The new Eurocode 2-1-2: BS EN 1992-1-2:2023

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MA CEng FIStructE MICE

Eurocode 2-1-2

BS EN 1992-1-2:2004+A1:2019
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Eurocode 2: Design of concrete structures

Part 1-2: General rules - Structural fire design

bsi.

BS EN 1992-1-2:2023

Eurocode 2 — Design of concrete structures

Part 1-2: Structural fire design

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Eurocode 2: Part 1.2 Structural Fire Design

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94 Pages

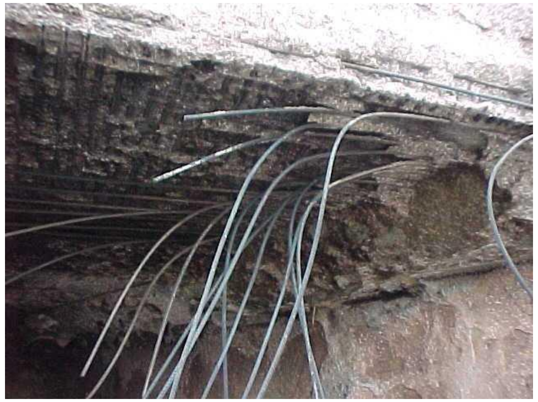
Basis of Fire Design

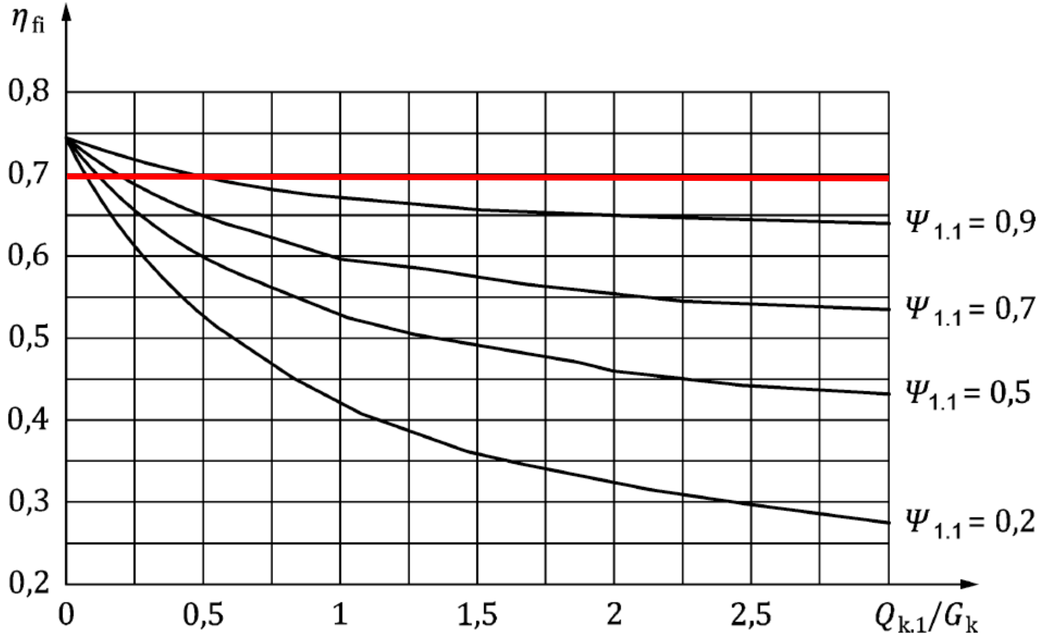
- Verification methods $E_{d,fi} \leq R_{d,fi,t}$ (4.2)
- Member Analysis $E_{d,fi} = \eta_{fi} E_d$ (1991-1-2)

  E_d is the design value for normal temperature design

  η_{fi} is the reduction factor for the fire situation

  $\eta_{fi} = (G_k + \psi_{fi} Q_{k.1})/(\gamma_G G_k + \gamma_{Q.1} Q_{k.1})$ ψ_{fi} is taken as $\boldsymbol{\psi_1}$ or $\boldsymbol{\psi_2}$ (= ψ_1 - NA)



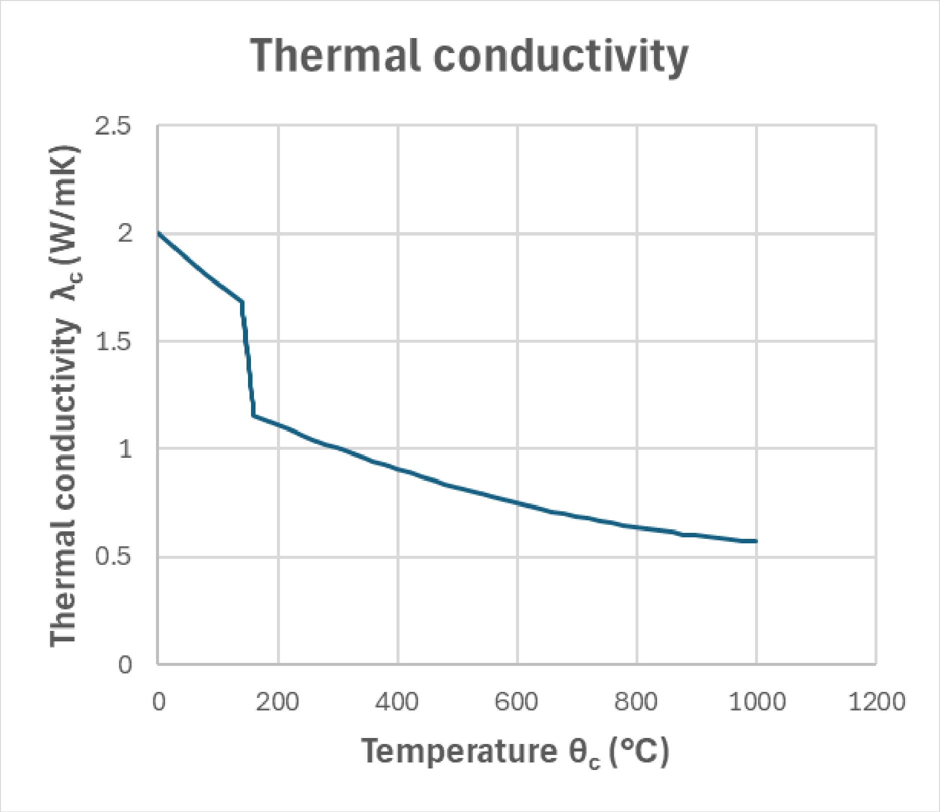


Design Procedures

- Tabulated data (Clause 6)
- Simplified calculation methods (Clause 7)
- Advanced calculation method (Clause 8)

Thermal conductivity

- Merged high and low curves for thermal conductivity



5.2.2 Thermal conductivity

(1) The thermal conductivity $\lambda_c(\theta_c)$ of concrete should be taken as:

$\lambda_c(\theta_c) = 2 - 0{,}2451\ (\theta_c/100) + 0{,}0107\ (\theta_c/100)^2$ (W/(m K)) for $\theta_c \leq 140$ °C

$\lambda_c(\theta_c) = -0{,}02604\ \theta_c + 5{,}324$ (W/(m K)) for $140 < \theta_c < 160$ °C

$\lambda_c(\theta_c) = 1{,}36 - 0{,}136\ (\theta_c/100) + 0{,}0057\ (\theta_c/100)^2$ (W/(m K)) for 160 °C $\leq \theta_c \leq$ 1 200 °C

Specific heat

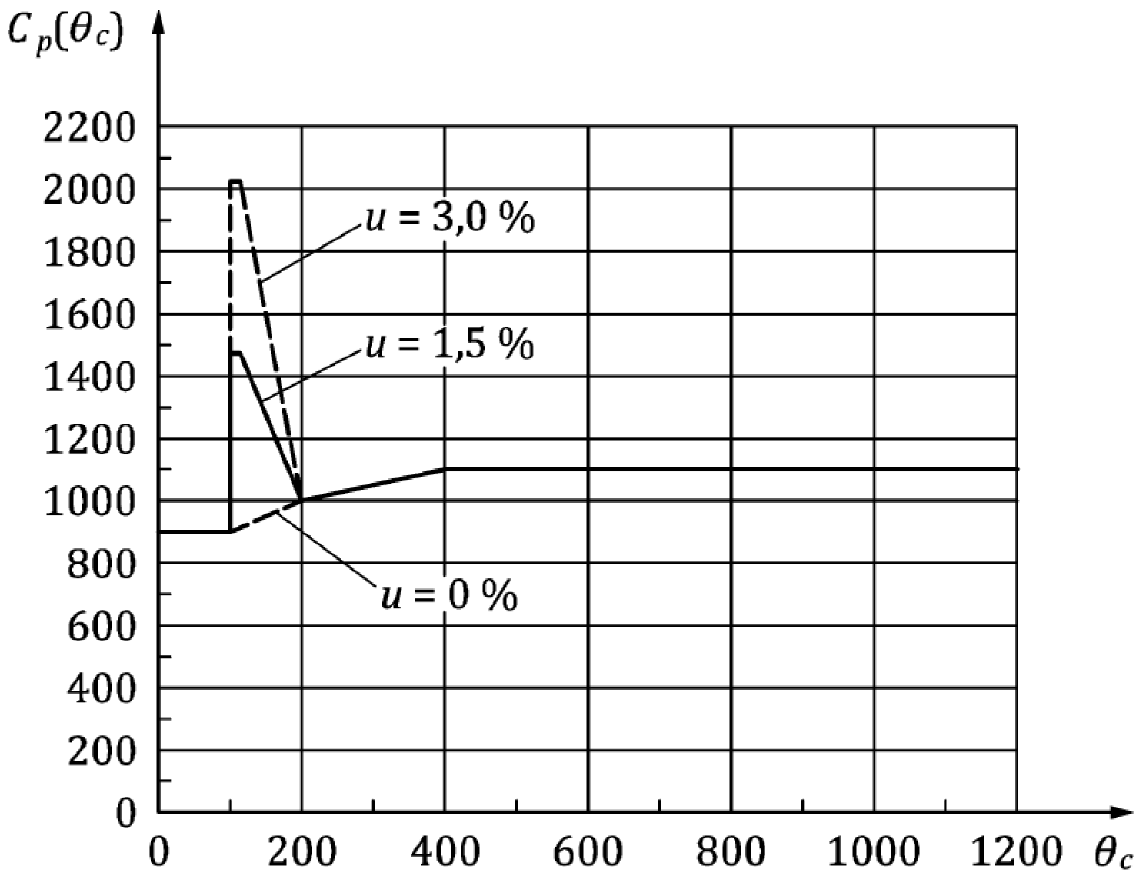


Table 5.1 — Values for the main parameters of the stress-strain relationships of normal weight concrete with siliceous or calcareous aggregates at elevated temperatures

Concrete temp. θ	$k_{c,\theta} = f_{c,\theta}/f_{ck}$			$\varepsilon_{c1,\theta}$	$\varepsilon_{cu1,\theta}$
	$f_{ck} < 70$ MPa		$f_{ck} \geq 70$ MPa		
	Siliceous aggregates	Calcareous aggregates	any type of aggregates		
[°C]	[–]	[–]	[–]	[–]	[–]
1	2	3	4	5	6
20	1,00	1,00	1,00	0,0025	0,0200
100	1,00	1,00	0,75	0,0040	0,0225
200	0,95	0,97	0,75	0,0055	0,0250
300	0,85	0,91	0,75	0,0070	0,0275
400	0,75	0,85	0,75	0,0100	0,0300
500	0,60	0,74	0,60	0,0150	0,0325
600	0,45	0,60	0,45	0,0250	0,0350
700	0,30	0,43	0,30	0,0250	0,0375
800	0,15	0,27	0,15	0,0250	0,0400
900	0,08	0,15	0,08	0,0250	0,0425
1 000	0,04	0,06	0,04	0,0250	0,0450
1 100	0,01	0,02	0,01	0,0250	0,0475
1 200	0,00	0,00	0,00	–	–

NOTE The values at 20°C are conventional values to be used for calculations in a fire situation. The softening branch is indicated for the purpose of numerical calculations.

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Cooling and cooled concrete

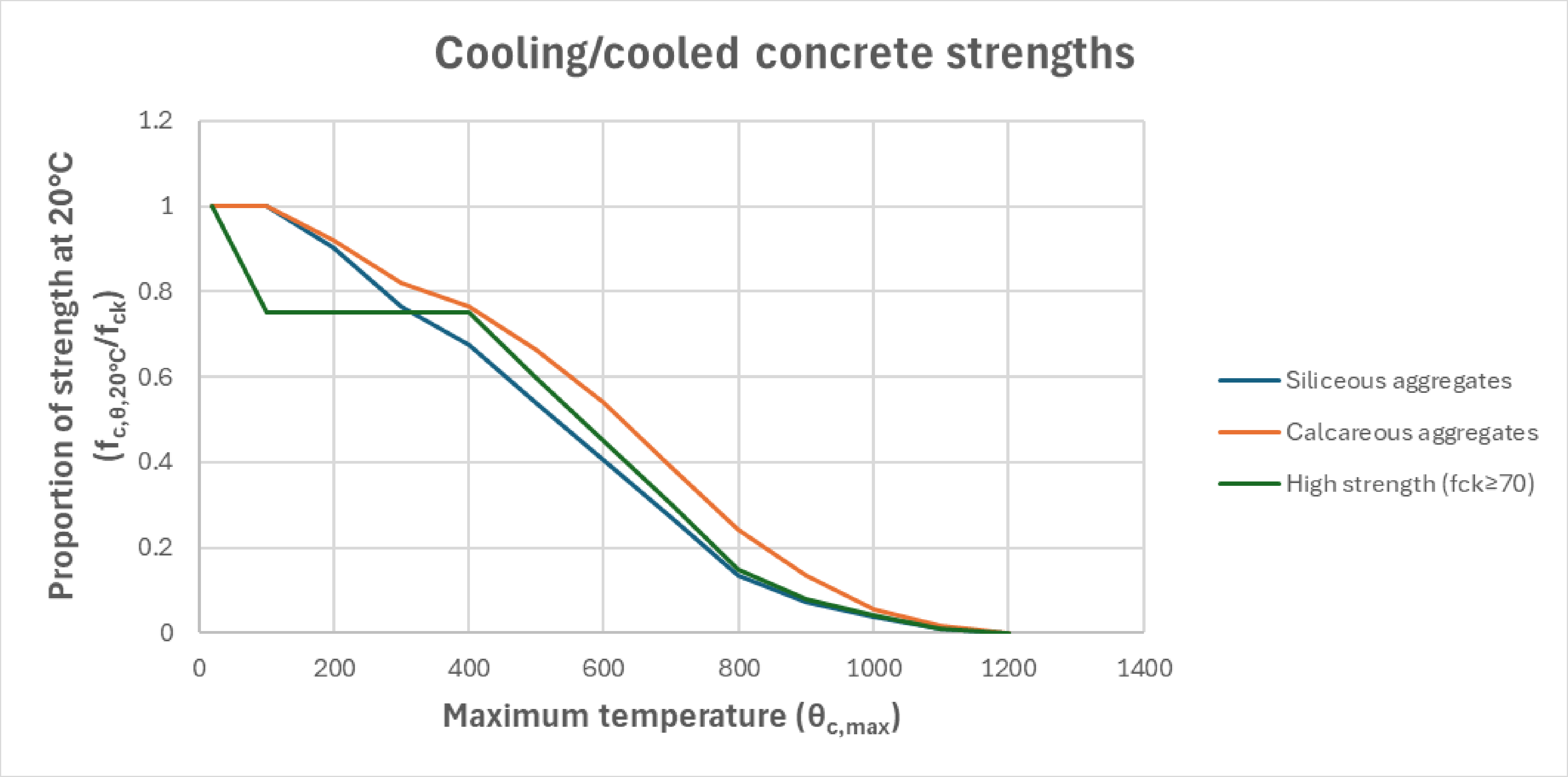


Table 5.3 — Values for the parameters of the stress-strain relationship of hot rolled and cold worked reinforcing steel at elevated temperatures

Steel temperature θ [°C]	$k_{sy,\theta} = f_{sy,\theta}/f_{yk}$		$k_{sp,\theta} = f_{sp,\theta}/f_{yk}$		$k_{se,\theta} = f_{se,\theta}/f_{yk}$	$k_{Es,\theta} = E_{s,\theta}/E_s$	
	hot rolled	cold worked	hot rolled	cold worked	hot rolled or cold worked	hot rolled	cold worked
1	2	3	4	5	6	7	8
20	1,00	1,00	1,00	1,00	1,00	1,00	1,00
100	1,00	1,00	1,00	0,96	1,00	1,00	1,00
200	1,00	1,00	0,81	0,92	0,95	0,90	0,87
300	1,00	1,00	0,61	0,81	0,90	0,80	0,72
400	1,00	0,94	0,42	0,63	0,85	0,70	0,56
500	0,78	0,67	0,36	0,44	0,60	0,60	0,40
600	0,47	0,40	0,18	0,26	0,35	0,31	0,24
700	0,23	0,12	0,07	0,08	0,10	0,13	0,08
800	0,11	0,11	0,05	0,06	0,08	0,09	0,06
900	0,06	0,08	0,04	0,05	0,06	0,07	0,05
1 000	0,04	0,05	0,02	0,03	0,04	0,04	0,03
1 100	0,02	0,03	0,01	0,02	0,02	0,02	0,02
1 200	0,00	0,00	0,00	0,00	0,00	0,00	0,00

Section 6. Tabulated Data

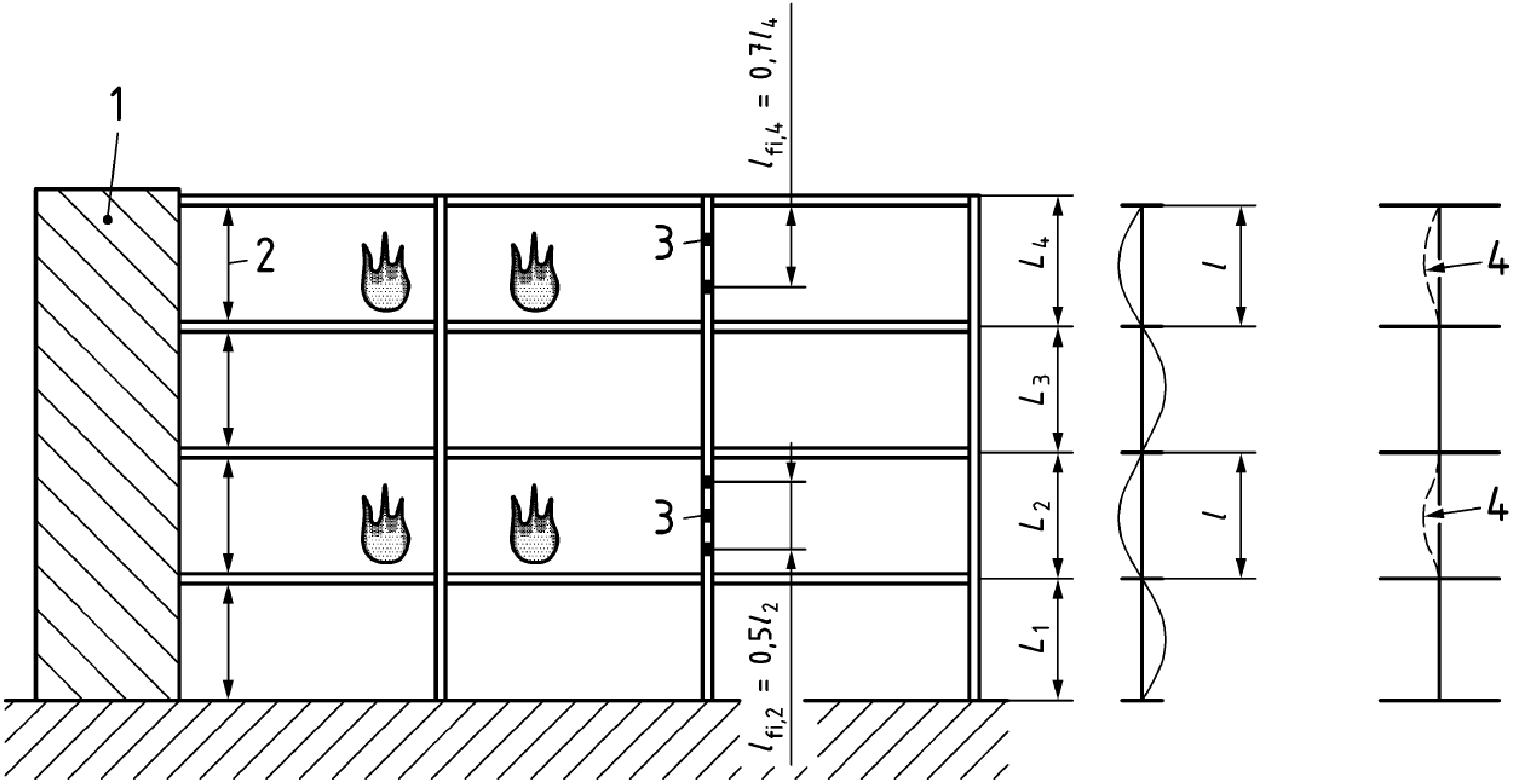
Provides design solutions for the standard fire exposure up to 4 hours

- The tables have been developed on an empirical basis confirmed by experience and theoretical evaluation of tests
- Values are given for normal weight concrete made with siliceous aggregates. Minimum dimensions can be reduced by 10% if using calcareous aggregates.
- Tabulated data shouldn't be used for R 180 and R240 if $f_{ck} \geq 70MPa$
- No further checks are required for shear, torsion or anchorage
- Linear interpolation may be used, extrapolation shouldn't be used.

Columns Tabular Approach

- Two approaches
- Method A is only for braced structures
- Annex D covers both braced and unbraced columns by considering slenderness

Effective length



Columns: Method A

Standard fire resistance	Minimum dimensions (mm) Column width b_{min}/axis distance a of the main reinforcement		
	$\mu_{fi} = 0,2$	$\mu_{fi} = 0,5$	$\mu_{fi} = 0,7$
1	2	3	4
R 30	200/25	200/25	200/32 300/27
R 60	200/25	200/36 300/31	250/46 350/40
R 90	200/31 300/25	300/45 400/38	350/53 450/40[a]
R 120	250/40 350/35	350/45[a] 450/40[a]	350/57[a] 450/51[a]
R 180	350/45[a]	350/63[a]	450/70[a]
R 240	350/61[a]	450/75[a]	-

NOTE 1 For prestressed columns, the increase of axis distance according to 6.2(2) should be noted.
NOTE 2 Table 6.1 has been generated from Formula (6.6) with $l_{0,fi}$ = 3 m.
NOTE 3 Table 6.1 can be used for columns exposed on two parallel sides

[a] Minimum 8 bars

$\mu_{fi} = N_{Ed,fi} / N_{Rd}$

$N_{Ed,fi}$ is the design axial load in the fire condition

N_{Rd} is the design axial resistance at normal temperature for an effective length = $2l_{0,fi}$

Limitations to Method A

- The structure is braced
- Effective length of the column under fire conditions

  $l_{0,fi} \leq 3$m and $l_0 \leq 6$m (rectangular sections)

  $l_{0,fi} \leq 2.5$m and $l_0 \leq 5$m (circular sections)
- First order eccentricity under fire conditions:

  $M_{0Ed,fi} / N_{Ed,fi} \leq 0.25\, h$
- Amount of reinforcement:

  $A_s \leq 0.04\, A_c$

Method B - Annex D

Table D.4 — Maximum permissible effective column length l_0 for braced and unbraced columns: R 90

$l_{0,fi} = 1{,}0\ l_0$		$0{,}1 \le \omega_{mod} \le 1{,}0$																	
	b (mm):	≥ 600			500			400			350			300			250		
	μ_{FI}:	0,3	0,5	0,7	0,3	0,5	0,7	0,3	0,5	0,7	0,3	0,5	0,7	0,3	0,5	0,7	0,3	0,4	0,5
e_0	a (mm)	$l_{0,max}$ (m)			$l_{0,max}$ (m)			$l_{0,max}$ (m)			$l_{0,max}$ (m)			$l_{0,max}$ (m)			$l_{0,max}$ (m)		
20 mm	30	8,9	6,6	3,1	6,9	5,1		4,8	2,8		3,7	1,9		2,3					
20 mm	40	9,2	7,8	5,4	7,2	6,0	3,5	5,1	4,2		4,0	3,2		2,8					
20 mm	55	10,4	8,8	7,3	8,2	6,8	5,5	5,9	4,7	3,5	4,6	3,7	2,5	3,4	2,6		2,2		
20 mm	70	12,0	9,7	8,3	9,2	7,5	6,2	6,5	5,2	3,9	5,1	4,0	2,8	3,6	2,7		2,2		
0,25 b	30	5,4	4,0		4,2	2,9		2,9			2,1								
0,25 b	40	7,1	5,0	3,1	5,5	3,9		3,8	2,5		3,0	1,8		1,6					
0,25 b	55	11,4	7,1	5,4	8,5	5,3	3,9	5,7	3,6	2,0	4,4	2,7		2,8					
0,25 b	70	24,0	8,8	6,6	20,0	6,6	4,8	8,1	4,3	2,5	6,0	3,1		3,4	2,0				
0,50 b	30																		
0,50 b	40	7,4			5,6			3,6			2,2								
0,50 b	55	21,5	8,0		15,9	5,8		10,4	3,1		7,9			4,0					
0,50 b	70	24,0	12,5	5,4	20,0	9,5		16,0	5,7		14,0	3,7		6,2					

$l_{0,fi} = 0{,}7\ l_0$		$0{,}1 \le \omega_{mod} \le 1{,}0$																	
	b (mm):	≥ 600			500			400			350			300			250		
	μ_{FI}:	0,3	0,5	0,7	0,3	0,5	0,7	0,3	0,5	0,7	0,3	0,5	0,7	0,3	0,5	0,7	0,3	0,4	0,5
e_0	a (mm)	$l_{0,max}$ (m)			$l_{0,max}$ (m)			$l_{0,max}$ (m)			$l_{0,max}$ (m)			$l_{0,max}$ (m)			$l_{0,max}$ (m)		
20 mm	30	12,9	10,4	5,2	10,1	7,8		7,1	4,3		5,5	3,0		3,5			2,2		
20 mm	40	13,6	11,9	8,9	10,5	9,1	6,0	7,4	6,3		5,9	5,1		4,1	1,9		2,8	2,2	
20 mm	55	17,3	13,9	11,9	14,0	10,7	9,1	9,6	7,4	5,9	7,6	5,8	4,3	5,1	4,0	2,0	3,4	3,0	2,4
20 mm	70	24,0	16,6	14,1	20,0	12,6	10,5	11,5	8,4	6,8	8,9	6,5	4,9	5,7	4,3	2,6	3,6	3,1	2,5
0,25 b	30	8,4	5,7		6,4	4,1		4,3	2,5		3,2								
0,25 b	40	13,1	7,9	5,7	9,9	6,0		6,4	3,8		4,9	2,7		2,4					
0,25 b	55	24,0	17,3	9,4	20,0	12,4	6,8	16,0	6,8	4,0	14,0	4,6	2,5	6,8	2,5		3,0	1,9	
0,25 b	70	24,0	24,0	17,3	20,0	20,0	11,3	16,0	16,0	5,4	14,0	14,0	3,6	12,0	3,3		4,6	2,4	
0,50 b	30																		
0,50 b	40	18,6			13,4			8,4			5,9								
0,50 b	55	24,0	24,0		20,0	20,0		16,0	10,7		14,0	6,4		12,0			6,9		
0,50 b	70	24,0	24,0	24,0	20,0	20,0		16,0	16,0		14,0	14,0		12,0			10,0		

Parameters required for Annex D

b, h	Dimensions of column cross-section, $b \leq h$;
μ_{fi}	Degree of utilization in the fire situation: $\mu_{fi} = \frac{\lvert N_{Ed,fi} \rvert}{N_{Rd}}$;
e_0	First order eccentricity of the axial forces, equal for N_{Rd} and $N_{Ed,fi}$;
a	Axis distance of the main reinforcing steel bars;
ω_{mod}	Modified mechanical reinforcement degree $\omega_{mod} = \frac{2\min(A_{s0}, A_{s1}) f_{yd}}{A_c f_{cd}}$, while A_{s0} and A_{s1} are defined in (5);
$N_{Ed,fi}$	The design axial load in the fire condition;
N_{Rd}	The design axial load resistance under ambient condition.

Worked example

300 x 300 column, C30/37 concrete, storey height of 3.5m at top of building with 4H12 bars as main rebar. Check that this is suitable for an R90 requirement.

- Take $\mu_{fi} = 0.3$, $e_0 = 75$mm, a = 45mm
- Calculate ω: 4H12 = 452mm^2
- $\omega = A_s f_{yd} / A_c f_{cd} = (452*435)/(300^2*17) = 0.13$
- Take $l_{0,fi} = 0.7\ l$
- From table

Annex D

Table D.4 — Maximum permissible effective column length l_0 for braced and unbraced columns: R 90

		$l_{0,fi} = 1,0\ l_0$			$0,1 \le \omega_{mod} \le 1,0$														
	b (mm):	≥ 600			500			400			350			300			250		
	μ_{FI}:	0,3	0,5	0,7	0,3	0,5	0,7	0,3	0,5	0,7	0,3	0,5	0,7	0,3	0,5	0,7	0,3	0,4	0,5
e_0	a (mm)	$l_{0,max}$ (m)			$l_{0,max}$ (m)			$l_{0,max}$ (m)			$l_{0,max}$ (m)			$l_{0,max}$ (m)			$l_{0,max}$ (m)		
20 mm	30	8,9	6,6	3,1	6,9	5,1		4,8	2,8		3,7	1,9		2,3					
20 mm	40	9,2	7,8	5,4	7,2	6,0	3,5	5,1	4,2		4,0	3,2		2,8					
20 mm	55	10,4	8,8	7,3	8,2	6,8	5,5	5,9	4,7	3,5	4,6	3,7	2,5	3,4	2,6		2,2		
20 mm	70	12,0	9,7	8,3	9,2	7,5	6,2	6,5	5,2	3,9	5,1	4,0	2,8	3,6	2,7		2,2		
0,25 b	30	5,4	4,0		4,2	2,9		2,9			2,1								
0,25 b	40	7,1	5,0	3,1	5,5	3,9		3,8	2,5		3,0	1,8		1,6					
0,25 b	55	11,4	7,1	5,4	8,5	5,3	3,9	5,7	3,6	2,0	4,4	2,7		2,8					
0,25 b	70	24,0	8,8	6,6	20,0	6,6	4,8	8,1	4,3	2,5	6,0	3,1		3,4	2,0				
0,50 b	30																		
0,50 b	40	7,4			5,6			3,6			2,2								
0,50 b	55	21,5	8,0		15,9	5,8		10,4	3,1		7,9			4,0					
0,50 b	70	24,0	12,5	5,4	20,0	9,5		16,0	5,7		14,0	3,7		6,2					

		$l_{0,fi} = 0,7\ l_0$			$0,1 \le \omega_{mod} \le 1,0$														
	b (mm):	≥ 600			500			400			350			300			250		
	μ_{FI}:	0,3	0,5	0,7	0,3	0,5	0,7	0,3	0,5	0,7	0,3	0,5	0,7	0,3	0,5	0,7	0,3	0,4	0,5
e_0	a (mm)	$l_{0,max}$ (m)			$l_{0,max}$ (m)			$l_{0,max}$ (m)			$l_{0,max}$ (m)			$l_{0,max}$ (m)			$l_{0,max}$ (m)		
20 mm	30	12,9	10,4	5,2	10,1	7,8		7,1	4,3		5,5	3,0		3,5			2,2		
20 mm	40	13,6	11,9	8,9	10,5	9,1	6,0	7,4	6,3		5,9	5,1		4,1	1,9		2,8	2,2	
20 mm	55	17,3	13,9	11,9	14,0	10,7	9,1	9,6	7,4	5,9	7,6	5,8	4,3	5,1	4,0	2,0	3,4	3,0	2,4
20 mm	70	24,0	16,6	14,1	20,0	12,6	10,5	11,5	8,4	6,8	8,9	6,5	4,9	5,7	4,3	2,6	3,6	3,1	2,5
0,25 b	30	8,4	5,7		6,4	4,1		4,3	2,5		3,2								
0,25 b	40	13,1	7,9	5,7	9,9	6,0		6,4	3,8		4,9	2,7		2,4					
0,25 b	55	24,0	17,3	9,4	20,0	12,4	6,8	16,0	6,8	4,0	14,0	4,6	2,5	6,8	2,5		3,0	1,9	
0,25 b	70	24,0	24,0	17,3	20,0	20,0	11,3	16,0	16,0	5,4	14,0	14,0	3,6	12,0	3,3		4,6	2,4	
0,50 b	30																		
0,50 b	40	18,6			13,4			8,4			5,9								
0,50 b	55	24,0	24,0		20,0	20,0		16,0	10,7		14,0	6,4		12,0			6,9		
0,50 b	70	24,0	24,0	24,0	20,0	20,0		16,0	16,0		14,0	14,0		12,0			10,0		

Max effective length = 3.9m

Actual effective length - 0.7*3.5 = 2.45m

Walls

Standard fire resistance	Minimum dimensions (mm) Wall thickness h_w/axis distance a			Standard fire resistance	Minimum dimensions (mm) Wall thickness h_w/axis distance a		
	$\mu_{fi} = 0,2$	$\mu_{fi} = 0,5$	$\mu_{fi} = 0,7$		$\mu_{fi} = 0,2$	$\mu_{fi} = 0,5$	$\mu_{fi} = 0,7$
Exposed on one side				Exposed on both sides			
1	2	3	4	5	6	7	8
REI 30	100/10	110/10	120/10	R 30	100/10	120/10	130/10
REI 60	110/10	120/15	130/20	R 60	120/15	155/20	170/25
REI 90	120/20	135/25	140/30	R 90	140/20	185/30	210/35
REI 120	135/25	150/30	160/35	R 120	165/30	210/40	240/45
REI 180	155/35	170/40	180/45	R 180	200/45	250/50	280/55
REI 240	180/40	200/45	210/50	R 240	250/50	305/55	340/60

Walls

- Four tables given, two in the main part and two in Annex E
- Effective lengths of 2.5m, 4.5m, 6m and 8m
- Assume that $l_{0,fi}/l_0$ = 0.5 otherwise calculate N_{Rd} for an effective length of $2l_{0,fi}$
- Structure is braced
- First order eccentricity doesn’t exceed 25% b
- Clear height to thickness ≤ 40
- The exposure of the wall ends does not affect the fire resistance for walls exposed on both sides, provided the minimum axis distance is met.
- Interpolation between the tables is allowed

Continuous Beams

- Table 6.7

Standard fire resistance	Minimum dimensions (mm)					
	Possible combinations of a and b_{min} where a is the average axis distance and b_{min} is the width of beam				Web thickness $b_{w,min}$	Web thickness $b_{w,min}$ for a length of $2h$ from an intermediate support
1	2	3	4	5	6	7
R 30	b_{min} = 80	160	—	—	80	80
	a = 15[a]	12[a]	—	—	—	—
R 60	b_{min} = 120	200	—	—	100	120
	a = 25	12[a]	—	—	—	—
R 90	b_{min} = 150	250	—	—	110	150
	a = 35	25	—	—	—	—
R 120	b_{min} = 200	300	450	500	120	200
	a = 45	35	35	30	—	—
R 180	b_{min} = 240	400	550	600	140	240
	a = 60	50	50	40	—	—
R 240	b_{min} = 280	500	650	700	160	280
	a = 75	60	55	50	—	—

NOTE 1 For tensile and simply supported members subject to bending (except those with unbonded tendons), in which the critical temperature is different from 500 °C, see 6.2(3) for modifications to tabulated values.

NOTE 2 For a_{sd}, see 6.6.2(2)

[a] Normally the cover required by EN 1992-1-1 will be larger.

Flat Slabs

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Standard fire resistance	Minimum dimensions (mm)	
	slab-thickness *h*	axis-distance *a*
1	**2**	**3**
REI 30	150	10[a]
REI 60	180	15[a]
REI 90	200	25
REI 120	200	35
REI 180	200	45
REI 240	200	50

NOTE For tensile and simply supported members subject to bending (except those with unbonded tendons), in which the critical temperature is different from 500 °C, see 6.2(3).

[a] Normally the cover required by EN 1992-1-1 will be larger.

Chapter 7: simplified design methods

The simplified formulae are based on the following assumptions:

- The emissivity related to the concrete surface is 0.7 .
- The thermal conductivity of concrete is as given;
- The specific heat of concrete assumes a moisture content of 1.5 %, (the formulae are conservative for moisture contents greater than 1.5 %);
- The density of concrete at 20 °C is 2300 kg/m^3;
- The convection factor is 25 W/(m^2·K).

General formula for one-sided exposure

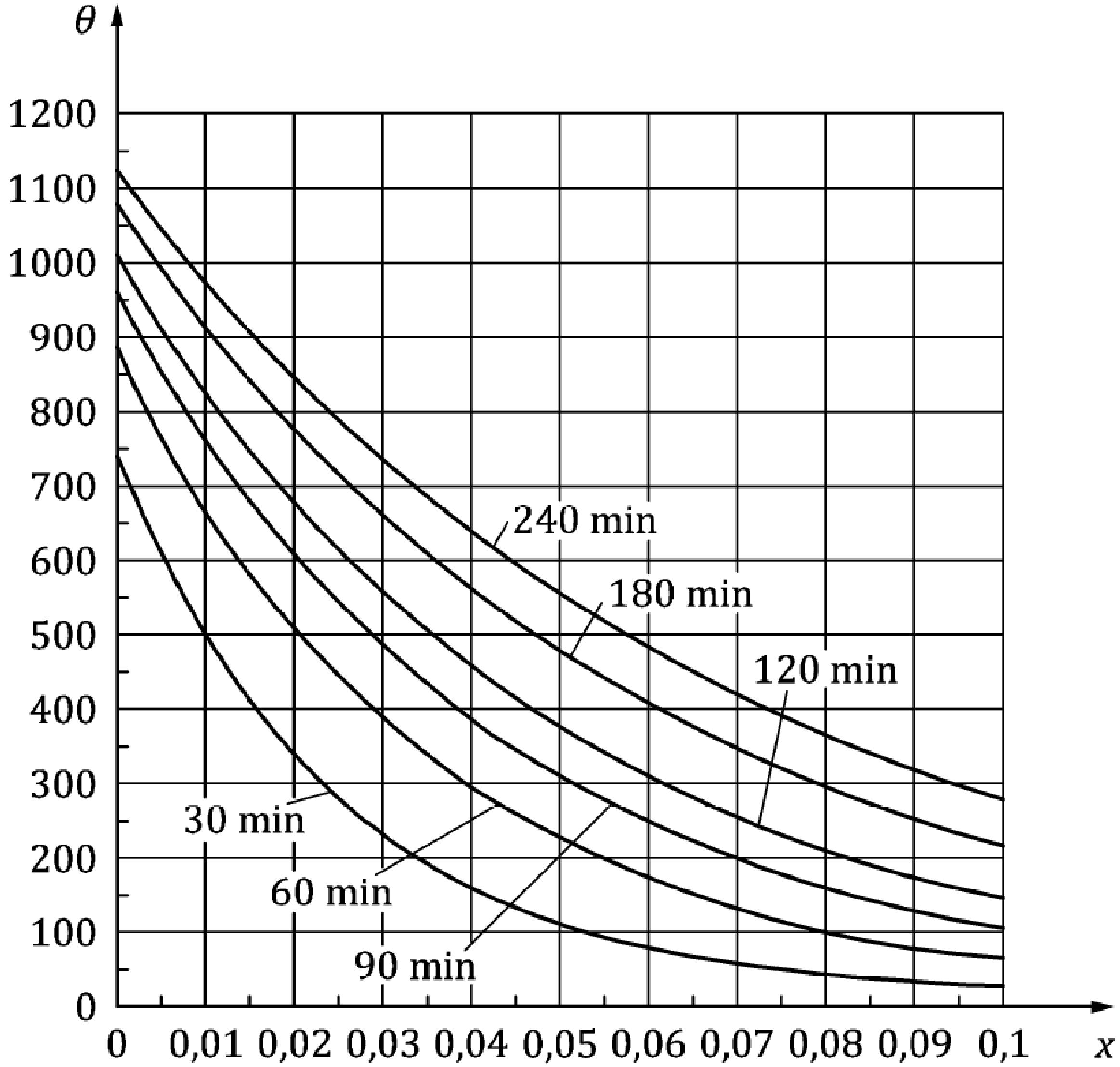
$$\theta(x,t) = \theta_1(x,t) + 20[°C]$$

$$\theta_1(x,t) = 345 \cdot \lg_{10}\left(\frac{7(t-\Delta t)}{60} + 1\right) \cdot \exp\left(-x\sqrt{\frac{k}{t}}\right) \qquad (7.2)$$

t	is the duration of the standard fire (in seconds), $t \geq 1\,800$ s;
x	is the distance from the exposed surface (in m);
$\Delta t = 720$ s	represents a delay between the temperature in the fire compartment and the concrete surface temperature as an approximation for the effects of convection and radiation;

$$k = 3 \cdot 10^6 \text{ s/m}^2 \qquad (7.3)$$

Temperature profile



Spalling

Table 10.1 — Overview of the rules for spalling

Verification for spalling	
R15	Verification of spalling may be omitted except Clause 10(2)
— structures in a water saturated environment — insulating permanent formwork which prevents concrete from drying	Specific assessment of spalling should be undertaken or polypropylene fibres should be specified See Clause 10(7), (8), (9) or (10)
$f_{ck} < 70$ MPa and silica fume content < 6 % by weight of cement	Verification of spalling may be omitted except Clause 10(3) and (5)
$f_{ck} < 70$ MPa and silica fume content ≥ 6 % by weight of cement or $f_{ck} \geq 70$ MPa	Specific assessment of spalling should be undertaken or polypropylene fibres should be specified See Clause 10(7), (8), (9) or (10)

Spalling clauses

- 10(7) Protective layers can be used
- 10(8) Spalling can be taken into account by considering the loss of strength due to a reduced cross-section. The extent of spalling can be based on experimental assessment
- 10(9) If an experimental assessment is undertaken it should be based on representative conditions (geometry, stress and moisture content)
- 10(10) Polypropylene fibres (2kg/m^3) can be used to mitigate spalling
- For lightweight concrete a specific assessment of spalling should be done whatever the strength of the concrete.

Recycled aggregates

- In Annex C, which is informative
- NA committee currently considering whether to adopt
- If 20% recycled aggregate or less are used then the typical properties can be assumed, otherwise properties should be based on experimental evidence.
- Specific assessment of spalling should be undertaken, or polypropylene fibres added

Thank you