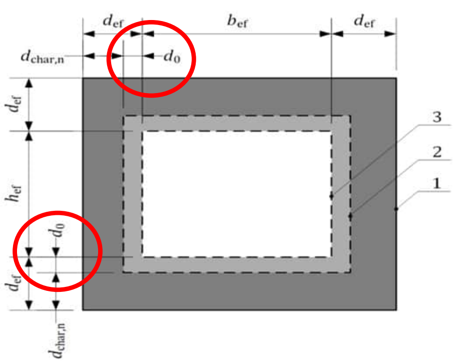
Zero-strength layer d_0

(8) <RCM> Unless other rules are given in this document, the value of zero-strength layer depth d_0 for the design of linear timber members should be:

$$d_0 = 14\,mm$$

(9) <PER> For linear timber members subjected predominantly to **bending or tension**, the value of zero-strength layer depth d_0 for all sides exposed to fire may be:

$$d_0 = 10\,mm$$



Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

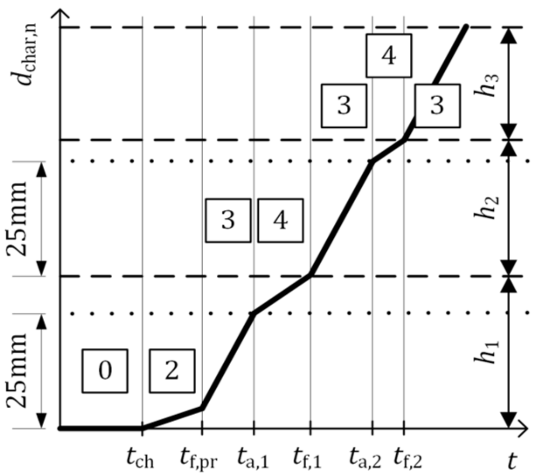
Reto Fahrni. PhD thesis ETH Zürich

EN 1995-1-2:2004

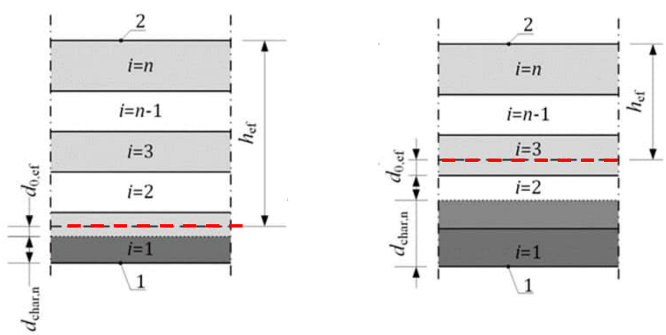
d_0=7 mm

7.2.3 Design of plane timber members made of cross-laminated timber

Initially **protected** timber member, bond line integrity **not** maintained



Zero-strength layer depth d_0



Fire exposed side and position of the char line	Floors	
	Initially unprotected	Initially protected
Tension side for first layer (i = 1)	7[a]	12[a]
Tension side for other layers	12[a b]	
Compression side for first layer (i = 1)	10[c]	16[c]
Compression side for other layers	16[c d]	

[a] When the calculated d_{ef} is within a layer in the y-direction, the final d_{ef} should be increased to reduce the following layer in the x-direction by minimum of 2 mm.

[b] When the calculated d_{ef} is within a layer in the x-direction, the final d_{ef} should be at least as large to reduce this layer by 2 mm.

[c] When the calculated d_{ef} is within a layer in the y-direction, the final d_{ef} should be increased to reduce the following layer in the x-direction by minimum of 4 mm.

[d] When the calculated d_{ef} is within a layer in the x-direction, the final d_{ef} should be at least as large to reduce this layer by 4 mm.

Horizontal

Phase 3 β_n = 2,0*0,65 = 1,3 mm/min

Phase 4 β_n = 0,65 mm/min

Vertical

Phase 3 First layer β_n = 2,0*0,65 = 1,3 mm/min

Other layers: β_n = 1,3*0,65 = 0,85 mm/min

Phase 4 β_n = 0,65 mm/min

EN 1995-1-2:2004

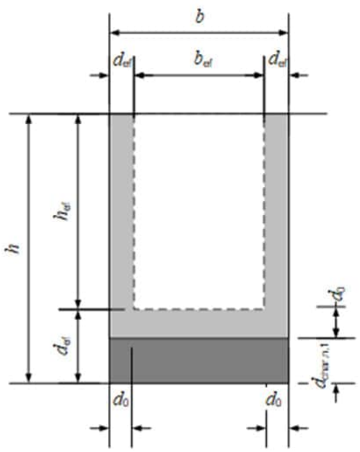
No rules

7.2.4 Design of timber frame assemblies

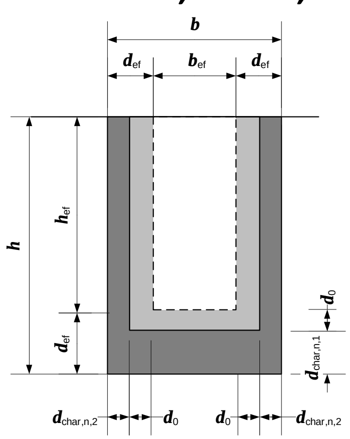
Meget konservativ antagelse for PL1, mere følger

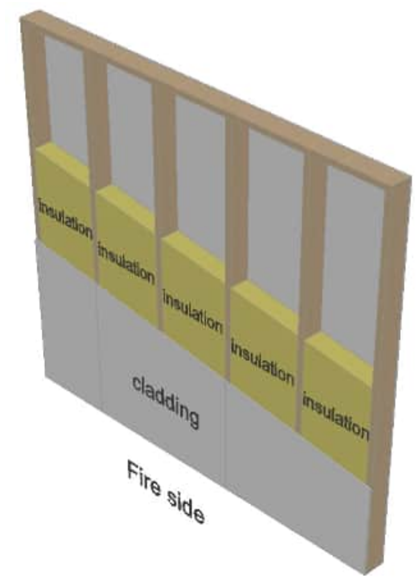
Protection level PL	Insulation material	Density
PL 1	Stone wool	≥ 26 kg/m³
PL 2	Glass wool	≥ 14 kg/m³
	Wood fibre	≥ 50 kg/m³
	Cellulose fibre	≥ 50 kg/m³
PL 3	XPS	-
	EPS	-
	PUR	-
	PIR	-
	Not assessed insulation materials	-

PL1



PL2, PL3, void





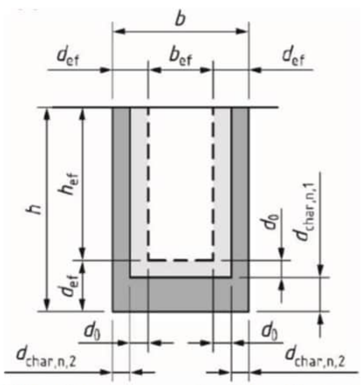
Mattia Tiso. The contribution of cavity insulations to the load-bearing capacity of timber frame assemblies exposed to fire. PhD thesis. Tallinn University of Technology. 2018

EN 1995-1-2:2004

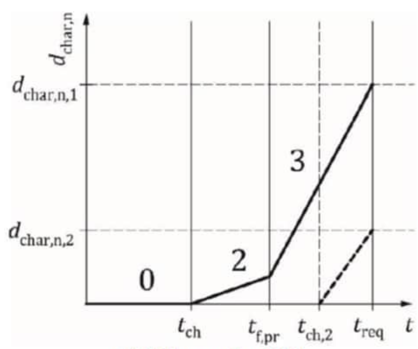
Reduced Properties Method
Stone wool, glass wool

7.2.4 Design of timber frame assemblies

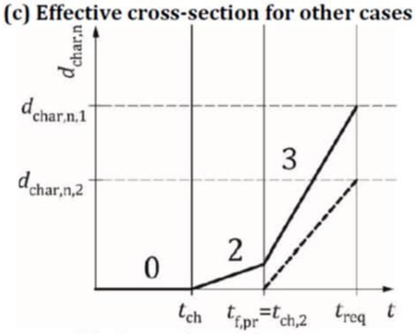
PL 2 and **PL 3**



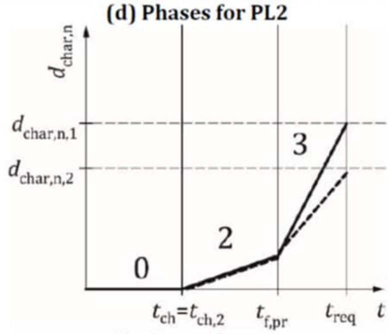
(c) Effective cross-section for other cases



(d) Phases for PL2



(e) Phases for void cavities



(f) Phases for PL3

$$d_{ef} = d_{char,n,1} + d_0 \qquad d_{char,n,1} = \sum_{Phases}(\beta_n \cdot t)$$

$$d_{ef} = d_{char,n,2} + d_0 \qquad d_{char,n,2} = \sum_{Phases}(\beta_n \cdot t)$$

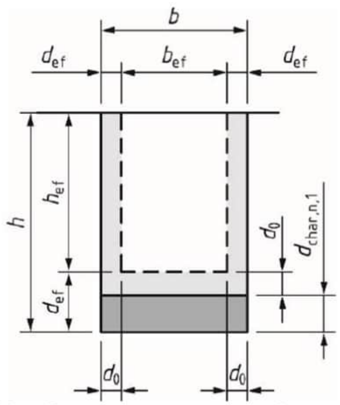
Phase 2	$\beta_n = k_2 \cdot k_{s,n,1} \cdot \beta_0$	
Phase 3	$\beta_n = k_{3,1} \cdot k_{s,n,1} \cdot \beta_0$	for the fire exposed side
Phase 3	$\beta_n = k_{3,2} \cdot k_{s,n,2} \cdot \beta_0$	for the lateral side
Phase 4	$\beta_n = k_{s,n,2} \cdot \beta_0$	for the lateral side

EN 1995-1-2:2004

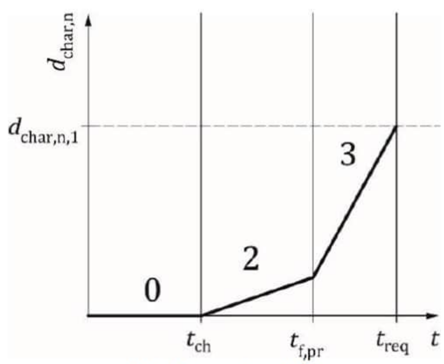
Only glass wool,
only until t_f

7.2.4 Design of timber frame assemblies

PL 1



(a) Effective cross-section for PL1



(b) Phases for PL1

Table 7.7 — Values of zero-strength layer depth d_0 in mm for timber members of timber frame assemblies with cavity insulation qualified as PL1

Verification case	Zero-strength layer depth d_0	
Bending member with the fire exposed side in tension:	$d_0 = 10 - \frac{b}{100} + \frac{h}{75}$	(7.40)
Bending member with the fire exposed side in compression	$d_0 = 9 - \frac{b}{100} + \frac{h}{25}$	(7.41)
Out-of-plane buckling of compression member	$d_0 = 3 - \frac{b}{10} + \frac{h}{20}$	(7.42)
In-plane buckling of compression member	$d_0 = 6 + \frac{b}{30} - \frac{h}{80}$	(7.43)

where

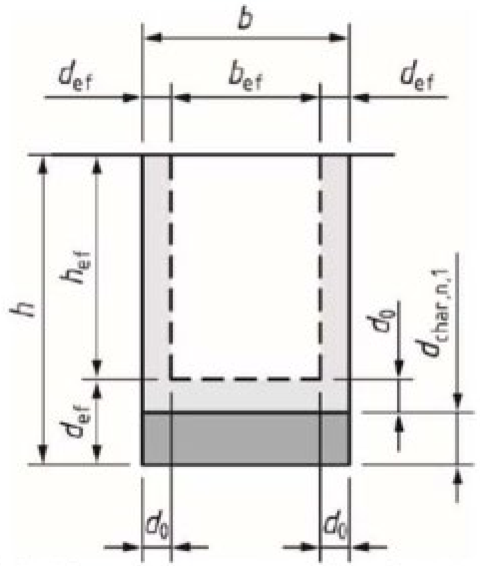
b is the width of the initial cross-section of the timber member, in mm;

h is the depth of the initial cross-section of the timber member, in mm.

7.2.4 Design of timber frame assemblies

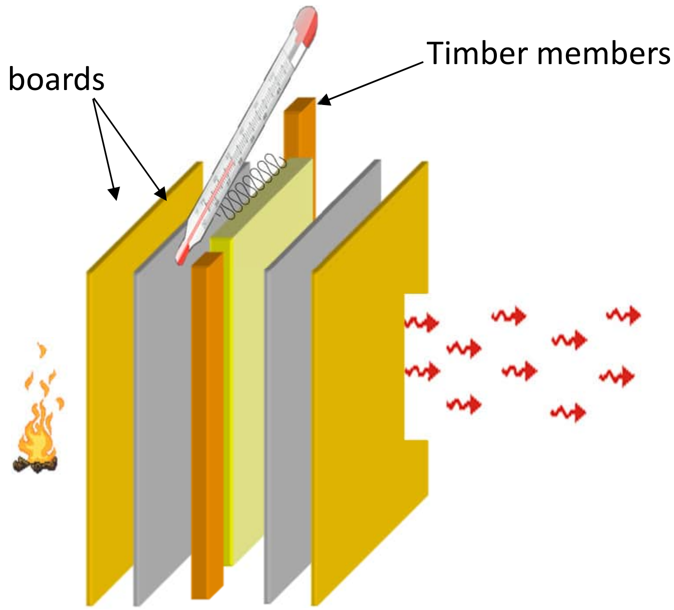
[7.40]	Typisk bjælkelag med brand nedefra								
[7.41]	Typisk vægge udsat for bade vandret og lodret last, f.eks. facader								
[7.42]	Søjler, der svigter i planet								
[7.43]	Søjler, der svigter ud af planet								
b	h	d_0 [7.40]	b_{ef} [7.40]	d_0 [7.41]	**b_{ef} [7.41]**	d_0 [7.42]	b_{ef} [7.42]	d_0 [7.43]	b_{ef} [7.43]
45	95	10,8	23,4	12,4	**20,3**	3,3	38,5	6,3	32,4
45	120	11,2	22,7	13,4	**18,3**	4,5	36,0	6,0	33,0
45	145	11,5	22,0	14,4	**16,3**	5,8	33,5	5,7	33,6
45	170	11,8	21,4	15,4	**14,3**	7,0	31,0	5,4	34,3
45	195	12,2	20,7	16,4	**12,3**	8,3	28,5	5,1	34,9
45	220	12,5	20,0	17,4	**10,3**	9,5	26,0	4,8	35,5
45	245	12,8	19,4	18,4	**8,3**	10,8	23,5	4,4	36,1
Hvorfor er d_0 afhængig af højden og hvorfor stiger zone med højden, som er stadigt længere fra branden									

PL 1

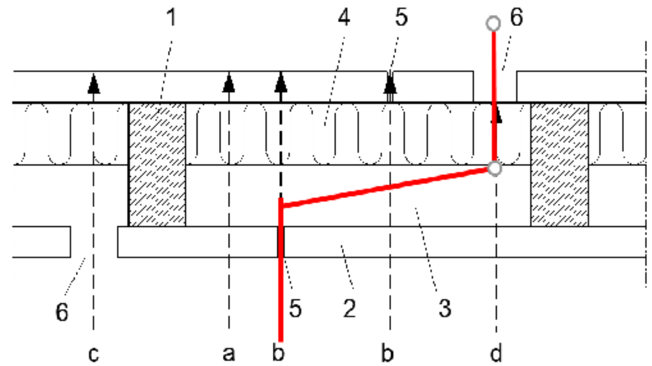


(a) Effective cross-section for PL1

7.3 Separating function method **Beregning af EI**



$$t_{ins} = \sum_{i=1}^{i=n-1} t_{prot,i} + t_{ins,n}$$



Schleifer, V (2009) Zum Verhalten von raumabschliessenden mehrschichtigen Holzbauteilen im Brandfall. Diss. ETH Zürich.
with improvements by K. Mäger (TalTech) and M. Rauch (TUM)

Materials included

Generic materials

- Gypsum plasterboards, Type A, F
- Gypsum fibreboards
- Wood-based boards
- Mineral wool

New materials

- Cellulose fibre insulation
- Wood fibre insulation
- Lime plaster
- Clay plaster
- Cement screed







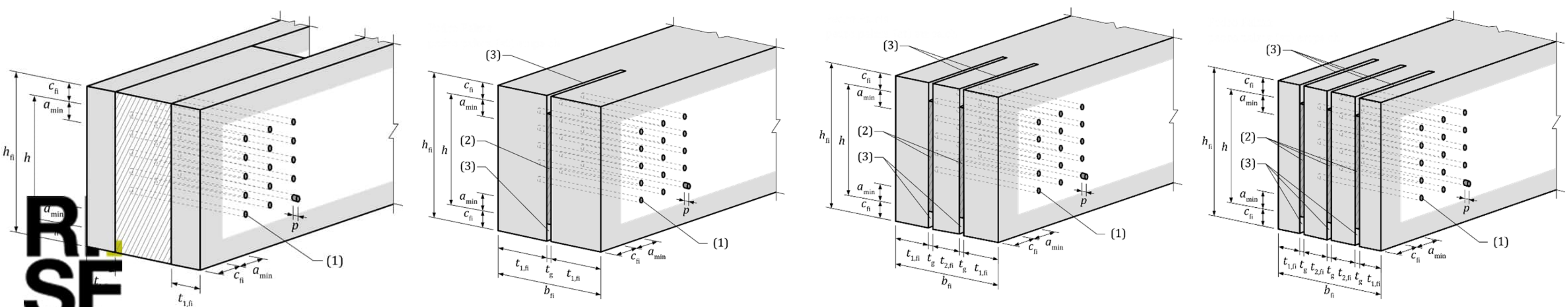

Bildquelle: dataholz.eu

9 Connections

Methods extended to fire resistance **up to 120 min**.

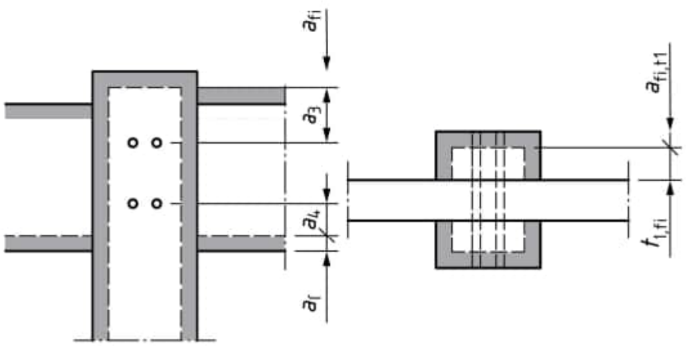
Connections with timber side members, kun symetriske forbindelser

- minimum fire resistance of initially unprotected timber-to-timber and steel-to-timber connections
- geometric requirements for a specific fire resistance up to 120 min

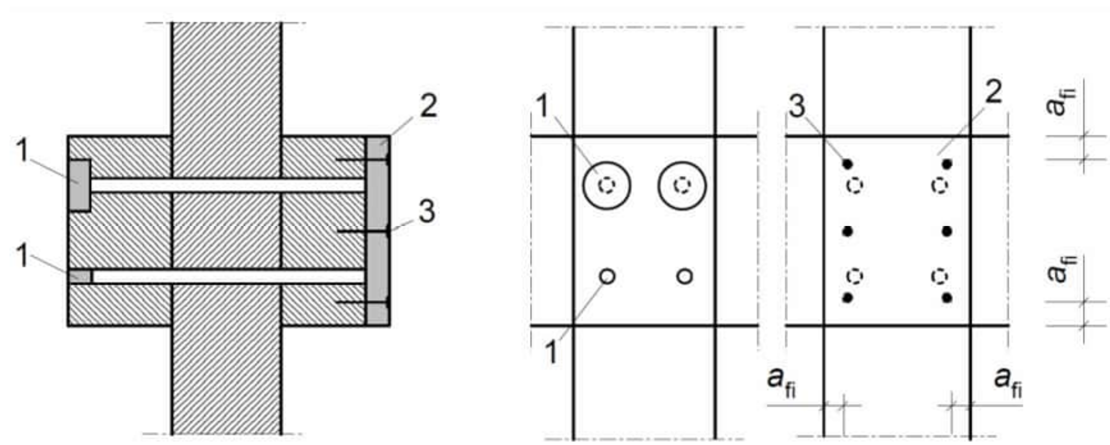


9 Connections

- Increased dimensions



- Protected connections



10 Detailing

Rules for

- dimensions and spacings
- fixing and connections of panels, gaps of joints
- fixing of cavity insulation
- joints in and between elements
- penetrations and openings

EN 1995-1-2:2004

Very few general rules (2 pages)
No rules for joints between the elements, penetrations

10.3 Insulation

(1) When the insulation is considered in the design according to 7, the premature failure (fall off) of the insulation shall be prevented.

(2) The premature failure of the insulation may be prevented using one of the following measures:

— the fire protection system;

— adequate mechanical means (with mechanical fasteners, steel net, resilient channels or timber battens);

— tight oversize fitting for walls using single layer insulation (batts, matts, boards or loose-fill cellulose and wood fibre cavity insulation).

(4) The insulation in horizontally orientated or inclined assemblies should be fixed by mechanical means or gluing (see examples in Figure 10.6).

Annexes (normative or informative)

Annex A Design of timber structures exposed to physically based design fires

Annex B Evaluation of the bond line integrity in fire

Annex C Determination of the basic design charring rate

Annex D Assessment of Protection Level (PL) of the cavity insulation

Annex E External flaming

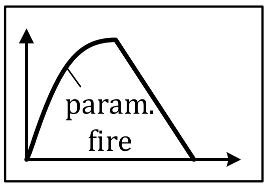
Annex F Assessment of the failure time of fire protection systems

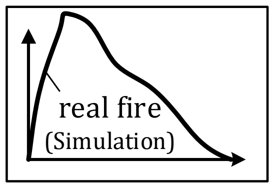
Annex G Implementation rules for Separating Function Method

Annex I Design model for timber frame assemblies with I-shaped timber member

Annex M Material properties

Physically based fire vs standard fire

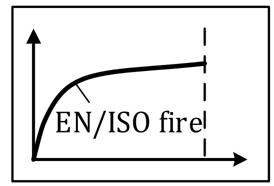




Fire Safety Engineering
(Physically based fire)

Eurocode 1 and 5

Structural fire load will be added to mobile fire load



Fire resistance calculation
(standard fire)

Eurocode 5 (EN 1995-1-2)

Annex A. Design of timber structures exposed to physically based design fires

$$q_{f,k} = q_{m,k} + q_{st,k}$$

- Structural fire load according to Annex H of EN 1991-1-2

- Design models apply to compartments comprising timber members fulfilling one of the following requirements:

— products which are encapsulated for the entire fire duration;

— initially unprotected structural timber products;

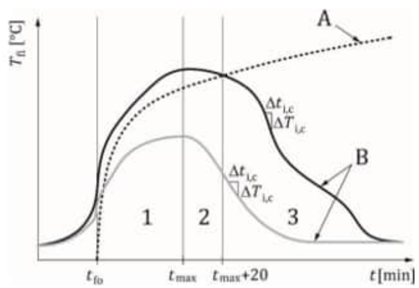
— initially unprotected timber products which maintain bond line integrity of face bonds in fire.

RI. SE

EN 1995-1-2:2004

No rules for actual use

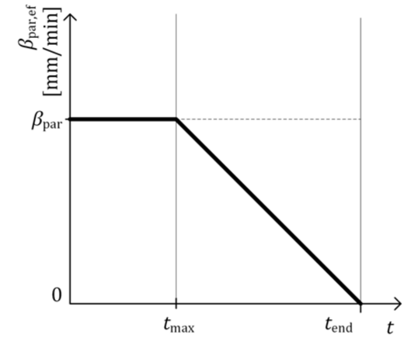
Annex A. Design of timber structures exposed to physically based design fires



Key

t_{fo}	time of flashover	2	intermediate phase
t_{max}	time of maximum compartment temperature	3	cooling phase
$\Delta t_{i,c}$	time difference in the cooling phase (evaluation step i)	A	standard fire
$\Delta T_{i,c}$	temperature difference in the cooling phase (evaluation step i)	B	physically based fire
1	heating phase		

$$d_{char,t} = \left(\frac{\int_0^t \quad (T^2)dt}{1{,}35 \cdot 10^5} \right)^{\frac{1}{1{,}6}}$$



Design model for general time-temperature curves

Design model for parametric temperature-time curves

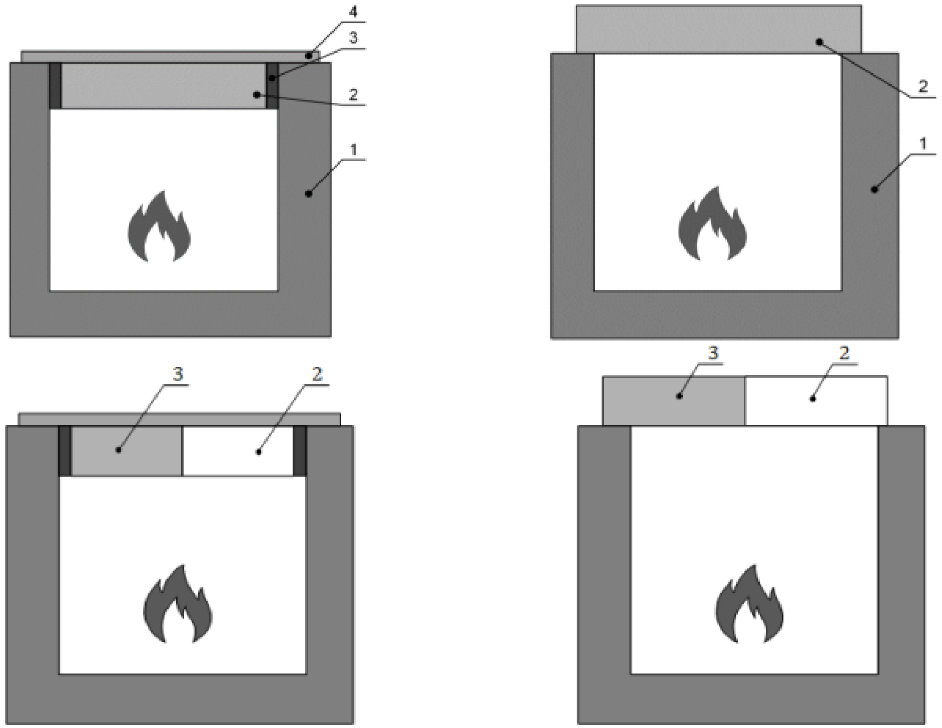
Annex B.3 Bond line integrity of face bonds

- Lille ovn ca. 50x50 cm, hvor emner brandpåvirkes nedefra.

- Problemstilling: Spændingstilstand kunne påvirke limens egenskab, f.eks. ved deformationer eller forskydningskræfter.
    - Metoden er ikke valideret i forhold til dette! Det vides derfor ikke om metoden er tilstrækkelig konservativ.

- EN1365-2 kunne blive brugt i stedet

-

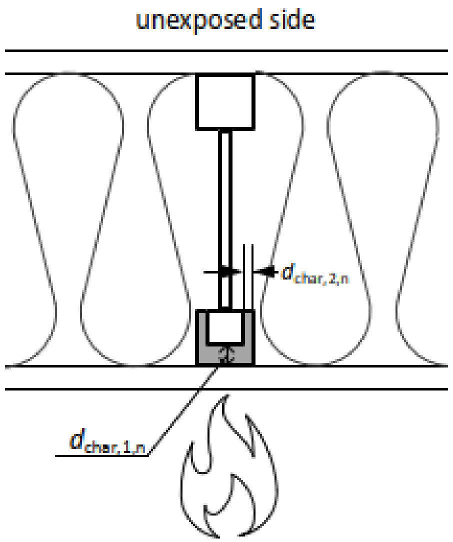


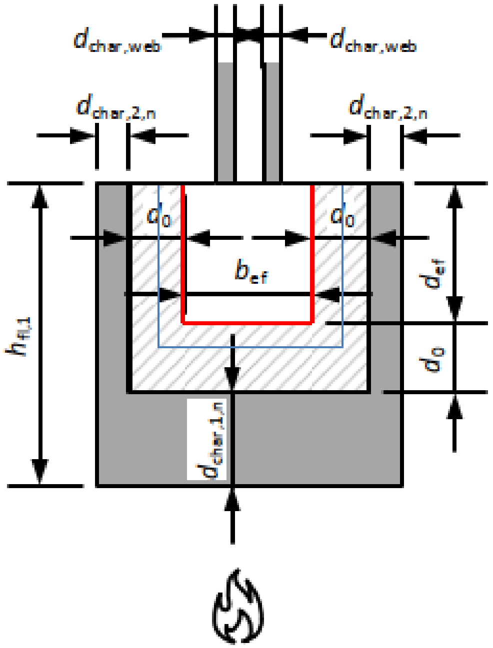
(a) (b)

Key:
1 Furnace;
2 Test specimen;
3 Reference specimen;
4 Fitting part (insulation);
5 Supporting frame.

Design of the I-shaped members

NB: Indbrænding ved krop?

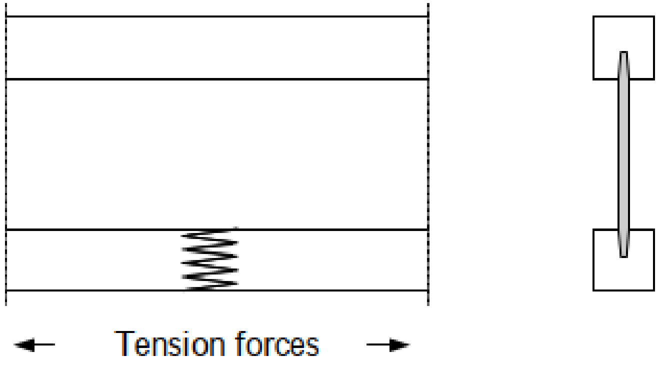




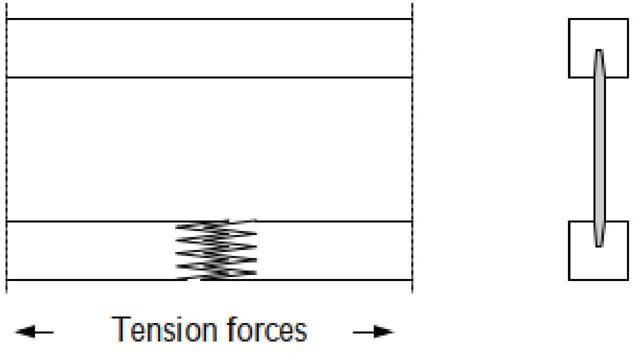
Walls

Floors

Bondline integrity maintained



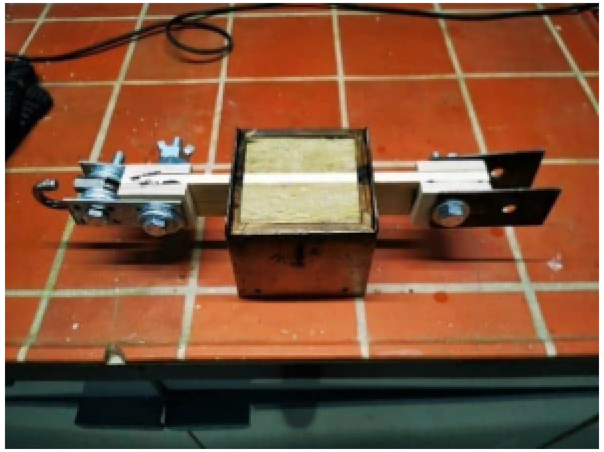
Bondline integrity not maintained

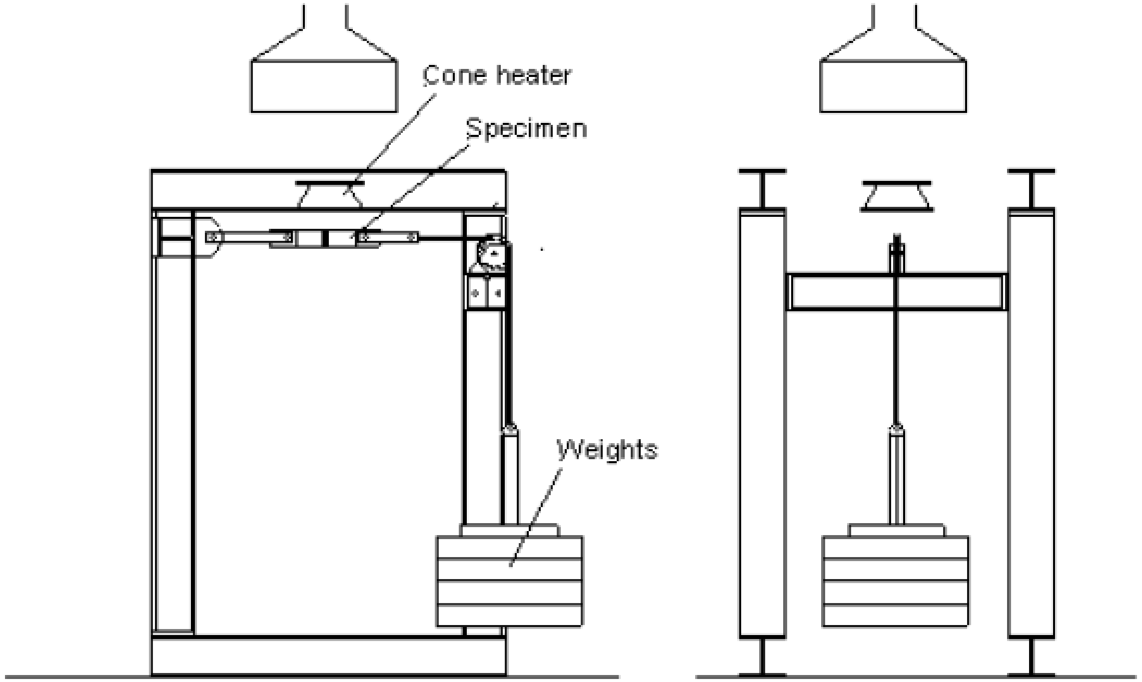


EN 1995-1-2:2004

No rules

Annex B.4. Finger joint classes

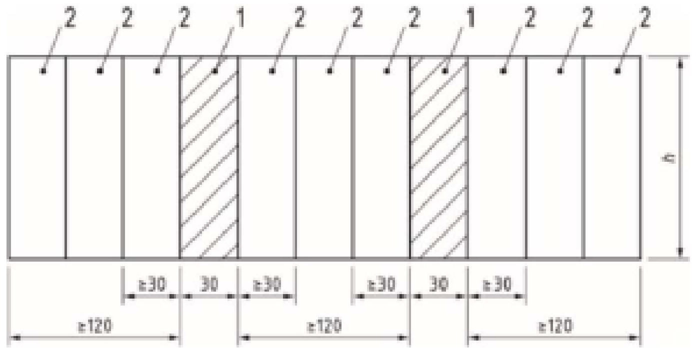


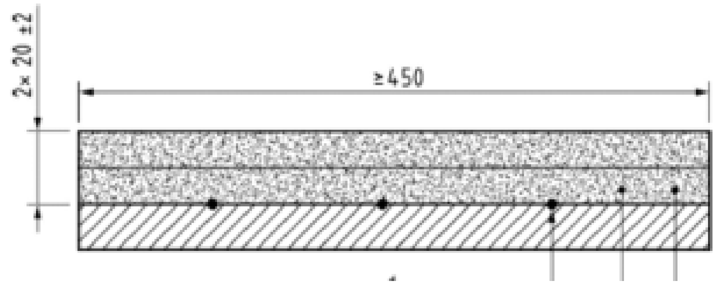


Denne test foregår mod kant, men det er lige så relevant at undersøge på flade, f.eks. i forhold til GL lameller.

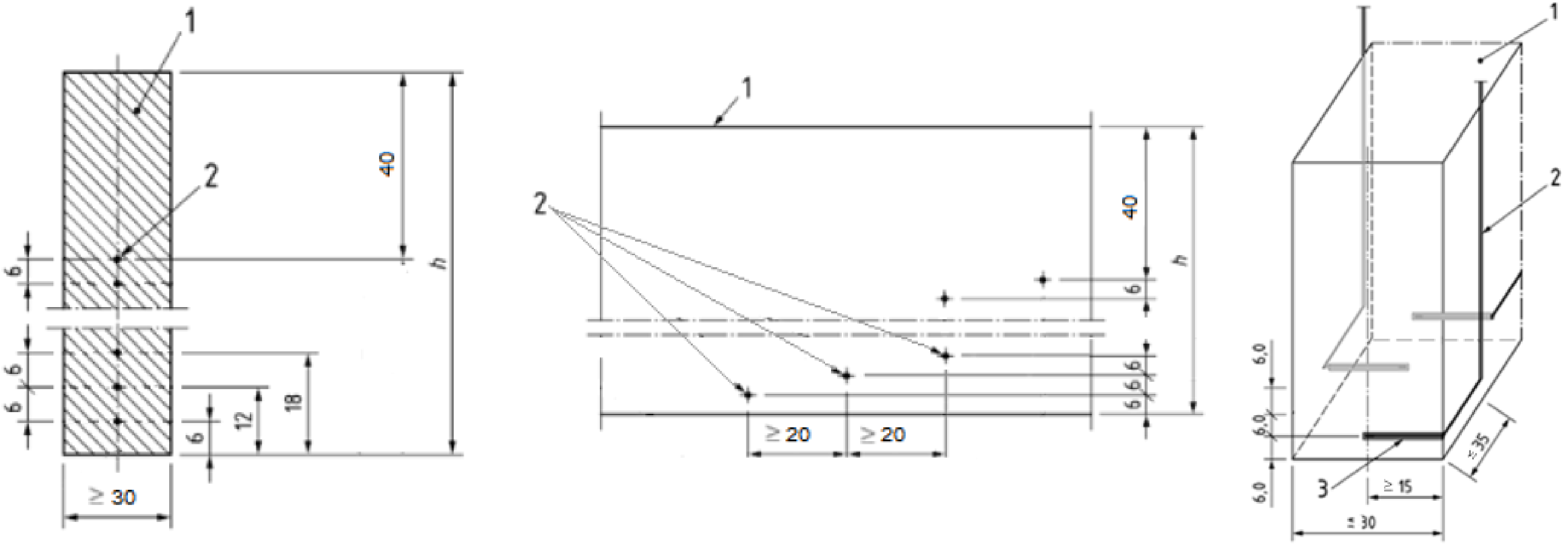
Annex C (normative) – Determination of the basic charring rate

- Other species
- Other products (not in Table 5.4)
- Different configuration for
  - Timber members
  - Wood-based boards





Annex C (normative) – Determination of the basic charring rate



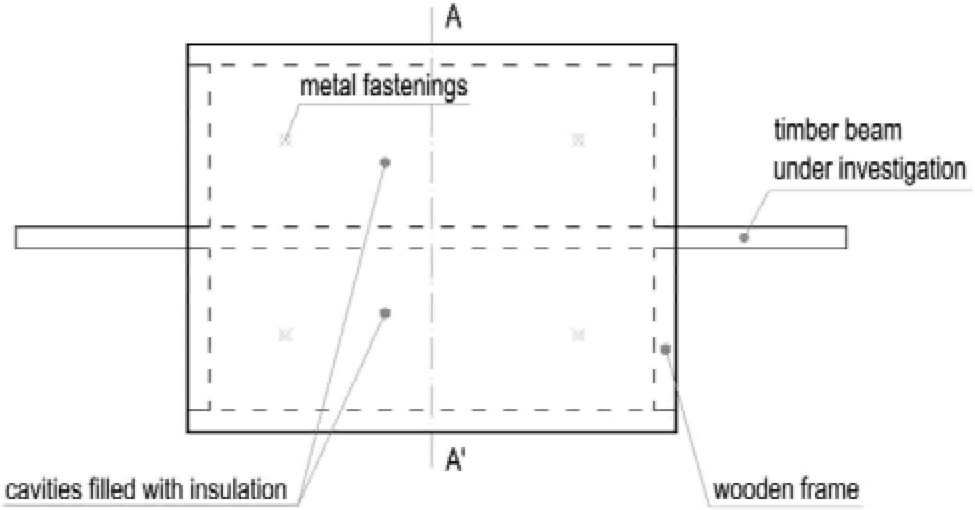
Key:

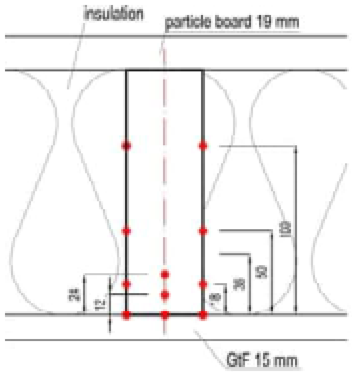
1 Instrumented timber beam
2 Internal thermocouples
3 Bore hole for thermocouple wire
h Cross-section height of the beam

units in mm

Testmetoden minder om test i EN 13381-7:2019. Hvorfor ikke henvise til denne. Mangler lidt realistisk beskrivelse af udførelse.

Annex D. Assessment of Protection Level (PL) of the cavity insulation

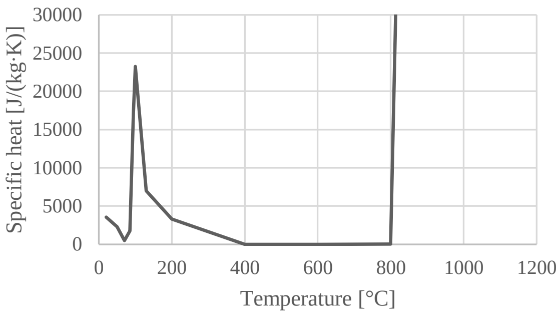


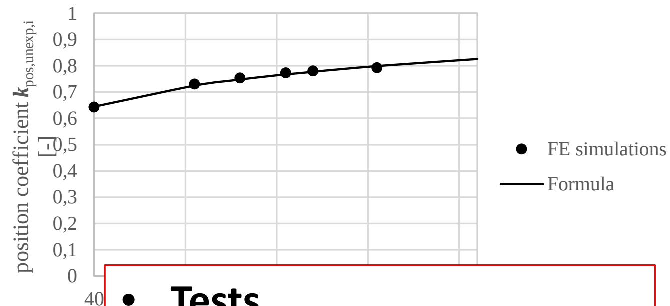


Mattia Tiso. The contribution of cavity insulations to the load-bearing capacity of timber frame assemblies exposed to fire. PhD thesis. Tallinn University of Technology. 2018

Test med beklædning skal køre 45 min med beklædning, hvorefter denne skal fjernes og test skal fortsætte: Testpersonaler har svært ved at se hvordan dette kan gøres arbejdsmiljømæssigt forsvarligt, hvis test ikke skal afbrydes.

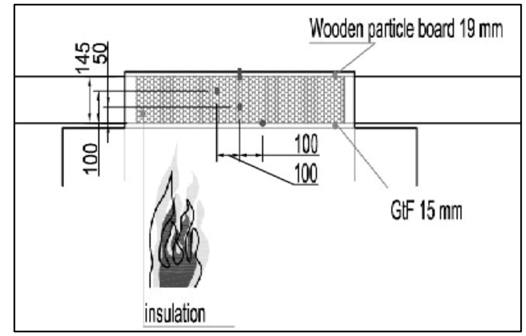
Annex G. Implementation of new materials

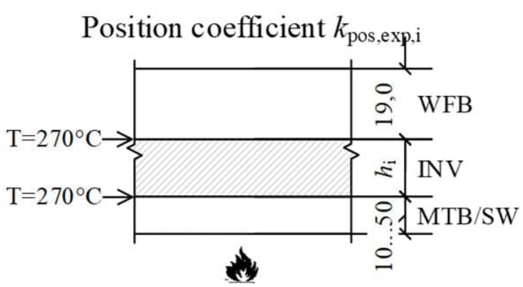




- **Tests**
- **Calibration of effective properties**
- **Simulations**
- **Equations**

$$t_{prot,0,i} = 2{,}3 + 0{,}14 \cdot h_i \ [\text{min}]$$





Mäger et al. Procedure for implementing new materials to the component additive method. Fire Safety Journal 107, 2019.

$$k_{pos,exp,i} = \begin{cases} 1 - 0{,}7 \cdot \dfrac{\sum t_{prot,p}}{t_{prot,0,i}}, & if \ \sum_{p=1}^{i-1} t_{prot,p} < 9 \\ \left(\dfrac{h_i}{1420} + 0{,}42\right) \cdot \left(\dfrac{t_{prot,0,i}}{\sum t_{prot,p}}\right)^{1{,}86-0{,}3\ln h_i}, & if \ \sum_{p=1}^{i-1} t_{prot,p} \geq 9 \end{cases}$$

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Konklusion
EN1995-1-2:2025 vs EN1995-1-2:2004

- Nu for design op til 120 min, men primært baseret på standardbrandforløb
- Indbrændingshastighed baseres på en-dimentional værdi β_0 og korrektionsfaktorer k_x
- Øget indbrændingshastighed og generelt større d_0 giver mindre resttværsnit, idet styrkeparametre er uændret
  Beregning efter EN1995-1-2:2025 vil derfor kræve større trædimensioner end efter EN1995-1-2:2004
- d_0 for sidetræ ved PL1 (stenuld) er meget konservativ - beregningsmetode bliver reelt uinteressant
- CLT er omfattet, men kun én limtype er præaccepteret i forhold til at undgå afskalning. For andre limtyper skal der fremlægges dokumentation iht. test anført i EN1995-1-2:2025.
- Regler for I-formede bjælker er indført
- Forbedrede regler for samlinger – nu også op til 120 min
- Regler for adskillende bygningsdele (EI) (og ikke kun bærende bygningsdele (R))
- Diverse testmetoder i annekser burde være selvstændige standarder