

Job title: **Ramsetreid PIR ChemSet Reo502 EF Plus, Epcon C6 EF Plus, Epcon G5 PRO
Fire Analysis**

Report code: **259-2021-R01**

Report title: **Fire Evaluation of Post-installed rebar connections with Ramsetreid ChemSet
Reo502 EF Plus, Epcon C6 EF Plus, Epcon G5 PRO injection systems**

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1 INTRODUCTION

Ramsetreid has manufactured the injection systems ChemSet Reo502 EF Plus, Epcon C6 EF Plus, Epcon G5 PRO holding the ETA number ETA 20/0752 for post-installed rebar (reinforcing bar) connections with mortar.

The scope of this expert report is the evaluation of the fire resistance according to a procedure agreed with the manufacturer, which is responsible for the declared performances.

Under no circumstances this report can be assumed as equivalent to a Product Specification or to a Design Report. The conformity of the suggested approach to each specific design situation shall be verified by the designer, under their sole responsibility.

2 REFERENCES

- [1] ETA 20/0752, European Technical Assessment for Ramsetreid ChemSet Reo502 EF Plus, Epcon C6 EF Plus, Epcon G5 PRO, issued by ZÜS Technical and Test Institute for Construction Prague, in 11/10/2020
- [2] EN 1991-1-1 Eurocode 1: Actions on structures – Part1-1: General actions – Densities, self-weight, imposed loads for buildings, approved by CEN on 30 November 2001
- [3] EN 1991-1-2 Eurocode 1: Actions on structures – Part1-2: General actions – Actions on structures exposed to fire, approved by CEN on 1 September 2002
- [4] EN 1992-1-1 Eurocode 2: Design of concrete structures – Part1-1: General rules and rules for buildings, approved by CEN on 16 April 2004
- [5] EN 1992-1-2 Eurocode 2: Design of concrete structures – Part1-2: General rules – Structural fire design, approved by CEN on 8 July 2004
- [6] ISO 834-1:1999 Fire-resistance tests – Elements of building construction – Part 1: General requirements, International Organisation for Standardisation, 2016

3 DESCRIPTION OF THE INJECTION SYSTEMS FOR POST-INSTALLED REBAR CONNECTIONS

A detailed description of the injection systems for post-installed rebar connections, their installation procedure, factory production control and manufacturing processes are in the documents provided by the manufacturer, and they are reported in [1].

4 METHODOLOGY

4.1 Bond Strength vs. Increasing Temperature

To evaluate the fire resistance of post-installed rebar connections, the first step is to determine the modification in the bond strength of the injection system utilised for the post-installed rebar connection with increasing temperature. This modification due to increasing temperature is characterized by temperature reduction factor $0 < k(\theta) < 1$. This step has already been performed for ChemSet Reo502 EF Plus, Epcon C6 EF Plus, Epcon G5 PRO injection systems by the manufacturer, and the details are given in Chapter 0 of this document.

4.2 Temperature analysis

Introduction

The next step to evaluate the fire resistance of post-installed rebar connections is to evaluate the temperature distribution along the post-installed rebar in the structure under fire exposure for given structural connection cases and fire scenario. For this purpose, thermal analysis is performed according to the method described in EN 1991-1-2 Section 3 on the two cases previously agreed with the manufacturer and the temperature distribution along the structure is obtained.

Structural Connection Cases

The two structural connection cases for post-installed rebars are determined as follows:

- Case 1: **Overlap joint in slab-slab connection**
 - The lower surface of the slab is exposed to fire.
 - The temperature distribution along the bonded-in bars positioned parallel to the lower surface of the slab at a given concrete distance is uniform. Therefore, the bond strength is constant along the post-installed rebars.
- Case 2: **End anchoring of beams in beam-wall connection**
 - The wall surface at the connection side, and the side surfaces and lower surface of the beam are exposed to fire.
 - The temperature distribution along the bonded-in bars inside the wall is not uniform. Therefore, the bond strength varies along the post-installed rebars.
 - The fire resistance is evaluated by integration of the bond strength along the length of the rebar.

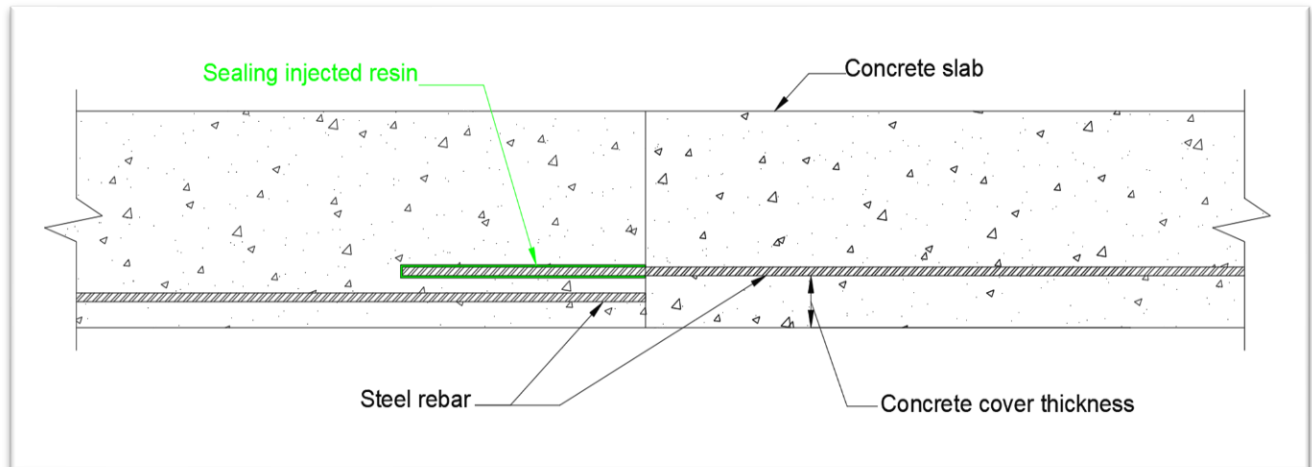


Figure 4.1 Overlap joint in slab-slab connection

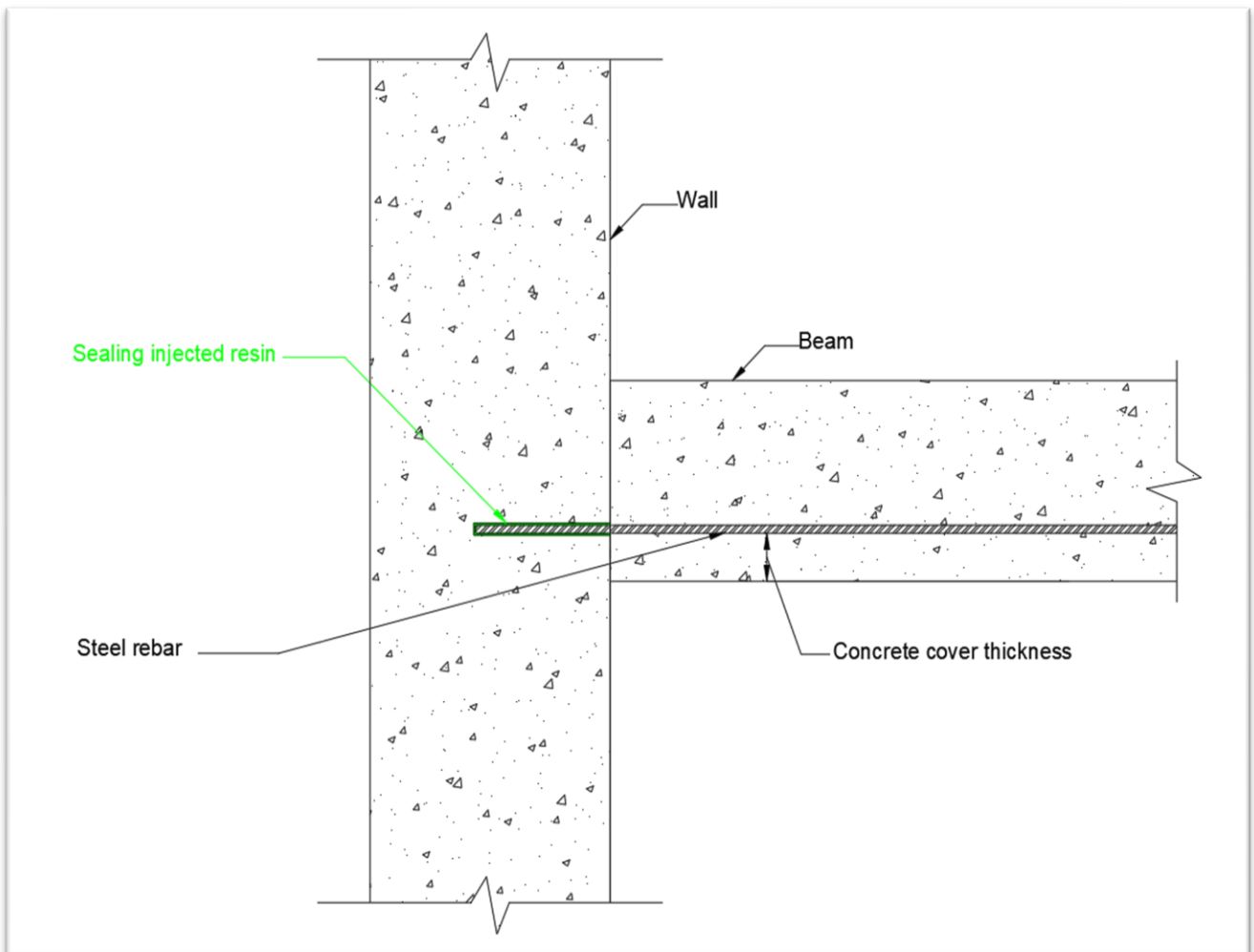


Figure 4.2 Anchoring of beam in beam-wall connection

Software Overview

The simulations of fire exposed structures and the thermal analyses of the previously mentioned cases are performed on VOLTRA, a software which is validated according to the 2D test reference case provided in EN 1992-1-2:2004, Annex A, and is licensed to Siggma by its developer company Physibel.

VOLTRA is a thermal analysis program for transient heat transfer in 3-D rectangular objects covering time-dependent boundary conditions, which are described with functions. VOLTRA is used to simulate fire exposed structures with use of the RADCON module, also licensed to Siggma by Physibel, which allows to include the simulation of non-linear radiation based on geometric view factors. The thermal conductivity, λ , and specific heat, c , of materials are allowed to be defined as temperature dependent. VOLTRA performs the fire simulation and evaluates the temperature distribution throughout the structure. The results are available in both graphic output and text output, the latter can be drawn in software like Microsoft Excel as tables. The output nodes defined by the user are points to which reference is made in a report text output to show the course of temperatures in those points as a function of time.

General analysis parameters

The parameters that are common for each structural connection case are as defined:

Time-temperature curve

For each fire simulation, the standard time-temperature curve given in ISO 834-1, §6.1.1 and [3], §3.2.1 was used to simulate fire exposure. This fire curve is characterised by the Equation 4.1 and graphed in Figure 4.3.

$$T = 345 \log_{10}(8t + 1) + 20 \quad 4.1$$

Where:

T average temperature in the fire compartment, in degrees Celsius

t time, in minutes

Fire durations

The fire durations are considered as 30, 60, 90, 120, 180 and 240 minutes, to determine standard fire resistances of R30 to R240. At the beginning of each fire simulation ($t = 0 \text{ min}$), each element is considered with a temperature equal to 20°C.

Concrete characteristics

The fire resistance is valid for concrete class C20/25 or concrete classes presenting lower resistances.

The specific heat and density of concrete is modelled as temperature dependent as stated in [5], §3.3.2 for 1.5% moisture content. Even though in VOLTRA software density is constant, as in the transient heat transfer equations always the product of the specific heat and the density occur, this problem was solved by considering the change of density in the change of the specific heat. The specific heat considering the change of density used in VOLTRA is graphed in Figure 4.4.

The thermal conductivity of concrete, which is graphed in Figure 4.5, is modelled as temperature dependent as stated in [5], §3.3.3, according to the lower limit as recommended in [5], Annex A.

The concrete density at 20°C, ρ , emissivity related to the concrete surface, ε , and the convection factor is given in Table 4.1.

Calculation Parameters and Principles

The calculation parameters used in VOLTRA are shown in Figure 4.6. For the first time step of calculation, a steady-state system based on the boundary condition function values evaluated at the initial time is set up and solved. 20 iteration cycles are used to get good initial temperature dependent properties. For the next time steps, the boundary condition function values are updated, and the material volume capacity is taken into account. The Cranck-Nicolson finite difference method is used to formulate the energy balance for all control volumes around material nodes. For all nodes without capacity, the energy balance at the current time step is formulated. The temperature-dependent thermal conductivity and specific heat of concrete are adapted before each new iteration cycle, and each next iteration step based on the obtained temperatures in the previous iteration cycle or previous time step.

Rebar characteristics

The diameters of rebars considered in this study are 8, 10, 12, 14, 16, 20, 24, 25, 26, 28, 32 and 40 mm with a yield strength of 500 MPa.

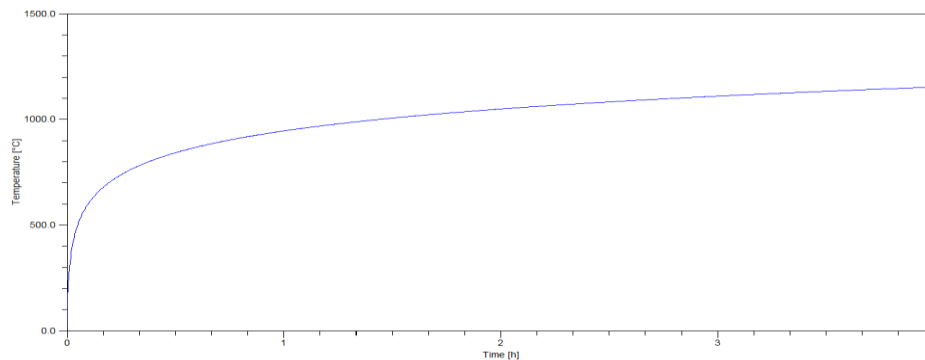


Figure 4.3 Standard time/temperature curve according to [5] as used in VOLTRA

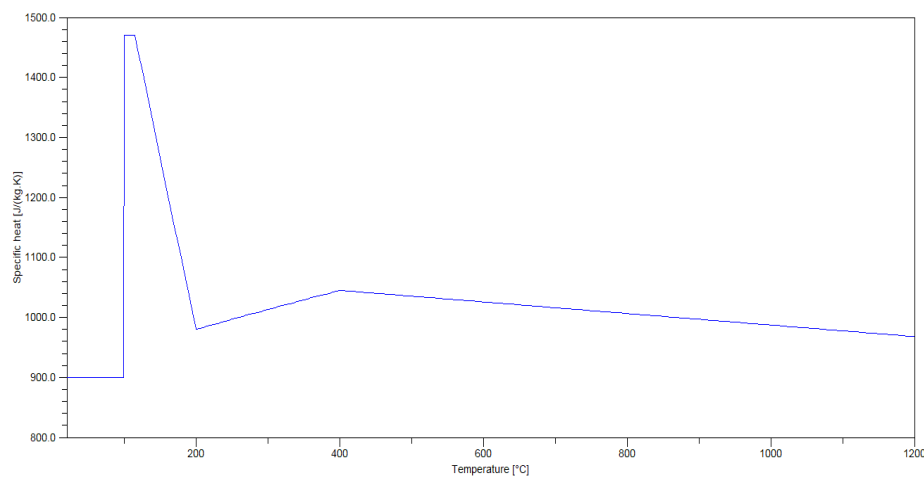


Figure 4.4 The specific heat vs temperature function for concrete C20/25 including the change in density with temperature, according to [5], as used in VOLTRA

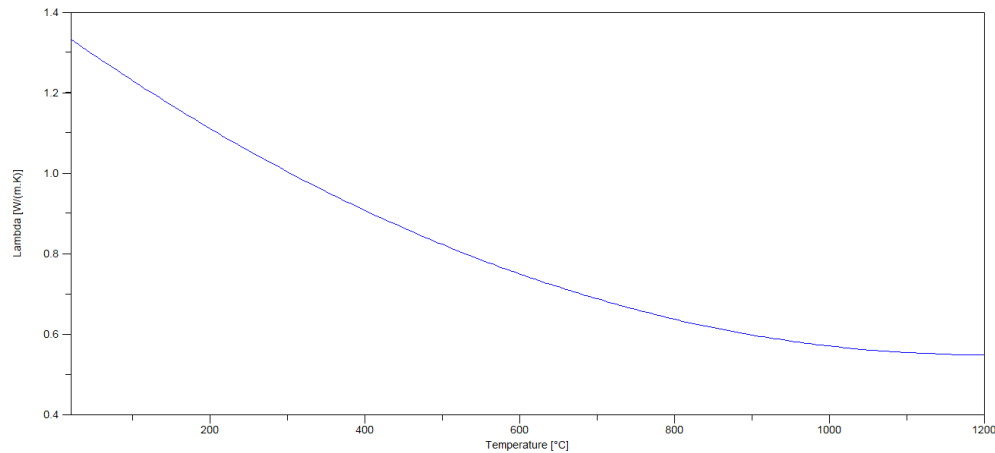


Figure 4.5 Thermal conductivity of concrete C20/25 according to [5], lower limit as used in VOLTRA

Table 4.1 Constant parameters related to concrete under fire exposure as used in VOLTRA

Constant parameters related to concrete under fire exposure		Notes
Concrete density at 20°C, ρ [kg/m^3]	2300	(1)
Emissivity related to concrete surface, ε [-]	0.7	-
Convection factor, h_c [W/m^2K]	25	-

(1) The variation of concrete density with temperature according to [5], 3.3.2, (3) is taken into account in specific heat

Calculation Parameters

Time axis

Time step

0000:00:01:00

ddd:hh:mm:ss

Start-up calculation duration

0000:00:00:00

ddd:hh:mm:ss

Calculation duration

0000:04:00:00

ddd:hh:mm:ss

Day number at start of calculation

1

i

Iterations

Iteration cycles

20

Maximum number of iterations (per iteration cycle)

10000

Maximum temperature difference

0.0001

°C

Max. heat flow divergence for total object

0.001

%

Max. heat flow divergence for any node

1

%

Radiation

☐ Linear
 ☒ Non-linear

Black radiation heat transfer coefficient (linear radiation)

5.25

W/(m².K)

Smallest accepted view factor

0.0001

Number of visibility rays between radiative surfaces

100

CEN values

☒ Yes
 ☐ No

Recalculation of CEN values (before each iteration cycle)

Default temperature difference across airspace

10

°C

OK

Cancel

Set As Default

Figure 4.6 Calculation parameters used in VOLTRA

4.3 Evaluation of bond strength

After obtaining the temperature distribution throughout the structure after each fire duration, evaluation of bond strength for given structural configurations is performed according to the temperature readings at output nodes corresponding to bonded-in positions of rebars.

For overlap joint in slab-slab connection case, the temperature values along the bonded-in length of the rebar are constant for a given concrete cover. The details of evaluation of bond strength are given in Chapter 6 of this document.

For end anchoring of beams in beam-wall connection case, the temperature values along the bonded-in length of the rebar vary along the length. As the distance from the fire exposed side of the wall towards non-exposed side of the wall increases, the temperature values decrease, and hence the bond strength values increase. The details of evaluating bond strength are given in Chapter 7 of this document.

4.4 Evaluation of bond lengths and fire resistance

Evaluation of bond lengths and fire design loads associated with bond lengths for given concrete cover values are obtained only for anchoring of beam in beam-wall connections in this study. The fire resistance loads are evaluated through integration of the design bond strength values. This procedure is detailed in Chapter 7.

4.5 Comparison between models with and without steel for end anchoring of beams in beam-wall connections

The effect of including the steel rebar in the thermal analysis 3-D model is also investigated for end anchoring of beams in beam-wall connections in this study. The fire resistance is evaluated by modelling the steel rebar for 12 mm diameter and concrete cover thickness values of 30 mm and 70 mm. The comparison of the temperature distribution and fire resistance is then made and detailed in Chapter 8.

5 EVALUATION OF THE BOND STRENGTH AT HIGH TEMPERATURES

The fire resistance of post-installed rebars is initially evaluated in terms of bond strength with respect to temperature. It is assumed that the decay in the bond resistance is a function only of the maximum temperature reached in given positions of reinforced concrete element, which is only indirectly a function of the fire duration.

As stated by the manufacturer, the design value of the bond strength $f_{bd,fi}$ for hammer drilling under fire exposure must be calculated according to the following equation:

$$f_{bd,fi}(\theta) = k_{fi}(\theta) \cdot f_{bd,PIR} \cdot \frac{\gamma_c}{\gamma_{M,fi}} \quad (5.1)$$

For	$20^{\circ}\text{C} \leq \theta \leq 50.8^{\circ}\text{C}$	$k_{fi}(\theta) = 1$
	$50.8^{\circ}\text{C} \leq \theta \leq 179.7^{\circ}\text{C}$	$k_{fi}(\theta) = 68359 \cdot \theta^{-2.248} / (f_{bd,PIR} \cdot 4.3) \leq 1$
	$\theta > 179.7^{\circ}\text{C}$	$k_{fi}(\theta) = 0$

Where:

k_{fi} temperature reduction factor

(θ) temperature in $^{\circ}\text{C}$

$f_{bd,PIR}$ design value of the bond strength in N/mm^2 for ambient temperature 20°C according to [1] considering the concrete class, the rebar diameter, and the bond conditions according to [4]

γ_c partial safety factor according to [4]

$\gamma_{M,fi}$ partial safety factor according to [4]

6 EVALUATION OF FIRE RESISTANCE FOR SLAB-SLAB CONNECTIONS

As explained in Chapter 4, the temperature distribution throughout the concrete slab after exposure to fire is obtained through finite elements method in accordance with [3] using VOLTRA software. The parameters and characteristics of the thermal analysis are detailed in Chapter 4.

A concrete slab with 50 cm thickness was modelled. The lower surface of the slab was exposed to fire. Adiabatic boundary conditions are considered for other surfaces of the slab. The temperature distribution after each fire duration is obtained and shown in Figure 6.1. It is worth noting that the temperature profile is constant horizontally, which results in constant bond strength along the length of the bonded-in part of the post-installed rebar. The temperature distribution with respect to depth in the slab is given in Table 6.1 and shown in Figure 6.2.

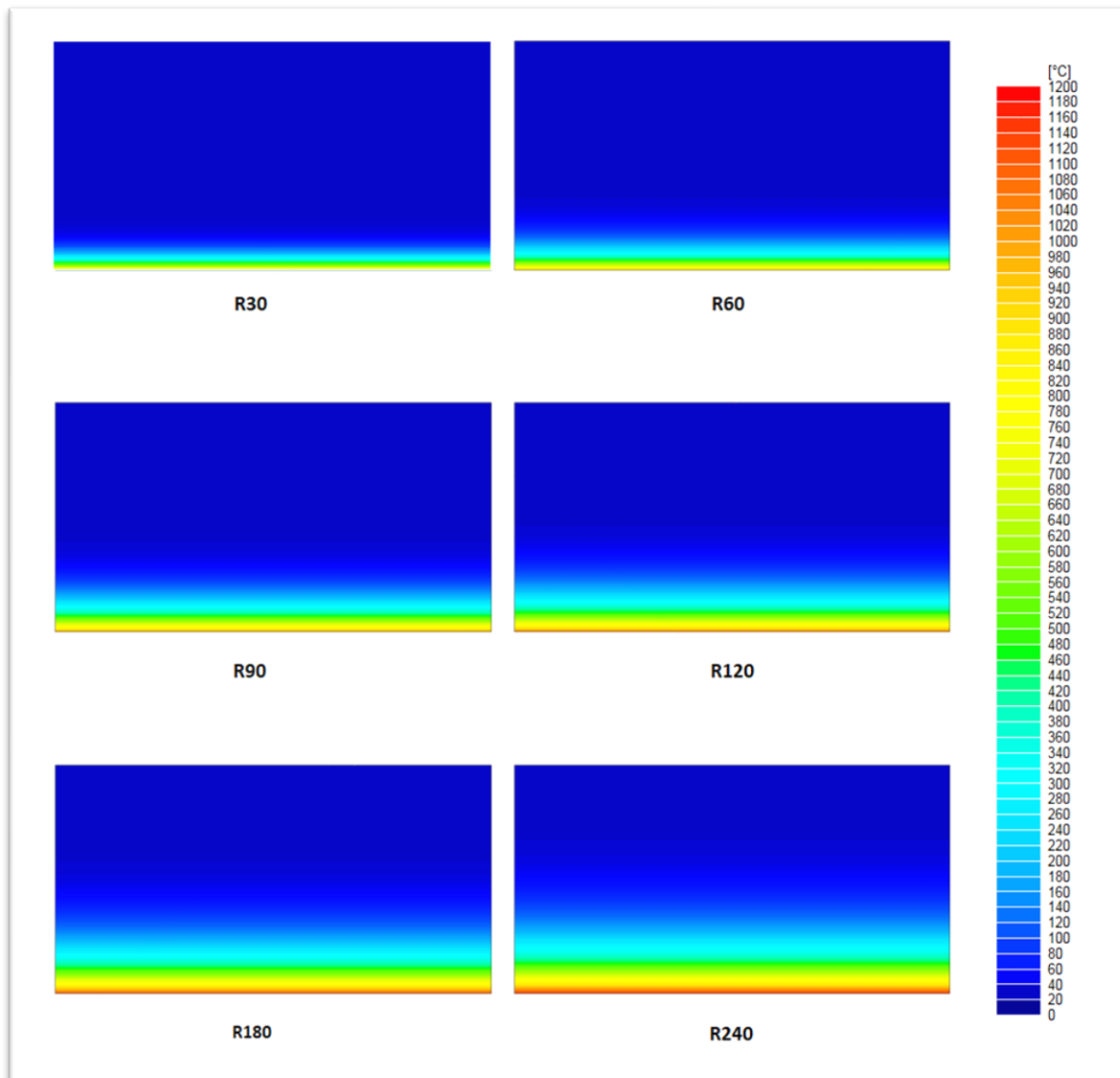


Figure 6.1 The temperature distributions throughout the slab at 30, 60, 90, 120, 180, and 240 min. for ISO 834-1 fire exposure

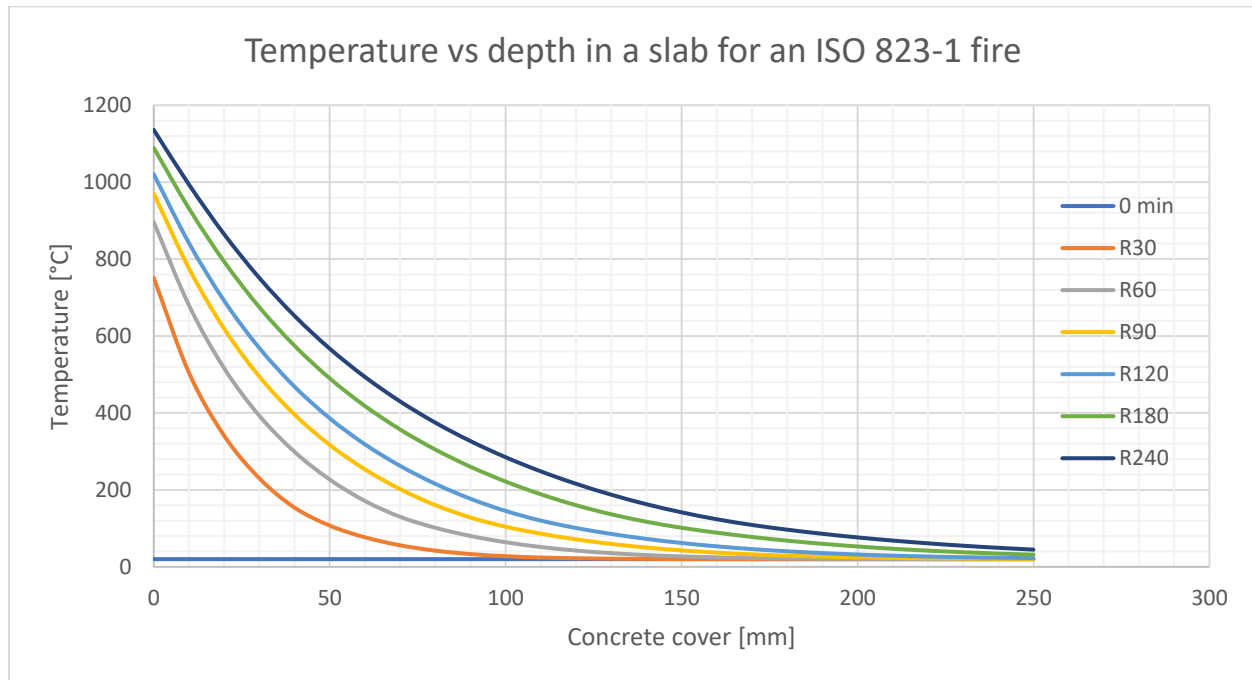


Figure 6.2 Temperature vs. concrete cover graph for 30, 60, 90, 120, 180 and 240 min of ISO 834-1 fire exposure

The design values of bond strength under fire exposure, $f_{bd,fi}$, is calculated for each concrete cover according to Equation 5.1.

$$f_{bd,PIR} = 2.3 \text{ MPa for sizes } \Phi 8\text{-}\Phi 32 \text{ and concrete C20/25}$$

$$f_{bd,PIR} = 2.1 \text{ MPa for size } \Phi 40 \text{ and concrete C20/25}$$

$$\gamma_C = 1.5$$

$$\gamma_{M,fi} = 1$$

The temperature reduction factor for ChemSet Reo502 EF Plus, Epcon C6 EF Plus, Epcon G5 PRO injection system, $k_{fi}(\theta)$, is plotted in Figure 6.3.

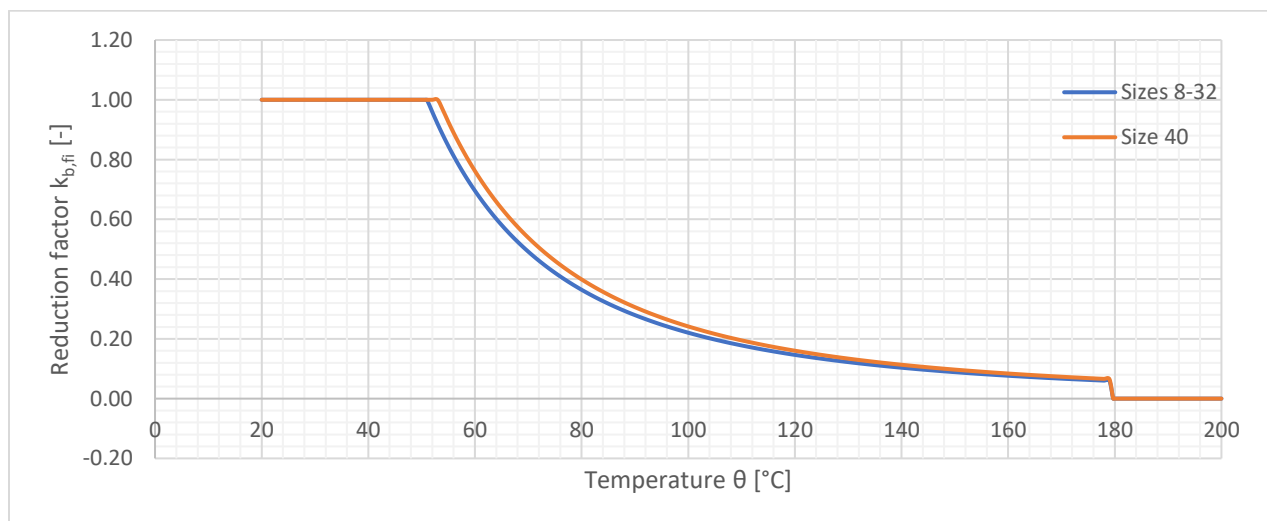


Figure 6.3 Graph of temperature reduction factor, $k_{fi}(\theta)$, with respect to temperature for concrete strength class C20/25

Table 6.2 Fire design bond strength values for concrete covers between 40 and 220mm for ISO 834-1 fire exposure at 30, 60, 90, 120, 180 and 240 minutes for rebars with diameter between 8 and 32mm

Fire Design Bond Strength $f_{bd,fi}$ for sizes $\phi 8$ - $\phi 32$ installed in Concrete C20/25 [N/mm ²]						
Concrete Cover [mm]	R30	R60	R90	R120	R180	R240
40	0.28					
50	0.64					
60	1.37	0.22				
70	2.80	0.41				
80	3.45	0.73	0.26			
90		1.22	0.43	0.21		
100		2.08	0.68	0.33		
110		3.31	1.04	0.50	0.28	
120		3.45	1.59	0.73	0.41	0.26
130			2.40	1.07	0.60	0.38
140			3.45	1.54	0.83	0.52
150				2.15	1.16	0.73
160				3.04	1.64	0.99
170				3.45	2.23	1.33
180					3.04	1.75
190					3.45	2.40
200						3.17
210						3.45
220						

Table 6.3 Fire design bond strength values for concrete covers between 40 and 210mm for ISO 834-1 fire exposure at 30, 60, 90, 120, 180 and 240 minutes for rebars with diameter 40mm

Fire Design Bond Strength $f_{bd,fi}$ for size $\phi 40$ installed in Concrete C20/25 [N/mm ²]						
Concrete Cover [mm]	R30	R60	R90	R120	R180	R240
40	0.28					
50	0.64					
60	1.37	0.22				
70	2.80	0.41				
80	3.15	0.73	0.26			
90		1.22	0.43	0.21		
100		2.08	0.68	0.33		
110		3.15	1.04	0.50	0.28	
120			1.59	0.73	0.41	0.26
130			2.40	1.07	0.60	0.38
140			3.15	1.54	0.83	0.52
150				2.15	1.16	0.73
160				3.04	1.64	0.99
170				3.15	2.23	1.33
180					3.04	1.75
190					3.15	2.40
200						3.15
210						

7 EVALUATION OF FIRE RESISTANCE FOR BEAM-WALL CONNECTIONS

As explained in Chapter 4, the temperature distribution throughout the beam-wall connection after exposure to fire is obtained through finite elements method in accordance with [3] using VOLTRA software.

The parameters and characteristics of the thermal analysis are detailed in Chapter 4. The height and width of the beam is considered as 30 cm and 40 cm, respectively. The wall thickness is considered as 50 cm.

A three-dimensional mesh was used. Benefitting from the symmetry of the structure, the half of the beam-wall connection was modelled.

For end anchoring of beams in walls, the bonded-in part of the rebars is inside the wall and differently from overlap joints in slab-slab connections, the temperature is not uniform along the bonded-in part of the rebar.

The temperature distribution along the bonded-in length of the post-installed rebar is obtained through thermal analysis for concrete cover thicknesses 10, 20, 30, 40, 50, 60, 70, 80, 100, 120, 140 and 160 mm. An example temperature distribution for concrete cover thickness of 30 mm is given in Table 7.2. The temperature fields for the mentioned fire durations are given in Figure 7.2.

The fire resistance load values are evaluated for anchorage lengths, l_v , starting from the minimum anchorage length values for 20°C given in Table 7.1 and required anchorage length values for given fire exposure guaranteeing steel yield for a steel yield strength of 500MPa. The anchorage length values exceeding maximum permissible embedment depth values provided in Table B2 of [1], are written in red colour in the provided fire resistance tables.

The fire design load resistances $N_{Rd,fire}$ are evaluated through integration of the design bond strength values obtained according to the temperature distribution along the bonded-in length of the post-installed rebar for each concrete cover thickness value.

$$N_{Rd,fire} = \pi \cdot d \cdot \int_0^{l_v} f_{bd,fi}(\theta(x)) dx = \pi \cdot d \cdot f_{bd,PIR} \cdot \int_0^{l_v} k(\theta(x)) dx \quad (7.1)$$

The integration is performed by finite differences considering the temperature changes every 10 mm ($\Delta x = 10 \text{ mm}$) portion of the bonded-in length of the post-installed rebar:

$$N_{Rd,fire} \approx \pi \cdot d \cdot f_{bd,PIR} \cdot \frac{\gamma_c}{\gamma_{M,fi}} \cdot \sum_0^{l_v} k_{fi}(\theta(x)) \cdot \Delta x \quad (7.2)$$

Where:

d is the diameter of the post-installed rebar

x is the bonded-in length of the post-installed rebar from beam-wall connection side towards the inside of the wall

$f_{bd,PIR}, \gamma_c, \gamma_{M,fi}$ are as given in Chapter 6.

$k_{fi}(\theta)$ is as given in Chapter 5 and plotted in Figure 6.3.

The fire design load resistance values for end anchoring of beams in beam-wall connections realized by using ChemSet Reo502 EF Plus, Epcon C6 EF Plus and Epcon G5 PRO injection systems, for given concrete cover thickness, steel diameters and anchorage lengths considering the declared concrete class and steel yield strength are provided in tables from Table 7.3 to Table 7.14. The following notes must be highlighted for tables from Table 7.3 to Table 7.14:

- The fire design load resistance values provided in these tables are valid for end anchoring of beams in beam-wall connections applications for beams with at least 300 mm height and 400 mm width.
- The fire design load resistance values provided in these tables are only valid for accidental fire situations. The design in the ambient temperature or any other accidental situations must be carried out separately.
- The connection must be designed according to ambient temperature before fire design.
- The anchorage lengths written in red colour exceed the maximum permissible embedment depth values stated in [1] Table B2.
- The minimum declared concrete cover thickness values declared in [1], Table B1 are not taken into account for these tables.

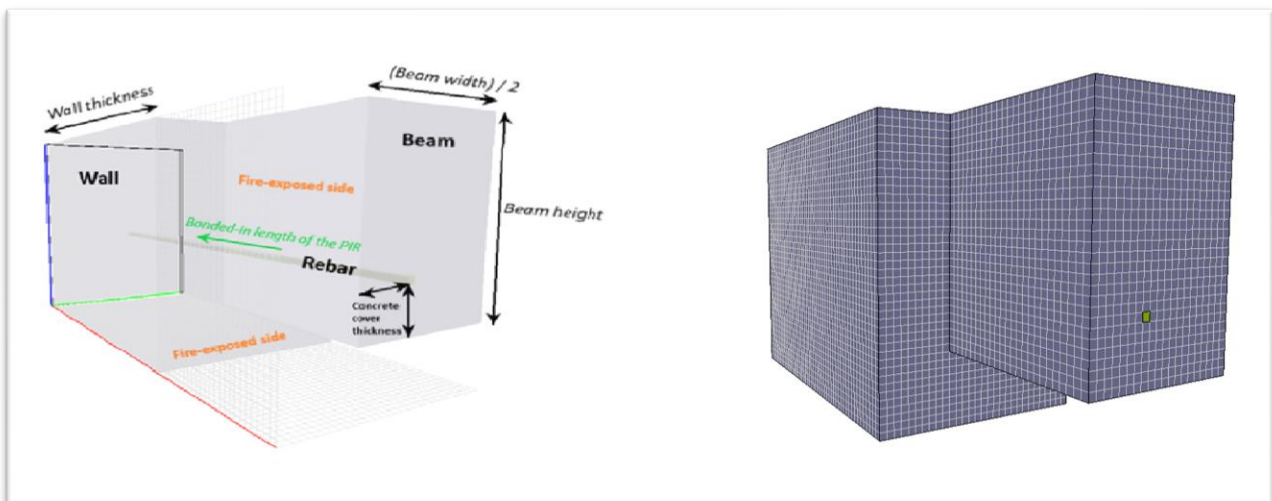


Figure 7.1 The 3-D model used in VOLTRA and the 3-D mesh (only concrete is modelled for the results presented in this chapter, the steel rebar in this figure is just for illustration purposes)

Table 7.1 Design Yielding Loads and Minimum Anchorage Lengths considering $f_y = 500\text{MPa}$

Rebar diameter	Rebar cross-section area	Design yielding load of the rebar	Required anchorage length for 20°C	Minimum anchorage length for 20°C
[mm]	[mm ²]	[kN]	[mm]	[mm]
8	50	16.8	290	100
10	79	26.2	362	109
12	113	37.7	435	130
14	154	51.3	507	152
16	201	67.0	580	174
20	314	104.7	725	217
24	452	150.8	870	261
25	491	163.6	906	272
26	531	177.0	942	283
28	616	205.3	1014	304
32	804	268.1	1159	348
40	1257	418.9	1587	476

Table 7.2 Temperature distribution for concrete cover 30mm and ISO 834-1 fire of 30, 60, 90, 120, 180 and 240 min.

Distance from the wall-beam joint towards wall [cm]	Concrete Cover 30 mm					
	R30	R60	R90	R120	R180	R240
50	20	20	20	20	20	20
48	20	20	20	20	20	20
46	20	20	20	20	20	20
44	20	20	20	20	20	20
42	20	20	20	20	20	20
40	20	20	20	20	20	21
39	20	20	20	20	20	21
38	20	20	20	20	20	21
37	20	20	20	20	20	22
36	20	20	20	20	20	22
35	20	20	20	20	21	23
34	20	20	20	20	21	23
33	20	20	20	20	21	24
32	20	20	20	20	22	25
31	20	20	20	20	22	26
30	20	20	20	20	23	27
29	20	20	20	20	23	29
28	20	20	20	21	24	31
27	20	20	20	21	25	33
26	20	20	20	21	27	36
25	20	20	20	22	29	39
24	20	20	21	23	31	43
23	20	20	21	24	33	47
22	20	20	22	25	37	52
21	20	20	22	26	40	58
20	20	20	23	29	45	64
19	20	21	24	31	50	72
18	20	21	26	35	57	81
17	20	21	28	38	64	90
16	20	23	32	44	73	102
15	20	24	36	51	83	115
14	20	27	41	59	95	131
13	21	30	48	68	109	150
12	21	34	56	80	126	172
11	22	40	67	94	147	197
10	24	48	80	111	172	227
9	27	59	96	132	202	260
8	31	73	116	159	236	297
7	38	90	143	193	275	340
6	48	113	177	233	321	389
5	63	144	219	280	374	445
4	84	185	270	335	434	508
3	110	237	329	399	503	579
2	147	297	398	472	579	656
1	195	365	472	549	659	737
0	246	432	545	625	735	812

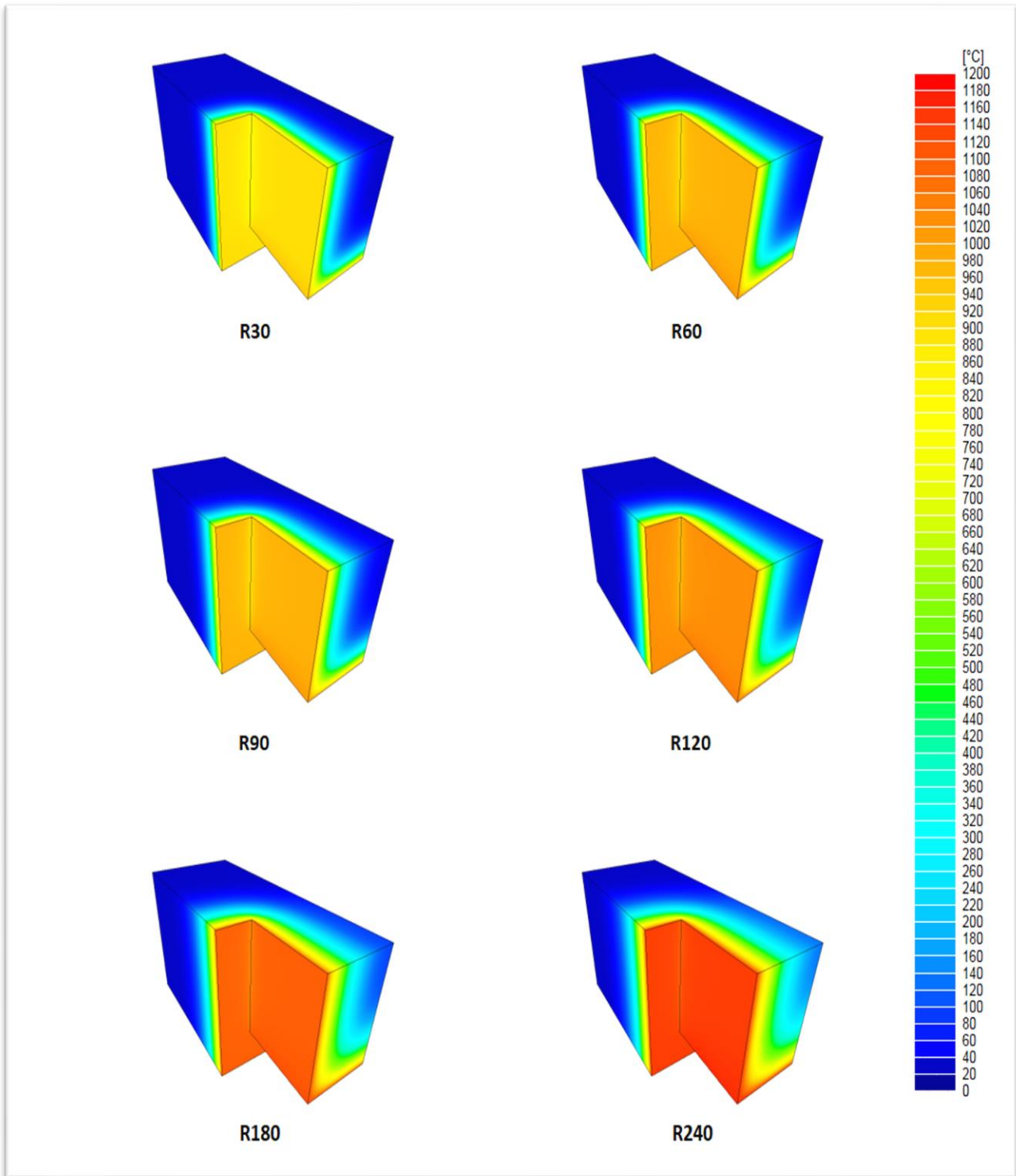


Figure 7.2 Temperature distribution for the beam-wall connection at 30, 60, 90, 120, 180 and 240 min during an ISO 834-1 fire

Table 7.3 Fire design load resistance values for end anchoring of beams in beam-wall connections with a concrete cover of 10 mm for rebar diameters 8 and 10 mm

Concrete Cover = 10 mm		Fire Design Load Resistance $N_{Rd,Fire}$ [kN]					
Diameter [mm]	length l_v [mm]	R30	R60	R90	R120	R180	R240
8	100	4.5	1.7	0.6	0.2	0.0	0.0
	140	8.0	5.2	3.1	1.5	0.5	0.2
	180	11.4	8.6	6.6	4.8	2.1	0.9
	220	14.9	12.1	10.1	8.3	5.4	3.0
	250	16.8	14.7	12.7	10.9	8.0	5.6
	270		16.4	14.4	12.7	9.8	7.4
	280		16.8	15.3	13.5	10.6	8.2
	300			16.8	15.3	12.4	10.0
	320				16.8	14.1	11.7
	360					16.8	15.2
	380						16.8
10	110	6.7	3.2	1.2	0.5	0.1	0.0
	150	11.0	7.6	5.0	2.8	0.9	0.3
	190	15.4	11.9	9.4	7.1	3.5	1.6
	230	19.7	16.2	13.7	11.5	7.9	4.9
	270	24.0	20.6	18.0	15.8	12.2	9.2
	290	26.2	22.7	20.2	18.0	14.4	11.4
	330		26.2	24.5	22.3	18.7	15.7
	350			26.2	24.5	20.9	17.9
	370				26.2	23.0	20.1
	400					26.2	23.3
	440						26.2

Table 7.4 Fire design load resistance values for end anchoring of beams in beam-wall connections with a concrete cover of 20 mm for rebar diameters 8, 10, 12, 14, 16 and 20 mm

Concrete Cover = 20 mm		Fire Design Load Resistance $N_{Rd,Fire}$ [kN]					
Diameter [mm]	length l_v [mm]	R30	R60	R90	R120	R180	R240
8	100	4.8	2.0	0.6	0.3	0.0	0.0
	140	8.3	5.5	3.4	1.7	0.5	0.2
	180	11.7	9.0	6.8	5.1	2.2	1.0
	220	15.2	12.4	10.3	8.6	5.7	3.2
	240	16.8	14.2	12.1	10.3	7.4	4.9
	270		16.8	14.7	12.9	10.0	7.5
	300			16.8	15.5	12.6	10.1
	320				16.8	14.3	11.9
	350					16.8	14.5
	380						16.8
10	110	7.1	3.6	1.3	0.6	0.1	0.0
	150	11.4	8.0	5.3	3.1	1.0	0.4
	190	15.8	12.3	9.6	7.5	3.8	1.7
	230	20.1	16.6	14.0	11.8	8.1	5.1
	270	24.4	21.0	18.3	16.1	12.5	9.4
	290	26.2	23.1	20.5	18.3	14.7	11.6
	320		26.2	23.7	21.6	17.9	14.8
	350			26.2	24.8	21.2	18.1
	370				26.2	23.3	20.2
	400					26.2	23.5
	440						26.2
12	130	11.1	7.0	3.8	1.7	0.5	0.1
	190	18.9	14.8	11.6	9.0	4.6	2.0
	250	26.7	22.6	19.4	16.8	12.4	8.7
	310	34.5	30.4	27.2	24.6	20.2	16.5
	340	37.7	34.3	31.1	28.5	24.1	20.4
	370		37.7	35.0	32.4	28.0	24.3
	400			37.7	36.3	31.9	28.2
	420				37.7	34.5	30.8
	460					37.7	36.0
	480						37.7

The table continues to the next page.

Concrete Cover = 20 mm		Fire Design Load Resistance $N_{Rd,Fire}$ [kN]					
Diameter [mm]	length l_v [mm]	R30	R60	R90	R120	R180	R240
14	160	17.5	12.7	9.0	5.9	2.0	0.8
	220	26.6	21.8	18.1	15.0	9.9	5.6
	280	35.7	30.9	27.2	24.1	19.0	14.7
	340	44.8	40.0	36.3	33.2	28.1	23.8
	390	51.3	47.6	43.9	40.8	35.7	31.4
	420		51.3	48.4	45.3	40.2	35.9
	440			51.3	48.4	43.3	39.0
	460				51.3	46.3	42.0
	500					51.3	48.1
	540						51.3
16	180	23.5	17.9	13.7	10.2	4.4	2.0
	240	33.9	28.3	24.1	20.6	14.8	9.9
	300	44.3	38.8	34.5	31.0	25.2	20.3
	360	54.7	49.2	44.9	41.4	35.6	30.7
	440	67.0	63.0	58.8	55.3	49.5	44.5
	480		67.0	65.7	62.2	56.4	51.5
	500			67.0	65.7	59.9	54.9
	520				67.0	63.3	58.4
	560					67.0	65.3
	580						67.0
20	220	38.0	31.1	25.8	21.4	14.1	8.0
	280	51.0	44.1	38.8	34.4	27.1	21.0
	340	64.0	57.1	51.8	47.4	40.1	34.0
	400	77.1	70.1	64.8	60.4	53.1	47.0
	460	90.1	83.1	77.8	73.4	66.2	60.0
	520	103.1	96.1	90.8	86.5	79.2	73.0
	540	104.7	100.5	95.2	90.8	83.5	77.3
	560		104.7	99.5	95.1	87.8	81.7
	600			104.7	103.8	96.5	90.4
	620				104.7	100.8	94.7
	640					104.7	99.0
	680						104.7

Table 7.5 Fire design load resistance values for end anchoring of beams in beam-wall connections with a concrete cover of 30 mm for rebar diameters 8, 10, 12, 14, 16, 20, 24, 25, 26, and 28 mm

Concrete Cover = 30 mm		Fire Design Load Resistance $N_{Rd,Fire}$ [kN]					
Diameter [mm]	length l_v [mm]	R30	R60	R90	R120	R180	R240
8	100	5.4	2.3	0.8	0.3	0.1	0.0
	140	8.8	5.8	3.7	1.9	0.6	0.2
	180	12.3	9.3	7.1	5.4	2.5	1.1
	220	15.8	12.8	10.6	8.8	5.9	3.4
	240	16.8	14.5	12.3	10.6	7.7	5.2
	270		16.8	14.9	13.2	10.3	7.8
	300			16.8	15.8	12.9	10.4
	320				16.8	14.6	12.1
	350					16.8	14.7
	380						16.8
10	110	7.8	4.0	1.6	0.7	0.2	0.0
	150	12.1	8.4	5.7	3.5	1.1	0.5
	190	16.5	12.7	10.0	7.8	4.2	1.9
	230	20.8	17.0	14.4	12.1	8.5	5.4
	270	25.1	21.4	18.7	16.5	12.8	9.7
	280	26.2	22.4	19.8	17.6	13.9	10.8
	320		26.2	24.1	21.9	18.3	15.2
	340			26.2	24.1	20.4	17.3
	360				26.2	22.6	19.5
	400					26.2	23.8
	440						26.2
12	130	12.0	7.4	4.2	1.9	0.6	0.2
	170	17.2	12.6	9.4	6.8	2.7	1.2
	210	22.4	17.8	14.6	12.0	7.6	4.0
	250	27.6	23.0	19.8	17.2	12.8	9.1
	290	32.8	28.2	25.0	22.4	18.0	14.3
	330	37.7	33.4	30.2	27.6	23.2	19.5
	370		37.7	35.4	32.8	28.4	24.7
	390			37.7	35.4	31.0	27.3
	420				37.7	34.9	31.2
	460					37.7	36.4
	480						37.7

The table continues to the next page.

Concrete Cover = 30 mm		Fire Design Load Resistance $N_{Rd,Fire}$ [kN]					
Diameter [mm]	length l_v [mm]	R30	R60	R90	R120	R180	R240
14	160	18.5	13.2	9.5	6.4	2.2	1.0
	220	27.6	22.3	18.6	15.5	10.4	6.0
	280	36.7	31.4	27.7	24.6	19.5	15.1
	340	45.8	40.5	36.8	33.7	28.6	24.2
	380	51.3	46.6	42.9	39.8	34.7	30.3
	420		51.3	48.9	45.8	40.7	36.4
	440			51.3	48.9	43.8	39.4
	460				51.3	46.8	42.5
	500					51.3	48.5
	520						51.3
16	180	24.6	18.6	14.3	10.8	4.9	2.2
	240	35.0	29.0	24.7	21.2	15.4	10.4
	300	45.4	39.4	35.1	31.6	25.8	20.8
	360	55.8	49.8	45.5	42.0	36.2	31.2
	440	67.0	63.7	59.4	55.8	50.0	45.1
	460		67.0	62.8	59.3	53.5	48.5
	500			67.0	66.3	60.4	55.5
	520				67.0	63.9	58.9
	540					67.0	62.4
	580						67.0
20	220	39.4	31.9	26.5	22.1	14.9	8.6
	280	52.4	44.9	39.5	35.1	27.9	21.6
	340	65.5	57.9	52.5	48.1	40.9	34.6
	400	78.5	70.9	65.6	61.1	53.9	47.6
	460	91.5	83.9	78.6	74.1	66.9	60.6
	520	104.5	96.9	91.6	87.2	79.9	73.7
	540	104.7	101.2	95.9	91.5	84.2	78.0
	560		104.7	100.2	95.8	88.6	82.3
	600			104.7	104.5	97.2	91.0
	620				104.7	101.6	95.3
	640					104.7	99.7
	680						104.7

The table continues to the next page.

Concrete Cover = 30 mm		Fire Design Load Resistance $N_{Rd,Fire}$ [kN]					
Diameter [mm]	length l_v [mm]	R30	R60	R90	R120	R180	R240
24	270	60.3	51.3	44.8	39.6	30.8	23.4
	330	75.9	66.9	60.5	55.2	46.4	39.0
	390	91.5	82.5	76.1	70.8	62.0	54.6
	440	104.6	95.5	89.1	83.8	75.1	67.6
	500	120.2	111.1	104.7	99.4	90.7	83.2
	560	135.8	126.7	120.3	115.0	106.3	98.8
	620	150.8	142.3	135.9	130.6	121.9	114.4
	660		150.8	146.3	141.0	132.3	124.8
	680			150.8	146.2	137.5	130.0
	700				150.8	142.7	135.2
	740					150.8	145.6
	760						150.8
25	280	65.6	56.1	49.4	43.9	34.8	27.0
	340	81.8	72.4	65.7	60.2	51.1	43.3
	400	98.1	88.6	81.9	76.4	67.3	59.6
	460	114.3	104.9	98.2	92.7	83.6	75.8
	520	130.6	121.1	114.5	108.9	99.9	92.1
	580	146.8	137.4	130.7	125.2	116.1	108.3
	640	163.1	153.7	147.0	141.5	132.4	124.6
	660	163.6	159.1	152.4	146.9	137.8	130.0
	680		163.6	157.8	152.3	143.2	135.4
	720			163.6	163.1	154.0	146.3
	740				163.6	159.5	151.7
	760					163.6	157.1
	800						163.6

The table continues to the next page.

Concrete Cover = 30 mm		Fire Design Load Resistance $N_{Rd,Fire}$ [kN]					
Diameter [mm]	length l_v [mm]	R30	R60	R90	R120	R180	R240
26	290	71.0	61.2	54.2	48.5	39.0	30.9
	350	87.9	78.1	71.1	65.4	55.9	47.8
	400	102.0	92.2	85.2	79.5	70.0	61.9
	460	118.9	109.1	102.1	96.4	86.9	78.8
	520	135.8	126.0	119.0	113.3	103.8	95.8
	580	152.7	142.9	135.9	130.2	120.8	112.7
	640	169.6	159.8	152.9	147.1	137.7	129.6
	680	177.0	171.1	164.1	158.4	148.9	140.8
	720		177.0	175.4	169.7	160.2	152.1
	740			177.0	175.3	165.8	157.7
	760				177.0	171.5	163.4
	780					177.0	169.0
	820						177.0
28	310	82.5	71.9	64.5	58.3	48.1	39.4
	370	100.7	90.2	82.7	76.5	66.3	57.6
	420	115.9	105.3	97.8	91.7	81.5	72.8
	480	134.1	123.5	116.1	109.9	99.7	91.0
	540	152.3	141.7	134.3	128.1	117.9	109.2
	600	170.5	160.0	152.5	146.3	136.1	127.4
	660	188.7	178.2	170.7	164.5	154.3	145.6
	720	205.3	196.4	188.9	182.7	172.5	163.8
	760		205.3	201.0	194.8	184.7	176.0
	780			205.3	200.9	190.7	182.0
	800				205.3	196.8	188.1
	840					205.3	200.2
	860						205.3

Table 7.6 Fire design load resistance values for end anchoring of beams in beam-wall connections with a concrete cover of 40 mm for rebar diameters 8, 10, 12, 14, 16, 20, 24, 25, 26, 28, 32 and 40 mm

Concrete Cover = 40 mm		Fire Design Load Resistance $N_{Rd,Fire}$ [kN]					
Diameter [mm]	length l_v [mm]	R30	R60	R90	R120	R180	R240
8	100	6.1	2.8	1.0	0.4	0.1	0.0
	140	9.6	6.3	4.0	2.2	0.7	0.3
	180	13.0	9.7	7.5	5.7	2.7	1.2
	220	16.5	13.2	11.0	9.2	6.2	3.7
	230	16.8	14.1	11.8	10.0	7.0	4.6
	270		16.8	15.3	13.5	10.5	8.0
	290			16.8	15.2	12.2	9.8
	310				16.8	14.0	11.5
	350					16.8	15.0
	380						16.8
10	110	8.7	4.6	1.9	0.8	0.2	0.0
	150	13.0	8.9	6.1	3.9	1.3	0.5
	190	17.4	13.3	10.5	8.2	4.4	2.0
	230	21.7	17.6	14.8	12.6	8.8	5.7
	270	26.1	21.9	19.1	16.9	13.1	10.0
	280	26.2	23.0	20.2	18.0	14.2	11.1
	310		26.2	23.5	21.2	17.5	14.4
	340			26.2	24.5	20.7	17.6
	360				26.2	22.9	19.8
	400					26.2	24.1
	420						26.2
12	130	13.1	8.1	4.7	2.3	0.7	0.2
	190	20.9	15.9	12.6	9.9	5.3	2.4
	250	28.7	23.7	20.4	17.7	13.1	9.5
	310	36.5	31.5	28.2	25.5	20.9	17.3
	320	37.7	32.8	29.5	26.8	22.2	18.6
	360		37.7	34.7	32.0	27.4	23.8
	390			37.7	35.9	31.4	27.7
	420				37.7	35.3	31.6
	440					37.7	34.2
	480						37.7

The table continues to the next page.

Concrete Cover = 40 mm		Fire Design Load Resistance $N_{Rd,Fire}$ [kN]					
Diameter [mm]	length l_v [mm]	R30	R60	R90	R120	R180	R240
14	160	19.8	14.0	10.1	7.0	2.5	1.1
	220	28.9	23.1	19.2	16.1	10.8	6.5
	280	38.0	32.2	28.3	25.2	19.9	15.6
	340	47.1	41.3	37.4	34.3	29.0	24.7
	370	51.3	45.9	42.0	38.8	33.5	29.2
	420		51.3	49.5	46.4	41.1	36.8
	440			51.3	49.4	44.2	39.9
	460				51.3	47.2	42.9
	500					51.3	49.0
	520						51.3
16	180	26.1	19.5	15.0	11.4	5.4	2.4
	240	36.5	29.9	25.4	21.8	15.8	10.9
	300	46.9	40.3	35.8	32.2	26.2	21.3
	360	57.3	50.7	46.2	42.6	36.6	31.7
	420	67.0	61.1	56.6	53.0	47.0	42.1
	460		67.0	63.6	60.0	53.9	49.0
	480			67.0	63.4	57.4	52.5
	520				67.0	64.3	59.4
	540					67.0	62.9
	580						67.0
20	220	41.3	33.0	27.4	22.9	15.4	9.2
	280	54.3	46.0	40.4	36.0	28.4	22.3
	340	67.3	59.0	53.4	49.0	41.4	35.3
	400	80.3	72.1	66.4	62.0	54.4	48.3
	460	93.3	85.1	79.4	75.0	67.4	61.3
	520	104.7	98.1	92.5	88.0	80.4	74.3
	560		104.7	101.1	96.6	89.1	83.0
	580			104.7	101.0	93.4	87.3
	600				104.7	97.8	91.6
	640					104.7	100.3
	680						104.7

The table continues to the next page.

Concrete Cover = 40 mm		Fire Design Load Resistance $N_{Rd,Fire}$ [kN]					
Diameter [mm]	length l_v [mm]	R30	R60	R90	R120	R180	R240
24	270	62.5	52.6	45.9	40.5	31.5	24.1
	330	78.1	68.3	61.5	56.1	47.1	39.7
	390	93.7	83.9	77.1	71.8	62.7	55.3
	440	106.7	96.9	90.1	84.8	75.7	68.3
	500	122.4	112.5	105.7	100.4	91.3	83.9
	560	138.0	128.1	121.3	116.0	106.9	99.5
	620	150.8	143.7	137.0	131.6	122.5	115.1
	660		150.8	147.4	142.0	132.9	125.6
	680			150.8	147.2	138.1	130.8
	700				150.8	143.3	136.0
	740					150.8	146.4
	760						150.8
25	280	67.8	57.5	50.5	44.9	35.5	27.8
	340	84.1	73.8	66.8	61.2	51.8	44.1
	400	100.4	90.1	83.1	77.5	68.0	60.3
	460	116.6	106.3	99.3	93.7	84.3	76.6
	520	132.9	122.6	115.6	110.0	100.5	92.9
	580	149.1	138.8	131.8	126.2	116.8	109.1
	640	163.6	155.1	148.1	142.5	133.1	125.4
	680		163.6	158.9	153.3	143.9	136.2
	700			163.6	158.7	149.3	141.6
	720				163.6	154.7	147.0
	760					163.6	157.9
	800						163.6

The table continues to the next page.

Concrete Cover = 40 mm		Fire Design Load Resistance $N_{Rd,Fire}$ [kN]					
Diameter [mm]	length l_v [mm]	R30	R60	R90	R120	R180	R240
26	290	73.4	62.7	55.4	49.6	39.7	31.8
	350	90.3	79.6	72.3	66.5	56.7	48.7
	400	104.4	93.7	86.4	80.6	70.7	62.7
	460	121.3	110.6	103.3	97.5	87.7	79.7
	520	138.2	127.5	120.2	114.4	104.6	96.6
	580	155.1	144.4	137.1	131.3	121.5	113.5
	640	172.0	161.3	154.0	148.2	138.4	130.4
	660	177.0	166.9	159.6	153.8	144.0	136.0
	700		177.0	170.9	165.1	155.3	147.3
	740			177.0	176.4	166.6	158.6
	760				177.0	172.2	164.2
	780					177.0	169.8
	820						177.0
28	310	85.1	73.6	65.7	59.4	48.9	40.3
	370	103.3	91.8	83.9	77.6	67.1	58.5
	420	118.5	106.9	99.1	92.8	82.3	73.6
	480	136.7	125.1	117.3	111.0	100.5	91.9
	540	154.9	143.4	135.5	129.2	118.7	110.1
	600	173.1	161.6	153.7	147.4	136.9	128.3
	660	191.3	179.8	171.9	165.7	155.1	146.5
	720	205.3	198.0	190.1	183.9	173.3	164.7
	760		205.3	202.3	196.0	185.4	176.8
	780			205.3	202.1	191.5	182.9
	800				205.3	197.6	189.0
	840					205.3	201.1
	860						205.3

The table continues to the next page.

Concrete Cover = 40 mm		Fire Design Load Resistance $N_{Rd,Fire}$ [kN]					
Diameter [mm]	length l_v [mm]	R30	R60	R90	R120	R180	R240
32	350	111.1	97.9	89.0	81.8	69.7	59.9
	400	128.5	115.3	106.3	99.1	87.1	77.2
	460	149.3	136.1	127.1	120.0	107.9	98.0
	520	170.1	156.9	147.9	140.8	128.7	118.8
	580	190.9	177.7	168.7	161.6	149.5	139.7
	640	211.7	198.5	189.5	182.4	170.3	160.5
	700	232.5	219.3	210.4	203.2	191.1	181.3
	760	253.3	240.1	231.2	224.0	211.9	202.1
	820	268.1	261.0	252.0	244.8	232.7	222.9
	860		268.1	265.8	258.7	246.6	236.8
	880			268.1	265.6	253.5	243.7
	900				268.1	260.5	250.6
	940					268.1	264.5
	960						268.1
40	350	127.6	112.6	102.5	94.3	80.8	69.6
	400	147.4	132.4	122.3	114.1	100.5	89.4
	460	171.1	156.2	146.1	137.9	124.3	113.1
	520	194.9	179.9	169.8	161.6	148.0	136.9
	580	218.6	203.7	193.6	185.4	171.8	160.6
	640	242.4	227.4	217.3	209.1	195.5	184.4
	700	266.1	251.2	241.1	232.9	219.3	208.1
	760	289.9	274.9	264.8	256.6	243.0	231.9
	820	313.6	298.7	288.6	280.4	266.8	255.6
	880	337.4	322.4	312.3	304.1	290.5	279.4
	940	361.1	346.2	336.1	327.9	314.3	303.1
	1000	384.9	369.9	359.8	351.6	338.0	326.9
	1060	408.6	393.7	383.6	375.4	361.8	350.6
	1100	418.9	409.5	399.4	391.2	377.6	366.5
	1140		418.9	415.2	407.0	393.5	382.3
	1160			418.9	415.0	401.4	390.2
	1180				418.9	409.3	398.1
	1220					418.9	414.0
	1240						418.9

Table 7.7 Fire design load resistance values for end anchoring of beams in beam-wall connections with a concrete cover of 50 mm for rebar diameters 8, 10, 12, 14, 16, 20, 24, 25, 26, 28, 32 and 40 mm

Concrete Cover = 50 mm		Fire Design Load Resistance $N_{Rd,Fire}$ [kN]					
Diameter [mm]	length l_v [mm]	R30	R60	R90	R120	R180	R240
8	100	6.9	3.4	1.3	0.5	0.1	0.0
	140	10.4	6.9	4.3	2.5	0.8	0.3
	180	13.9	10.3	7.8	6.0	3.0	1.3
	220	16.8	13.8	11.2	9.4	6.5	4.0
	250		16.4	13.8	12.0	9.1	6.6
	260		16.8	14.7	12.9	9.9	7.4
	290			16.8	15.5	12.5	10.0
	310				16.8	14.3	11.8
	340					16.8	14.4
	370						16.8
10	110	9.8	5.3	2.4	1.0	0.3	0.1
	150	14.1	9.7	6.4	4.2	1.4	0.6
	190	18.4	14.0	10.8	8.5	4.8	2.2
	230	22.8	18.3	15.1	12.9	9.2	6.1
	270	26.2	22.7	19.5	17.2	13.5	10.4
	310		26.2	23.8	21.5	17.8	14.7
	340			26.2	24.8	21.1	18.0
	360				26.2	23.3	20.1
	390					26.2	23.4
	420						26.2
12	130	14.3	9.0	5.1	2.5	0.8	0.3
	190	22.1	16.8	12.9	10.2	5.8	2.7
	250	29.9	24.6	20.7	18.0	13.6	9.9
	310	37.7	32.4	28.5	25.9	21.4	17.7
	360		37.7	35.1	32.4	27.9	24.2
	380			37.7	35.0	30.5	26.8
	420				37.7	35.7	32.0
	440					37.7	34.6
	480						37.7

The table continues to the next page.

Concrete Cover = 50 mm		Fire Design Load Resistance $N_{Rd,Fire}$ [kN]					
Diameter [mm]	length l_v [mm]	R30	R60	R90	R120	R180	R240
14	160	21.2	15.1	10.5	7.4	2.8	1.2
	220	30.3	24.2	19.6	16.5	11.3	7.0
	280	39.5	33.3	28.8	25.6	20.4	16.1
	340	48.6	42.4	37.9	34.7	29.5	25.2
	360	51.3	45.4	40.9	37.7	32.6	28.2
	400		51.3	47.0	43.8	38.6	34.3
	440			51.3	49.9	44.7	40.3
	460				51.3	47.7	43.4
	500					51.3	49.5
	520						51.3
16	180	27.7	20.7	15.5	11.9	6.0	2.7
	240	38.2	31.1	25.9	22.3	16.4	11.4
	300	48.6	41.5	36.3	32.7	26.8	21.8
	360	59.0	51.9	46.7	43.1	37.2	32.2
	420	67.0	62.3	57.1	53.5	47.6	42.6
	460		67.0	64.1	60.5	54.6	49.6
	480			67.0	64.0	58.0	53.0
	500				67.0	61.5	56.5
	540					67.0	63.5
	580						67.0
20	220	43.4	34.5	28.1	23.6	16.2	10.0
	280	56.4	47.5	41.1	36.6	29.2	23.0
	340	69.4	60.5	54.1	49.6	42.2	36.0
	400	82.4	73.5	67.1	62.6	55.2	49.0
	460	95.4	86.5	80.1	75.6	68.2	62.0
	520	104.7	99.5	93.1	88.6	81.2	75.0
	560		104.7	101.8	97.3	89.9	83.7
	580			104.7	101.6	94.2	88.0
	600				104.7	98.6	92.3
	640					104.7	101.0
	660						104.7

The table continues to the next page.

Concrete Cover = 50 mm		Fire Design Load Resistance $N_{Rd,Fire}$ [kN]					
Diameter [mm]	length l_v [mm]	R30	R60	R90	R120	R180	R240
24	270	65.0	54.4	46.7	41.3	32.4	24.9
	330	80.6	70.0	62.3	56.9	48.0	40.6
	390	96.2	85.6	77.9	72.5	63.6	56.2
	440	109.3	98.6	90.9	85.5	76.6	69.2
	500	124.9	114.3	106.5	101.1	92.2	84.8
	560	140.5	129.9	122.1	116.7	107.9	100.4
	600	150.8	140.3	132.5	127.1	118.3	110.8
	660		150.8	148.1	142.7	133.9	126.4
	680			150.8	148.0	139.1	131.6
	700				150.8	144.3	136.8
	740					150.8	147.2
	760						150.8
25	280	70.4	59.4	51.3	45.7	36.5	28.7
	340	86.7	75.7	67.6	62.0	52.7	45.0
	400	103.0	91.9	83.9	78.2	69.0	61.2
	460	119.2	108.2	100.1	94.5	85.3	77.5
	520	135.5	124.4	116.4	110.8	101.5	93.7
	580	151.7	140.7	132.6	127.0	117.8	110.0
	640	163.6	156.9	148.9	143.3	134.0	126.2
	680		163.6	159.7	154.1	144.9	137.1
	700			163.6	159.5	150.3	142.5
	720				163.6	155.7	147.9
	760					163.6	158.8
	780						163.6

The table continues to the next page.

Concrete Cover = 50 mm		Fire Design Load Resistance $N_{Rd,Fire}$ [kN]					
Diameter [mm]	length l_v [mm]	R30	R60	R90	R120	R180	R240
26	290	76.1	64.6	56.2	50.4	40.8	32.7
	350	93.0	81.5	73.1	67.3	57.7	49.6
	400	107.1	95.6	87.2	81.4	71.8	63.7
	460	124.0	112.5	104.1	98.3	88.7	80.6
	520	140.9	129.4	121.0	115.2	105.6	97.5
	580	157.8	146.3	137.9	132.1	122.5	114.4
	640	174.7	163.2	154.8	149.0	139.4	131.3
	660	177.0	168.9	160.5	154.6	145.0	136.9
	700		177.0	171.8	165.9	156.3	148.2
	720			177.0	171.6	161.9	153.8
	740				177.0	167.6	159.5
	780					177.0	170.7
	820						177.0
28	310	88.0	75.6	66.6	60.3	50.0	41.2
	370	106.2	93.8	84.8	78.5	68.2	59.5
	420	121.4	109.0	100.0	93.7	83.3	74.6
	480	139.6	127.2	118.2	111.9	101.6	92.8
	540	157.8	145.4	136.4	130.1	119.8	111.0
	600	176.0	163.6	154.6	148.3	138.0	129.3
	660	194.2	181.8	172.8	166.5	156.2	147.5
	700	205.3	194.0	185.0	178.7	168.3	159.6
	740		205.3	197.1	190.8	180.5	171.7
	780			205.3	203.0	192.6	183.9
	800				205.3	198.7	189.9
	840					205.3	202.1
	860						205.3

The table continues to the next page.

Concrete Cover = 50 mm		Fire Design Load Resistance $N_{Rd,Fire}$ [kN]					
Diameter [mm]	length l_v [mm]	R30	R60	R90	R120	R180	R240
32	350	114.5	100.3	90.0	82.8	71.0	61.0
	400	131.8	117.7	107.3	100.2	88.3	78.4
	460	152.6	138.5	128.2	121.0	109.1	99.2
	520	173.4	159.3	149.0	141.8	129.9	120.0
	580	194.2	180.1	169.8	162.6	150.7	140.8
	640	215.0	200.9	190.6	183.4	171.6	161.6
	700	235.8	221.7	211.4	204.2	192.4	182.4
	760	256.7	242.5	232.2	225.0	213.2	203.2
	800	268.1	256.4	246.1	238.9	227.0	217.1
	840		268.1	259.9	252.8	240.9	231.0
	880			268.1	266.6	254.8	244.8
	900				268.1	261.7	251.8
	920					268.1	258.7
	960						268.1
40	480	182.8	166.7	155.3	147.0	133.7	122.4
	540	206.6	190.4	179.0	170.8	157.5	146.2
	600	230.3	214.2	202.8	194.5	181.2	169.9
	660	254.1	237.9	226.5	218.3	205.0	193.7
	720	277.8	261.7	250.3	242.0	228.7	217.4
	780	301.6	285.4	274.0	265.8	252.5	241.2
	840	325.3	309.2	297.8	289.5	276.2	264.9
	900	349.1	332.9	321.5	313.3	300.0	288.7
	960	372.8	356.7	345.3	337.0	323.7	312.4
	1020	396.6	380.4	369.0	360.8	347.5	336.2
	1080	418.9	404.2	392.8	384.5	371.2	359.9
	1120		418.9	408.6	400.4	387.1	375.8
	1160			418.9	416.2	402.9	391.6
	1180				418.9	410.8	399.5
	1220					418.9	415.4
	1240						418.9

Table 7.8 Fire design load resistance values for end anchoring of beams in beam-wall connections with a concrete cover of 60 mm for rebar diameters 8, 10, 12, 14, 16, 20, 24, 25, 26, 28, 32 and 40 mm

Concrete Cover = 60 mm		Fire Design Load Resistance $N_{Rd,Fire}$ [kN]					
Diameter [mm]	length l_v [mm]	R30	R60	R90	R120	R180	R240
8	100	7.9	4.2	1.7	0.7	0.2	0.0
	140	11.3	7.7	5.0	3.1	1.0	0.4
	180	14.8	11.1	8.5	6.5	3.4	1.5
	210	16.8	13.7	11.1	9.1	6.0	3.4
	250		16.8	14.6	12.6	9.5	6.9
	280			16.8	15.2	12.1	9.5
	300				16.8	13.8	11.2
	340					16.8	14.7
	370						16.8
10	110	10.9	6.3	3.0	1.3	0.4	0.1
	150	15.2	10.7	7.4	4.9	1.7	0.7
	190	19.6	15.0	11.7	9.2	5.3	2.5
	230	23.9	19.3	16.0	13.6	9.7	6.4
	260	26.2	22.6	19.3	16.8	12.9	9.7
	300		26.2	23.6	21.2	17.3	14.0
	330			26.2	24.4	20.5	17.3
	350				26.2	22.7	19.5
	390					26.2	23.8
	420						26.2
12	130	15.7	10.2	6.2	3.3	1.0	0.4
	190	23.5	18.0	14.0	11.1	6.4	3.0
	250	31.3	25.8	21.8	18.9	14.2	10.3
	300	37.7	32.3	28.4	25.4	20.7	16.8
	350		37.7	34.9	31.9	27.2	23.3
	380			37.7	35.8	31.1	27.2
	400				37.7	33.7	29.8
	440					37.7	35.0
	480						37.7

The table continues to the next page.

Concrete Cover = 60 mm		Fire Design Load Resistance $N_{Rd,Fire}$ [kN]					
Diameter [mm]	length l_v [mm]	R30	R60	R90	R120	R180	R240
14	160	22.9	16.4	11.8	8.4	3.2	1.4
	220	32.0	25.5	20.9	17.5	12.0	7.5
	280	41.1	34.7	30.0	26.6	21.1	16.6
	340	50.2	43.8	39.1	35.7	30.2	25.7
	350	51.3	45.3	40.7	37.2	31.7	27.2
	390		51.3	46.7	43.3	37.8	33.3
	420			51.3	47.8	42.4	37.9
	460				51.3	48.4	43.9
	480					51.3	47.0
	520						51.3
16	180	29.6	22.3	17.0	13.1	6.8	3.0
	240	40.0	32.7	27.4	23.5	17.2	12.0
	300	50.4	43.1	37.8	33.9	27.6	22.5
	360	60.8	53.5	48.2	44.3	38.0	32.9
	400	67.0	60.4	55.1	51.2	44.9	39.8
	440		67.0	62.1	58.1	51.9	46.7
	480			67.0	65.1	58.8	53.7
	500				67.0	62.3	57.1
	540					67.0	64.1
	560						67.0
20	220	45.7	36.5	29.9	25.0	17.2	10.7
	280	58.7	49.5	42.9	38.0	30.2	23.7
	340	71.7	62.5	55.9	51.0	43.2	36.7
	400	84.7	75.5	68.9	64.0	56.2	49.7
	460	97.7	88.5	81.9	77.0	69.2	62.7
	500	104.7	97.2	90.6	85.7	77.9	71.4
	540		104.7	99.3	94.4	86.5	80.1
	580			104.7	103.0	95.2	88.8
	600				104.7	99.5	93.1
	640					104.7	101.8
	660						104.7

The table continues to the next page.

Concrete Cover = 60 mm		Fire Design Load Resistance $N_{Rd,Fire}$ [kN]					
Diameter [mm]	length l_v [mm]	R30	R60	R90	R120	R180	R240
24	270	67.8	56.8	48.9	43.0	33.6	25.9
	330	83.4	72.4	64.5	58.6	49.2	41.5
	390	99.0	88.0	80.1	74.2	64.8	57.1
	440	112.0	101.0	93.1	87.2	77.8	70.1
	500	127.6	116.6	108.7	102.8	93.4	85.7
	560	143.2	132.2	124.3	118.4	109.0	101.3
	600	150.8	142.6	134.7	128.8	119.4	111.7
	640		150.8	145.1	139.2	129.8	122.1
	680			150.8	149.7	140.2	132.5
	700				150.8	145.5	137.7
	740					150.8	148.1
	760						150.8
25	280	73.3	61.9	53.6	47.5	37.7	29.7
	340	89.6	78.1	69.9	63.8	54.0	45.9
	400	105.9	94.4	86.2	80.0	70.2	62.2
	460	122.1	110.7	102.4	96.3	86.5	78.4
	520	138.4	126.9	118.7	112.5	102.7	94.7
	580	154.6	143.2	134.9	128.8	119.0	111.0
	620	163.6	154.0	145.8	139.6	129.8	121.8
	660		163.6	156.6	150.5	140.7	132.6
	700			163.6	161.3	151.5	143.5
	720				163.6	156.9	148.9
	760					163.6	159.7
	780						163.6

The table continues to the next page.

Concrete Cover = 60 mm		Fire Design Load Resistance $N_{Rd,Fire}$ [kN]					
Diameter [mm]	length l_v [mm]	R30	R60	R90	R120	R180	R240
26	290	79.1	67.2	58.6	52.2	42.0	33.7
	350	96.0	84.1	75.5	69.1	58.9	50.6
	400	110.1	98.2	89.6	83.2	73.0	64.7
	460	127.0	115.1	106.5	100.1	89.9	81.6
	520	143.9	132.0	123.4	117.0	106.8	98.5
	580	160.8	148.9	140.3	133.9	123.8	115.4
	640	177.0	165.8	157.2	150.9	140.7	132.3
	680		177.0	168.5	162.1	151.9	143.6
	720			177.0	173.4	163.2	154.8
	740				177.0	168.8	160.5
	780					177.0	171.7
	800						177.0
28	310	91.2	78.4	69.2	62.3	51.3	42.3
	370	109.5	96.6	87.4	80.5	69.5	60.5
	420	124.6	111.8	102.6	95.7	84.7	75.7
	480	142.8	130.0	120.8	113.9	102.9	93.9
	540	161.0	148.2	139.0	132.1	121.1	112.1
	600	179.3	166.4	157.2	150.3	139.3	130.3
	660	197.5	184.6	175.4	168.5	157.6	148.5
	700	205.3	196.8	187.5	180.7	169.7	160.7
	740		205.3	199.7	192.8	181.8	172.8
	760			205.3	198.9	187.9	178.9
	800				205.3	200.0	191.0
	820					205.3	197.1
	860						205.3

The table continues to the next page.

Concrete Cover = 60 mm		Fire Design Load Resistance $N_{Rd,Fire}$ [kN]					
Diameter [mm]	length l_v [mm]	R30	R60	R90	R120	R180	R240
32	350	118.2	103.5	92.9	85.1	72.5	62.2
	400	135.5	120.8	110.3	102.4	89.9	79.6
	460	156.3	141.6	131.1	123.2	110.7	100.4
	520	177.1	162.4	151.9	144.0	131.5	121.2
	580	197.9	183.3	172.7	164.9	152.3	142.0
	640	218.7	204.1	193.5	185.7	173.1	162.8
	700	239.5	224.9	214.3	206.5	193.9	183.6
	760	260.4	245.7	235.1	227.3	214.7	204.4
	800	268.1	259.6	249.0	241.2	228.6	218.3
	840		268.1	262.9	255.0	242.5	232.2
	860			268.1	262.0	249.4	239.1
	880				268.1	256.4	246.1
	920					268.1	259.9
	960						268.1
40	480	186.9	170.4	158.6	149.5	135.4	124.0
	540	210.6	194.2	182.3	173.3	159.1	147.7
	600	234.4	217.9	206.1	197.0	182.9	171.5
	660	258.1	241.7	229.8	220.8	206.6	195.2
	720	281.9	265.4	253.6	244.5	230.4	219.0
	780	305.6	289.2	277.3	268.3	254.1	242.7
	840	329.4	312.9	301.1	292.0	277.9	266.5
	900	353.1	336.7	324.8	315.8	301.6	290.2
	960	376.9	360.4	348.6	339.5	325.4	314.0
	1020	400.6	384.2	372.3	363.3	349.1	337.7
	1080	418.9	407.9	396.1	387.0	372.9	361.5
	1120		418.9	411.9	402.9	388.7	377.3
	1140			418.9	410.8	396.6	385.2
	1180				418.9	412.4	401.0
	1200					418.9	409.0
	1240						418.9

Table 7.9 Fire design load resistance values for end anchoring of beams in beam-wall connections with a concrete cover of 70 mm for rebar diameters 8, 10, 12, 14, 16, 20, 24, 25, 26, 28, 32 and 40 mm

Concrete Cover = 70 mm		Fire Design Load Resistance $N_{Rd,Fire}$ [kN]					
Diameter [mm]	length l_v [mm]	R30	R60	R90	R120	R180	R240
8	100	8.6	5.0	2.2	1.0	0.3	0.1
	140	12.0	8.5	5.7	3.6	1.2	0.5
	180	15.5	11.9	9.2	7.1	3.8	1.7
	200	16.8	13.7	10.9	8.8	5.6	3.0
	240		16.8	14.4	12.3	9.0	6.4
	270			16.8	14.9	11.6	9.0
	300				16.8	14.2	11.6
	330					16.8	14.2
	360						16.8
10	110	11.8	7.3	3.9	1.7	0.5	0.2
	150	16.1	11.7	8.2	5.6	2.0	0.9
	190	20.5	16.0	12.5	9.9	5.9	2.9
	230	24.8	20.3	16.9	14.3	10.2	6.9
	250	26.2	22.5	19.0	16.4	12.4	9.1
	290		26.2	23.4	20.8	16.7	13.4
	320			26.2	24.0	20.0	16.7
	340				26.2	22.1	18.8
	380					26.2	23.2
	420						26.2
12	130	16.8	11.4	7.2	4.1	1.3	0.5
	190	24.6	19.2	15.0	11.9	7.1	3.4
	250	32.4	27.0	22.8	19.7	14.9	10.9
	300	37.7	33.5	29.3	26.2	21.4	17.4
	340		37.7	34.5	31.4	26.6	22.6
	370			37.7	35.3	30.5	26.5
	390				37.7	33.1	29.1
	440					37.7	35.6
	460						37.7

The table continues to the next page.

Concrete Cover = 70 mm		Fire Design Load Resistance $N_{Rd,Fire}$ [kN]					
Diameter [mm]	length l_v [mm]	R30	R60	R90	R120	R180	R240
14	160	24.1	17.8	13.0	9.3	3.9	1.7
	220	33.2	26.9	22.1	18.4	12.8	8.2
	280	42.3	36.0	31.2	27.5	21.9	17.3
	340	51.3	45.2	40.3	36.7	31.0	26.4
	390		51.3	47.9	44.2	38.6	33.9
	420			51.3	48.8	43.1	38.5
	440				51.3	46.2	41.5
	480					51.3	47.6
	520						51.3
16	180	31.0	23.9	18.3	14.1	7.7	3.5
	240	41.4	34.3	28.7	24.5	18.1	12.8
	300	51.8	44.7	39.1	35.0	28.5	23.2
	360	62.2	55.1	49.5	45.4	38.9	33.6
	390	67.0	60.3	54.7	50.6	44.1	38.8
	440		67.0	63.4	59.2	52.8	47.5
	480			67.0	66.2	59.7	54.4
	500				67.0	63.2	57.9
	540					67.0	64.8
	560						67.0
20	220	47.4	38.5	31.6	26.3	18.3	11.6
	280	60.4	51.5	44.6	39.4	31.3	24.7
	340	73.4	64.5	57.6	52.4	44.3	37.7
	400	86.5	77.5	70.6	65.4	57.3	50.7
	460	99.5	90.5	83.6	78.4	70.3	63.7
	500	104.7	99.2	92.3	87.0	79.0	72.3
	540		104.7	100.9	95.7	87.6	81.0
	560			104.7	100.0	92.0	85.3
	600				104.7	100.6	94.0
	620					104.7	98.4
	660						104.7

The table continues to the next page.

Concrete Cover = 70 mm		Fire Design Load Resistance $N_{Rd,Fire}$ [kN]					
Diameter [mm]	length l_v [mm]	R30	R60	R90	R120	R180	R240
24	270	69.9	59.2	50.9	44.6	34.9	27.0
	330	85.5	74.8	66.5	60.2	50.5	42.6
	390	101.1	90.4	82.1	75.8	66.1	58.2
	440	114.1	103.4	95.1	88.8	79.1	71.2
	500	129.8	119.0	110.7	104.5	94.8	86.8
	560	145.4	134.6	126.3	120.1	110.4	102.4
	600	150.8	145.0	136.7	130.5	120.8	112.8
	640		150.8	147.1	140.9	131.2	123.2
	660			150.8	146.1	136.4	128.4
	680				150.8	141.6	133.6
	720					150.8	144.0
	760						150.8
25	280	75.5	64.4	55.7	49.2	39.1	30.8
	340	91.8	80.6	72.0	65.5	55.3	47.1
	400	108.1	96.9	88.2	81.7	71.6	63.3
	460	124.3	113.1	104.5	98.0	87.9	79.6
	520	140.6	129.4	120.7	114.2	104.1	95.8
	580	156.8	145.7	137.0	130.5	120.4	112.1
	620	163.6	156.5	147.8	141.3	131.2	122.9
	660		163.6	158.7	152.2	142.1	133.8
	680			163.6	157.6	147.5	139.2
	720				163.6	158.3	150.0
	740					163.6	155.5
	780						163.6

The table continues to the next page.

Concrete Cover = 70 mm		Fire Design Load Resistance $N_{Rd,Fire}$ [kN]					
Diameter [mm]	length l_v [mm]	R30	R60	R90	R120	R180	R240
26	290	81.4	69.8	60.8	54.0	43.5	34.9
	350	98.3	86.7	77.7	70.9	60.4	51.8
	400	112.4	100.8	91.8	85.0	74.5	65.9
	460	129.3	117.7	108.7	101.9	91.4	82.8
	520	146.2	134.6	125.6	118.8	108.3	99.7
	580	163.1	151.5	142.5	135.7	125.2	116.6
	640	177.0	168.4	159.4	152.6	142.1	133.5
	680		177.0	170.7	163.9	153.4	144.8
	720			177.0	175.2	164.6	156.0
	740				177.0	170.3	161.7
	780					177.0	172.9
	800						177.0
28	310	93.7	81.2	71.5	64.2	52.9	43.6
	370	111.9	99.4	89.7	82.4	71.1	61.8
	420	127.1	114.6	104.9	97.6	86.3	77.0
	480	145.3	132.8	123.1	115.8	104.5	95.2
	540	163.5	151.0	141.3	134.0	122.7	113.4
	600	181.7	169.2	159.5	152.2	140.9	131.6
	660	199.9	187.4	177.7	170.4	159.1	149.8
	680	205.3	193.5	183.8	176.5	165.2	155.9
	720		205.3	195.9	188.6	177.3	168.0
	760			205.3	200.8	189.4	180.2
	780				205.3	195.5	186.3
	820					205.3	198.4
	860						205.3

The table continues to the next page.

Concrete Cover = 70 mm		Fire Design Load Resistance $N_{Rd,Fire}$ [kN]					
Diameter [mm]	length l_v [mm]	R30	R60	R90	R120	R180	R240
32	350	121.0	106.7	95.6	87.2	74.3	63.7
	400	138.3	124.0	112.9	104.6	91.7	81.1
	460	159.1	144.8	133.7	125.4	112.5	101.9
	520	179.9	165.6	154.6	146.2	133.3	122.7
	580	200.8	186.4	175.4	167.0	154.1	143.5
	640	221.6	207.3	196.2	187.8	174.9	164.3
	700	242.4	228.1	217.0	208.6	195.7	185.1
	760	263.2	248.9	237.8	229.4	216.5	205.9
	780	268.1	255.8	244.7	236.4	223.4	212.9
	820		268.1	258.6	250.3	237.3	226.7
	860			268.1	264.1	251.2	240.6
	880				268.1	258.1	247.5
	920					268.1	261.4
	940						268.1
40	480	189.9	174.3	161.5	152.2	137.6	125.6
	540	213.6	198.0	185.3	176.0	161.3	149.4
	600	237.4	221.8	209.0	199.7	185.1	173.1
	660	261.1	245.5	232.8	223.5	208.8	196.9
	720	284.9	269.3	256.5	247.2	232.6	220.6
	780	308.6	293.0	280.3	271.0	256.3	244.4
	840	332.4	316.8	304.0	294.7	280.1	268.1
	900	356.1	340.5	327.8	318.5	303.8	291.9
	960	379.9	364.3	351.5	342.2	327.6	315.6
	1020	403.6	388.0	375.3	366.0	351.3	339.4
	1060	418.9	403.8	391.1	381.8	367.1	355.2
	1100		418.9	406.9	397.6	383.0	371.1
	1140			418.9	413.5	398.8	386.9
	1160				418.9	406.7	394.8
	1200					418.9	410.6
	1240						418.9

Table 7.10 Fire design load resistance values for end anchoring of beams in beam-wall connections with a concrete cover of 80 mm for rebar diameters 8, 10, 12, 14, 16, 20, 24, 25, 26, 28, 32 and 40 mm

Concrete Cover = 80 mm		Fire Design Load Resistance $N_{Rd,Fire}$ [kN]					
Diameter [mm]	length l_v [mm]	R30	R60	R90	R120	R180	R240
8	100	8.7	5.9	3.1	1.3	0.4	0.1
	140	12.1	9.4	6.6	4.3	1.5	0.6
	180	15.6	12.9	10.0	7.7	4.3	2.0
	200	16.8	14.6	11.8	9.5	6.0	3.3
	230		16.8	14.4	12.1	8.6	5.9
	260			16.8	14.7	11.3	8.5
	290				16.8	13.9	11.1
	330					16.8	14.6
	360						16.8
10	110	11.9	8.5	4.9	2.3	0.7	0.2
	150	16.3	12.8	9.3	6.4	2.5	1.0
	190	20.6	17.2	13.6	10.8	6.5	3.2
	230	24.9	21.5	18.0	15.1	10.8	7.4
	250	26.2	23.7	20.1	17.3	13.0	9.6
	280		26.2	23.4	20.5	16.2	12.8
	310			26.2	23.8	19.5	16.1
	340				26.2	22.7	19.3
	380					26.2	23.6
	420						26.2
12	130	16.9	12.8	8.5	5.1	1.6	0.6
	190	24.7	20.6	16.3	12.9	7.8	3.9
	250	32.5	28.4	24.1	20.7	15.6	11.5
	290	37.7	33.6	29.4	25.9	20.8	16.7
	330		37.7	34.6	31.1	26.0	21.9
	360			37.7	35.0	29.9	25.8
	390				37.7	33.8	29.7
	420					37.7	33.6
	460						37.7

The table continues to the next page.

Concrete Cover = 80 mm		Fire Design Load Resistance $N_{Rd,Fire}$ [kN]					
Diameter [mm]	length l_v [mm]	R30	R60	R90	R120	R180	R240
14	160	24.3	19.5	14.5	10.5	4.6	2.0
	220	33.4	28.6	23.6	19.6	13.6	8.8
	280	42.5	37.7	32.7	28.7	22.7	17.9
	340	51.3	46.8	41.8	37.8	31.8	27.0
	370		51.3	46.4	42.4	36.4	31.6
	420			51.3	50.0	44.0	39.2
	440				51.3	47.0	42.2
	480					51.3	48.3
	500						51.3
16	180	31.2	25.7	20.1	15.5	8.6	3.9
	240	41.6	36.1	30.5	25.9	19.0	13.6
	300	52.0	46.5	40.9	36.3	29.4	24.0
	360	62.4	56.9	51.3	46.7	39.8	34.4
	390	67.0	62.1	56.5	51.9	45.0	39.6
	420		67.0	61.7	57.1	50.2	44.8
	460			67.0	64.0	57.2	51.7
	480				67.0	60.7	55.2
	520					67.0	62.1
	560						67.0
20	220	47.7	40.8	33.7	28.0	19.5	12.6
	280	60.7	53.8	46.7	41.0	32.5	25.6
	340	73.7	66.8	59.8	54.0	45.5	38.6
	400	86.7	79.8	72.8	67.0	58.5	51.6
	460	99.7	92.9	85.8	80.0	71.5	64.6
	500	104.7	101.5	94.4	88.7	80.2	73.3
	520		104.7	98.8	93.0	84.5	77.6
	560			104.7	101.7	93.2	86.3
	580				104.7	97.5	90.6
	620					104.7	99.3
	660						104.7

The table continues to the next page.

Concrete Cover = 80 mm		Fire Design Load Resistance $N_{Rd,Fire}$ [kN]					
Diameter [mm]	length l_v [mm]	R30	R60	R90	R120	R180	R240
24	270	70.2	62.0	53.5	46.6	36.4	28.1
	330	85.8	77.6	69.1	62.2	52.0	43.7
	390	101.4	93.2	84.7	77.8	67.6	59.4
	440	114.5	106.2	97.7	90.8	80.6	72.4
	500	130.1	121.8	113.3	106.4	96.2	88.0
	560	145.7	137.4	128.9	122.1	111.8	103.6
	580	150.8	142.6	134.1	127.3	117.0	108.8
	620		150.8	144.5	137.7	127.4	119.2
	660			150.8	148.1	137.8	129.6
	680				150.8	143.0	134.8
	720					150.8	145.2
	760						150.8
25	280	75.9	67.3	58.4	51.3	40.6	32.0
	340	92.1	83.6	74.7	67.5	56.8	48.3
	400	108.4	99.8	91.0	83.8	73.1	64.5
	460	124.6	116.1	107.2	100.0	89.3	80.8
	520	140.9	132.3	123.5	116.3	105.6	97.1
	580	157.2	148.6	139.7	132.6	121.9	113.3
	620	163.6	159.4	150.6	143.4	132.7	124.1
	640		163.6	156.0	148.8	138.1	129.6
	680			163.6	159.7	149.0	140.4
	700				163.6	154.4	145.8
	740					163.6	156.7
	780						163.6

The table continues to the next page.

Concrete Cover = 80 mm		Fire Design Load Resistance $N_{Rd,Fire}$ [kN]					
Diameter [mm]	length l_v [mm]	R30	R60	R90	R120	R180	R240
26	290	81.7	72.8	63.6	56.1	45.0	36.1
	350	98.6	89.7	80.5	73.0	61.9	53.0
	400	112.7	103.8	94.6	87.1	76.0	67.1
	460	129.6	120.7	111.5	104.0	92.9	84.0
	520	146.5	137.6	128.4	121.0	109.8	100.9
	580	163.4	154.5	145.3	137.9	126.7	117.8
	640	177.0	171.4	162.2	154.8	143.6	134.7
	660		177.0	167.9	160.4	149.3	140.4
	700			177.0	171.7	160.6	151.7
	720				177.0	166.2	157.3
	760					177.0	168.6
	800						177.0
28	310	94.1	84.5	74.6	66.5	54.6	45.0
	370	112.3	102.7	92.8	84.7	72.8	63.2
	420	127.5	117.9	107.9	99.9	87.9	78.3
	480	145.7	136.1	126.1	118.1	106.1	96.6
	540	163.9	154.3	144.4	136.3	124.4	114.8
	600	182.1	172.5	162.6	154.5	142.6	133.0
	660	200.3	190.7	180.8	172.7	160.8	151.2
	680	205.3	196.8	186.8	178.8	166.8	157.3
	720		205.3	199.0	191.0	179.0	169.4
	760			205.3	203.1	191.1	181.5
	780				205.3	197.2	187.6
	820					205.3	199.7
	840						205.3

The table continues to the next page.

Concrete Cover = 80 mm		Fire Design Load Resistance $N_{Rd,Fire}$ [kN]					
Diameter [mm]	length l_v [mm]	R30	R60	R90	R120	R180	R240
32	350	121.4	110.4	99.1	89.9	76.2	65.3
	400	138.7	127.8	116.4	107.2	93.6	82.6
	460	159.5	148.6	137.2	128.1	114.4	103.4
	520	180.4	169.4	158.0	148.9	135.2	124.2
	580	201.2	190.2	178.8	169.7	156.0	145.0
	640	222.0	211.0	199.7	190.5	176.8	165.8
	700	242.8	231.8	220.5	211.3	197.6	186.7
	760	263.6	252.6	241.3	232.1	218.4	207.5
	780	268.1	259.6	248.2	239.0	225.4	214.4
	820		268.1	262.1	252.9	239.2	228.3
	840			268.1	259.9	246.2	235.2
	880				268.1	260.0	249.1
	920					268.1	263.0
	940						268.1
40	480	190.0	178.5	165.5	155.2	139.7	127.4
	540	213.8	202.3	189.3	178.9	163.5	151.1
	600	237.5	226.0	213.0	202.7	187.2	174.9
	660	261.3	249.8	236.8	226.4	211.0	198.6
	720	285.0	273.5	260.5	250.2	234.7	222.4
	780	308.8	297.3	284.3	273.9	258.5	246.1
	840	332.5	321.0	308.0	297.7	282.2	269.9
	900	356.3	344.8	331.8	321.4	306.0	293.6
	960	380.0	368.5	355.5	345.2	329.7	317.4
	1020	403.8	392.3	379.3	368.9	353.5	341.1
	1060	418.9	408.1	395.1	384.8	369.3	357.0
	1100		418.9	410.9	400.6	385.2	372.8
	1140			418.9	416.4	401.0	388.6
	1160				418.9	408.9	396.6
	1200					418.9	412.4
	1220						418.9

Table 7.11 Fire design load resistance values for end anchoring of beams in beam-wall connections with a concrete cover of 100 mm for rebar diameters 8, 10, 12, 14, 16, 20, 24, 25, 26, 28, 32 and 40 mm

Concrete Cover = 100 mm		Fire Design Load Resistance $N_{Rd,Fire}$ [kN]					
Diameter [mm]	length l_v [mm]	R30	R60	R90	R120	R180	R240
8	100	8.7	7.9	4.9	2.5	0.7	0.2
	140	12.1	11.4	8.4	5.9	2.3	0.9
	180	15.6	14.9	11.9	9.4	5.5	2.7
	200	16.8	16.6	13.6	11.1	7.3	4.3
	210		16.8	14.5	12.0	8.1	5.2
	240			16.8	14.6	10.7	7.8
	270				16.8	13.3	10.4
	310					16.8	13.8
	350						16.8
10	110	11.9	11.0	7.2	4.1	1.2	0.4
	150	16.3	15.3	11.6	8.5	3.7	1.6
	190	20.6	19.7	15.9	12.8	8.0	4.3
	230	24.9	24.0	20.2	17.1	12.3	8.6
	250	26.2	26.2	22.4	19.3	14.5	10.8
	290			26.2	23.6	18.8	15.1
	320				26.2	22.1	18.4
	360					26.2	22.7
	400						26.2
12	130	16.9	15.8	11.3	7.6	2.6	1.1
	190	24.7	23.6	19.1	15.4	9.6	5.1
	250	32.5	31.4	26.9	23.2	17.4	12.9
	290	37.7	36.6	32.1	28.4	22.6	18.1
	300		37.7	33.4	29.7	23.9	19.4
	340			37.7	34.9	29.1	24.6
	370				37.7	33.0	28.5
	420					37.7	35.0
	460						37.7

The table continues to the next page.

Concrete Cover = 100 mm		Fire Design Load Resistance $N_{Rd,Fire}$ [kN]					
Diameter [mm]	length l_v [mm]	R30	R60	R90	R120	R180	R240
14	160	24.3	23.0	17.7	13.4	6.6	2.9
	220	33.4	32.1	26.8	22.5	15.7	10.5
	280	42.5	41.2	35.9	31.6	24.9	19.6
	340	51.3	50.3	45.0	40.7	34.0	28.7
	350		51.3	46.6	42.2	35.5	30.3
	390			51.3	48.3	41.5	36.3
	420				51.3	46.1	40.9
	460					51.3	46.9
	500						51.3
16	180	31.2	29.7	23.7	18.8	11.1	5.4
	240	41.6	40.1	34.1	29.2	21.5	15.5
	300	52.0	50.5	44.5	39.6	31.9	25.9
	360	62.4	60.9	54.9	50.0	42.3	36.3
	390	67.0	66.1	60.1	55.2	47.5	41.5
	400		67.0	61.9	56.9	49.2	43.2
	440			67.0	63.8	56.1	50.2
	460				67.0	59.6	53.7
	520					67.0	64.1
	540						67.0
20	220	47.7	45.8	38.3	32.1	22.5	15.0
	280	60.7	58.8	51.3	45.1	35.5	28.0
	340	73.7	71.8	64.3	58.1	48.5	41.1
	400	86.7	84.8	77.3	71.1	61.5	54.1
	500	104.7	104.7	99.0	92.8	83.2	75.7
	540			104.7	101.5	91.9	84.4
	560				104.7	96.2	88.7
	600					104.7	97.4
	640						104.7

The table continues to the next page.

Concrete Cover = 100 mm		Fire Design Load Resistance $N_{Rd,Fire}$ [kN]					
Diameter [mm]	length l_v [mm]	R30	R60	R90	R120	R180	R240
24	270	70.2	68.0	59.0	51.5	40.0	31.1
	330	85.8	83.6	74.6	67.2	55.6	46.7
	390	101.4	99.2	90.2	82.8	71.2	62.3
	440	114.5	112.2	103.2	95.8	84.2	75.3
	500	130.1	127.8	118.8	111.4	99.8	90.9
	560	145.7	143.4	134.4	127.0	115.4	106.5
	580	150.8	148.6	139.6	132.2	120.6	111.7
	600		150.8	144.8	137.4	125.8	116.9
	640			150.8	147.8	136.2	127.3
	660				150.8	141.4	132.5
	700					150.8	142.9
	740						150.8
25	280	75.9	73.5	64.2	56.4	44.4	35.1
	340	92.1	89.8	80.4	72.7	60.6	51.3
	400	108.4	106.1	96.7	88.9	76.9	67.6
	460	124.6	122.3	112.9	105.2	93.2	83.8
	520	140.9	138.6	129.2	121.4	109.4	100.1
	580	157.2	154.8	145.5	137.7	125.7	116.4
	620	163.6	163.6	156.3	148.5	136.5	127.2
	660			163.6	159.4	147.3	138.0
	680				163.6	152.8	143.4
	720					163.6	154.3
	760						163.6
26	290	81.7	79.3	69.6	61.5	49.0	39.3
	350	98.6	96.2	86.5	78.4	65.9	56.2
	400	112.7	110.3	100.5	92.5	80.0	70.3
	460	129.6	127.2	117.5	109.4	96.9	87.2
	520	146.5	144.1	134.4	126.3	113.8	104.1
	580	163.4	161.0	151.3	143.2	130.7	121.0
	640	177.0	177.0	168.2	160.1	147.6	137.9
	680			177.0	171.4	158.9	149.2
	700				177.0	164.5	154.8
	760					177.0	171.7
	780						177.0

The table continues to the next page.

Concrete Cover = 100 mm		Fire Design Load Resistance $N_{Rd,Fire}$ [kN]					
Diameter [mm]	length l_v [mm]	R30	R60	R90	R120	R180	R240
28	310	94.1	91.5	81.0	72.3	58.8	48.4
	370	112.3	109.7	99.2	90.5	77.0	66.6
	420	127.5	124.8	114.4	105.7	92.2	81.8
	480	145.7	143.1	132.6	123.9	110.4	100.0
	540	163.9	161.3	150.8	142.1	128.6	118.2
	600	182.1	179.5	169.0	160.3	146.8	136.4
	660	200.3	197.7	187.2	178.5	165.0	154.6
	680	205.3	203.7	193.3	184.6	171.1	160.7
	700		205.3	199.3	190.6	177.2	166.7
	720			205.3	196.7	183.2	172.8
	760				205.3	195.4	184.9
	800					205.3	197.1
	840						205.3
32	350	121.4	118.4	106.4	96.5	81.1	69.2
	400	138.7	135.7	123.8	113.8	98.4	86.5
	460	159.5	156.6	144.6	134.6	119.2	107.3
	520	180.4	177.4	165.4	155.4	140.0	128.1
	580	201.2	198.2	186.2	176.2	160.9	148.9
	640	222.0	219.0	207.0	197.1	181.7	169.7
	700	242.8	239.8	227.8	217.9	202.5	190.5
	760	263.6	260.6	248.6	238.7	223.3	211.4
	780	268.1	267.5	255.5	245.6	230.2	218.3
	800		268.1	262.5	252.5	237.2	225.2
	820			268.1	259.5	244.1	232.2
	860				268.1	258.0	246.0
	900					268.1	259.9
	940						268.1

The table continues to the next page.

Concrete Cover = 100 mm		Fire Design Load Resistance $N_{Rd,Fire}$ [kN]					
Diameter [mm]	length l_v [mm]	R30	R60	R90	R120	R180	R240
40	480	190.0	187.4	174.1	163.0	145.3	131.9
	540	213.8	211.1	197.8	186.7	169.0	155.6
	600	237.5	234.9	221.6	210.5	192.8	179.4
	660	261.3	258.7	245.3	234.2	216.5	203.1
	720	285.0	282.4	269.1	258.0	240.3	226.9
	780	308.8	306.2	292.8	281.7	264.0	250.6
	840	332.5	329.9	316.6	305.5	287.8	274.4
	900	356.3	353.7	340.3	329.2	311.5	298.1
	960	380.0	377.4	364.1	353.0	335.3	321.9
	1020	403.8	401.2	387.8	376.7	359.0	345.6
	1060	418.9	417.0	403.7	392.6	374.9	361.5
	1080		418.9	411.6	400.5	382.8	369.4
	1100			418.9	408.4	390.7	377.3
	1140				418.9	406.5	393.1
	1180					418.9	409.0
	1220						418.9

Table 7.12 Fire design load resistance values for end anchoring of beams in beam-wall connections with a concrete cover of 120 mm for rebar diameters 8, 10, 12, 14, 16, 20, 24, 25, 26, 28, 32 and 40 mm

Concrete Cover = 120 mm		Fire Design Load Resistance $N_{Rd,Fire}$ [kN]					
Diameter [mm]	length l_v [mm]	R30	R60	R90	R120	R180	R240
8	100	8.7	8.7	7.0	4.4	1.4	0.5
	140	12.1	12.1	10.5	7.8	3.6	1.5
	180	15.6	15.6	13.9	11.3	7.1	3.7
	200	16.8	16.8	15.7	13.0	8.8	5.4
	220			16.8	14.8	10.6	7.2
	250				16.8	13.2	9.8
	300					16.8	14.1
	340						16.8
10	110	11.9	11.9	9.8	6.5	2.3	0.8
	150	16.3	16.3	14.2	10.9	5.6	2.4
	190	20.6	20.6	18.5	15.2	10.0	5.7
	230	24.9	24.9	22.8	19.5	14.3	10.1
	250	26.2	26.2	25.0	21.7	16.5	12.2
	270			26.2	23.9	18.6	14.4
	300				26.2	21.9	17.6
	340					26.2	22.0
	380						26.2
12	130	16.9	16.9	14.4	10.4	4.3	1.7
	190	24.7	24.7	22.2	18.3	11.9	6.9
	250	32.5	32.5	30.0	26.1	19.7	14.7
	290	37.7	37.7	35.2	31.3	25.0	19.9
	310			37.7	33.9	27.6	22.5
	340				37.7	31.5	26.4
	390					37.7	32.9
	440						37.7
14	160	24.3	24.3	21.3	16.7	9.4	4.1
	220	33.4	33.4	30.4	25.8	18.5	12.6
	280	42.5	42.5	39.5	35.0	27.6	21.7
	340	51.3	51.3	48.6	44.1	36.7	30.8
	360			51.3	47.1	39.7	33.8
	390				51.3	44.3	38.4
	440					51.3	45.9
	480						51.3

The table continues to the next page.

Concrete Cover = 120 mm		Fire Design Load Resistance $N_{Rd,Fire}$ [kN]					
Diameter [mm]	length l_v [mm]	R30	R60	R90	R120	R180	R240
16	180	31.2	31.2	27.8	22.6	14.2	7.4
	240	41.6	41.6	38.3	33.0	24.6	17.8
	300	52.0	52.0	48.7	43.4	35.0	28.2
	360	62.4	62.4	59.1	53.8	45.4	38.6
	390	67.0	67.0	64.3	59.0	50.6	43.8
	420			67.0	64.2	55.8	49.0
	440				67.0	59.3	52.5
	500					67.0	62.9
	540						67.0
20	220	47.7	47.7	43.5	36.9	26.4	17.9
	280	60.7	60.7	56.5	49.9	39.4	30.9
	340	73.7	73.7	69.5	62.9	52.4	44.0
	400	86.7	86.7	82.5	75.9	65.4	57.0
	460	99.7	99.7	95.5	88.9	78.4	70.0
	500	104.7	104.7	104.2	97.6	87.1	78.6
	520			104.7	102.0	91.4	83.0
	540				104.7	95.8	87.3
	600					104.7	100.3
	640						104.7
24	270	70.2	70.2	65.2	57.3	44.7	34.5
	330	85.8	85.8	80.8	72.9	60.3	50.1
	390	101.4	101.4	96.4	88.5	75.9	65.7
	440	114.5	114.5	109.4	101.5	88.9	78.8
	500	130.1	130.1	125.0	117.1	104.5	94.4
	560	145.7	145.7	140.6	132.8	120.1	110.0
	580	150.8	150.8	145.8	138.0	125.3	115.2
	600			150.8	143.2	130.5	120.4
	640				150.8	140.9	130.8
	680					150.8	141.2
	720						150.8

The table continues to the next page.

Concrete Cover = 120 mm		Fire Design Load Resistance $N_{Rd,Fire}$ [kN]					
Diameter [mm]	length l_v [mm]	R30	R60	R90	R120	R180	R240
25	280	75.9	75.9	70.6	62.4	49.3	38.7
	340	92.1	92.1	86.9	78.7	65.5	54.9
	400	108.4	108.4	103.1	94.9	81.8	71.2
	460	124.6	124.6	119.4	111.2	98.0	87.5
	520	140.9	140.9	135.6	127.4	114.3	103.7
	580	157.2	157.2	151.9	143.7	130.6	120.0
	620	163.6	163.6	162.7	154.5	141.4	130.8
	640			163.6	160.0	146.8	136.2
	660				163.6	152.2	141.6
	720					163.6	157.9
	760						163.6
26	290	81.7	81.7	76.3	67.7	54.1	43.0
	350	98.6	98.6	93.2	84.6	71.0	60.0
	400	112.7	112.7	107.2	98.7	85.1	74.0
	460	129.6	129.6	124.2	115.6	102.0	91.0
	520	146.5	146.5	141.1	132.5	118.9	107.9
	580	163.4	163.4	158.0	149.4	135.8	124.8
	640	177.0	177.0	174.9	166.4	152.7	141.7
	660			177.0	172.0	158.3	147.3
	680				177.0	164.0	152.9
	740					177.0	169.9
	780						177.0
28	310	94.1	94.1	88.2	79.0	64.3	52.4
	370	112.3	112.3	106.4	97.2	82.5	70.6
	420	127.5	127.5	121.6	112.4	97.7	85.8
	480	145.7	145.7	139.8	130.6	115.9	104.0
	540	163.9	163.9	158.0	148.8	134.1	122.2
	600	182.1	182.1	176.2	167.0	152.3	140.4
	660	200.3	200.3	194.4	185.2	170.5	158.6
	680	205.3	205.3	200.5	191.3	176.6	164.7
	700			205.3	197.4	182.6	170.8
	740				205.3	194.8	182.9
	780					205.3	195.1
	820						205.3

The table continues to the next page.

Concrete Cover = 120 mm		Fire Design Load Resistance $N_{Rd,Fire}$ [kN]					
Diameter [mm]	length l_v [mm]	R30	R60	R90	R120	R180	R240
32	350	121.4	121.4	114.7	104.2	87.3	73.8
	400	138.7	138.7	132.0	121.5	104.7	91.1
	460	159.5	159.5	152.8	142.3	125.5	111.9
	520	180.4	180.4	173.6	163.1	146.3	132.8
	580	201.2	201.2	194.4	183.9	167.1	153.6
	640	222.0	222.0	215.2	204.7	187.9	174.4
	700	242.8	242.8	236.0	225.6	208.7	195.2
	760	263.6	263.6	256.9	246.4	229.5	216.0
	780	268.1	268.1	263.8	253.3	236.5	222.9
	800			268.1	260.2	243.4	229.9
	840				268.1	257.3	243.7
	880					268.1	257.6
	920						268.1
40	480	190.0	190.0	183.5	171.8	152.7	137.3
	540	213.8	213.8	207.2	195.6	176.5	161.0
	600	237.5	237.5	231.0	219.3	200.2	184.8
	660	261.3	261.3	254.7	243.1	224.0	208.5
	720	285.0	285.0	278.5	266.8	247.7	232.3
	780	308.8	308.8	302.2	290.6	271.5	256.0
	840	332.5	332.5	326.0	314.3	295.2	279.8
	900	356.3	356.3	349.7	338.1	319.0	303.5
	960	380.0	380.0	373.5	361.8	342.7	327.3
	1020	403.8	403.8	397.2	385.6	366.5	351.0
	1060	418.9	418.9	413.1	401.4	382.3	366.9
	1080			418.9	409.3	390.2	374.8
	1120				418.9	406.1	390.6
	1160					418.9	406.5
	1200						418.9

Table 7.13 Fire design load resistance values for end anchoring of beams in beam-wall connections with a concrete cover of 140 mm for rebar diameters 8, 10, 12, 14, 16, 20, 24, 25, 26, 28, 32 and 40 mm

Concrete Cover = 140 mm		Fire Design Load Resistance $N_{Rd,Fire}$ [kN]					
Diameter [mm]	length l_v [mm]	R30	R60	R90	R120	R180	R240
8	100	8.7	8.7	8.6	6.4	2.4	1.0
	140	12.1	12.1	12.1	9.9	5.3	2.4
	180	15.6	15.6	15.5	13.4	8.8	5.2
	200	16.8	16.8	16.8	15.1	10.5	7.0
	220				16.8	12.3	8.7
	280					16.8	13.9
	320						16.8
10	110	11.9	11.9	11.8	9.1	3.7	1.6
	150	16.3	16.3	16.2	13.5	7.8	3.7
	190	20.6	20.6	20.5	17.8	12.1	7.6
	230	24.9	24.9	24.8	22.1	16.4	12.0
	250	26.2	26.2	26.2	24.3	18.6	14.1
	270				26.2	20.8	16.3
	310					25.1	20.6
	320					26.2	21.7
	360						26.1
	370						26.2
12	130	16.9	16.9	16.8	13.6	6.7	2.9
	190	24.7	24.7	24.6	21.4	14.5	9.2
	250	32.5	32.5	32.4	29.2	22.3	17.0
	290	37.7	37.7	37.6	34.4	27.5	22.2
	300			37.7	35.7	28.8	23.5
	320				37.7	31.4	26.1
	370					37.7	32.6
	420						37.7
14	160	24.3	24.3	24.2	20.4	12.4	6.3
	220	33.4	33.4	33.3	29.5	21.5	15.2
	280	42.5	42.5	42.4	38.6	30.6	24.3
	340	51.3	51.3	51.3	47.7	39.7	33.4
	370				51.3	44.3	38.0
	420					51.3	45.6
	460						51.3

The table continues to the next page.

Concrete Cover = 140 mm		Fire Design Load Resistance $N_{Rd,Fire}$ [kN]					
Diameter [mm]	length l_v [mm]	R30	R60	R90	R120	R180	R240
16	180	31.2	31.2	31.1	26.7	17.6	10.5
	240	41.6	41.6	41.5	37.2	28.0	20.9
	300	52.0	52.0	51.9	47.6	38.4	31.3
	360	62.4	62.4	62.3	58.0	48.8	41.7
	390	67.0	67.0	67.0	63.2	54.0	46.9
	420				67.0	59.2	52.1
	480					67.0	62.5
	520						67.0
20	220	47.7	47.7	47.5	42.1	30.7	21.8
	280	60.7	60.7	60.5	55.1	43.7	34.8
	340	73.7	73.7	73.5	68.1	56.7	47.8
	400	86.7	86.7	86.5	81.1	69.7	60.8
	460	99.7	99.7	99.5	94.1	82.7	73.8
	500	104.7	104.7	104.7	102.8	91.4	82.5
	520				104.7	95.7	86.8
	580					104.7	99.8
	620						104.7
24	270	70.2	70.2	70.0	63.5	49.9	39.1
	330	85.8	85.8	85.6	79.1	65.5	54.7
	390	101.4	101.4	101.2	94.7	81.1	70.3
	440	114.5	114.5	114.2	107.8	94.1	83.3
	500	130.1	130.1	129.9	123.4	109.7	98.9
	560	145.7	145.7	145.5	139.0	125.3	114.6
	580	150.8	150.8	150.7	144.2	130.5	119.8
	600			150.8	149.4	135.7	125.0
	620				150.8	140.9	130.2
	660					150.8	140.6
	700						150.8

The table continues to the next page.

Concrete Cover = 140 mm		Fire Design Load Resistance $N_{Rd,Fire}$ [kN]					
Diameter [mm]	length l_v [mm]	R30	R60	R90	R120	R180	R240
25	280	75.9	75.9	75.7	68.9	54.6	43.5
	340	92.1	92.1	91.9	85.1	70.9	59.7
	400	108.4	108.4	108.2	101.4	87.2	76.0
	460	124.6	124.6	124.4	117.7	103.4	92.2
	520	140.9	140.9	140.7	133.9	119.7	108.5
	580	157.2	157.2	156.9	150.2	135.9	124.7
	620	163.6	163.6	163.6	161.0	146.8	135.6
	640				163.6	152.2	141.0
	700					163.6	157.3
	740						163.6
26	290	81.7	81.7	81.5	74.5	59.6	48.0
	350	98.6	98.6	98.4	91.4	76.6	64.9
	400	112.7	112.7	112.5	105.5	90.6	79.0
	460	129.6	129.6	129.4	122.4	107.6	95.9
	520	146.5	146.5	146.3	139.3	124.5	112.8
	580	163.4	163.4	163.2	156.2	141.4	129.7
	640	177.0	177.0	177.0	173.1	158.3	146.6
	660				177.0	163.9	152.3
	720					177.0	169.2
	760						177.0
28	310	94.1	94.1	93.8	86.3	70.3	57.8
	370	112.3	112.3	112.0	104.5	88.5	76.0
	420	127.5	127.5	127.2	119.6	103.7	91.2
	480	145.7	145.7	145.4	137.8	121.9	109.4
	540	163.9	163.9	163.6	156.1	140.1	127.6
	600	182.1	182.1	181.8	174.3	158.3	145.8
	660	200.3	200.3	200.1	192.5	176.5	164.0
	680	205.3	205.3	205.3	198.5	182.6	170.1
	720				205.3	194.7	182.2
	760					205.3	194.3
	800						205.3

The table continues to the next page.

Concrete Cover = 140 mm		Fire Design Load Resistance $N_{Rd,Fire}$ [kN]					
Diameter [mm]	length l_v [mm]	R30	R60	R90	R120	R180	R240
32	350	121.4	121.4	121.1	112.5	94.2	79.9
	400	138.7	138.7	138.5	129.8	111.6	97.2
	460	159.5	159.5	159.3	150.6	132.4	118.1
	520	180.4	180.4	180.1	171.4	153.2	138.9
	580	201.2	201.2	200.9	192.2	174.0	159.7
	640	222.0	222.0	221.7	213.0	194.8	180.5
	700	242.8	242.8	242.5	233.8	215.6	201.3
	760	263.6	263.6	263.3	254.7	236.4	222.1
	780	268.1	268.1	268.1	261.6	243.4	229.0
	800				268.1	250.3	236.0
	860					268.1	256.8
	900						268.1
40	480	190.0	190.0	190.0	181.1	160.7	144.5
	540	213.8	213.8	213.8	204.8	184.5	168.3
	600	237.5	237.5	237.5	228.6	208.2	192.0
	660	261.3	261.3	261.3	252.3	232.0	215.8
	720	285.0	285.0	285.0	276.1	255.7	239.5
	780	308.8	308.8	308.8	299.8	279.5	263.3
	840	332.5	332.5	332.5	323.6	303.2	287.0
	900	356.3	356.3	356.3	347.3	327.0	310.8
	960	380.0	380.0	380.0	371.1	350.7	334.5
	1020	403.8	403.8	403.8	394.8	374.5	358.3
	1060	418.9	418.9	418.9	410.7	390.3	374.1
	1100				418.9	406.2	390.0
	1140					418.9	405.8
	1180						418.9

Table 7.14 Fire design load resistance values for end anchoring of beams in beam-wall connections with a concrete cover of 160 mm for rebar diameters 8, 10, 12, 14, 16, 20, 24, 25, 26, 28, 32 and 40 mm

Concrete Cover = 160 mm		Fire Design Load Resistance $N_{Rd,Fire}$ [kN]					
Diameter [mm]	length l_v [mm]	R30	R60	R90	R120	R180	R240
8	100	8.7	8.7	8.7	8.2	3.7	1.6
	140	12.1	12.1	12.1	11.7	7.1	3.4
	180	15.6	15.6	15.6	15.1	10.6	6.7
	200	16.8	16.8	16.8	16.8	12.3	8.4
	260					16.8	13.6
	300						16.8
10	110	11.9	11.9	11.9	11.3	5.7	2.5
	150	16.3	16.3	16.3	15.7	10.0	5.1
	190	20.6	20.6	20.6	20.0	14.3	9.4
	230	24.9	24.9	24.9	24.3	18.7	13.8
	250	26.2	26.2	26.2	26.2	20.8	15.9
	290					25.2	20.3
	300					26.2	21.4
	340						25.7
	350						26.2
12	130	16.9	16.9	16.9	16.2	9.4	4.3
	190	24.7	24.7	24.7	24.0	17.2	11.3
	250	32.5	32.5	32.5	31.8	25.0	19.1
	290	37.7	37.7	37.7	37.0	30.2	24.3
	300				37.7	31.5	25.6
	350					37.7	32.1
	400						37.7
14	160	24.3	24.3	24.3	23.4	15.5	8.6
	220	33.4	33.4	33.4	32.6	24.6	17.8
	280	42.5	42.5	42.5	41.7	33.7	26.9
	340	51.3	51.3	51.3	50.8	42.8	36.0
	350				51.3	44.3	37.5
	400					51.3	45.1
	460						51.3

The table continues to the next page.

Concrete Cover = 160 mm		Fire Design Load Resistance $N_{Rd,Fire}$ [kN]					
Diameter [mm]	length l_v [mm]	R30	R60	R90	R120	R180	R240
16	180	31.2	31.2	31.2	30.3	21.2	13.4
	240	41.6	41.6	41.6	40.7	31.6	23.8
	300	52.0	52.0	52.0	51.1	42.0	34.2
	360	62.4	62.4	62.4	61.5	52.4	44.6
	390	67.0	67.0	67.0	66.7	57.6	49.8
	400				67.0	59.3	51.5
	460					67.0	61.9
	500						67.0
20	220	47.7	47.7	47.7	46.5	35.2	25.4
	280	60.7	60.7	60.7	59.5	48.2	38.4
	340	73.7	73.7	73.7	72.5	61.2	51.4
	400	86.7	86.7	86.7	85.5	74.2	64.4
	460	99.7	99.7	99.7	98.5	87.2	77.4
	500	104.7	104.7	104.7	104.7	95.8	86.1
	560					104.7	99.1
	600						104.7
24	270	70.2	70.2	70.2	68.8	55.2	43.4
	330	85.8	85.8	85.8	84.4	70.8	59.0
	390	101.4	101.4	101.4	100.0	86.4	74.7
	440	114.5	114.5	114.5	113.0	99.4	87.7
	500	130.1	130.1	130.1	128.6	115.0	103.3
	560	145.7	145.7	145.7	144.2	130.6	118.9
	580	150.8	150.8	150.8	149.5	135.8	124.1
	600				150.8	141.0	129.3
	640					150.8	139.7
	700						150.8
25	280	75.9	75.9	75.9	74.4	60.2	48.0
	340	92.1	92.1	92.1	90.6	76.5	64.2
	400	108.4	108.4	108.4	106.9	92.7	80.5
	460	124.6	124.6	124.6	123.2	109.0	96.7
	520	140.9	140.9	140.9	139.4	125.2	113.0
	580	157.2	157.2	157.2	155.7	141.5	129.2
	620	163.6	163.6	163.6	163.6	152.3	140.1
	680					163.6	156.3
	720						163.6

The table continues to the next page.

Concrete Cover = 160 mm		Fire Design Load Resistance $N_{Rd,Fire}$ [kN]					
Diameter [mm]	length l_v [mm]	R30	R60	R90	R120	R180	R240
26	290	81.7	81.7	81.7	80.2	65.4	52.7
	350	98.6	98.6	98.6	97.1	82.3	69.6
	400	112.7	112.7	112.7	111.2	96.4	83.7
	460	129.6	129.6	129.6	128.1	113.3	100.6
	520	146.5	146.5	146.5	145.0	130.2	117.5
	580	163.4	163.4	163.4	161.9	147.1	134.4
	640	177.0	177.0	177.0	177.0	164.1	151.3
	700					177.0	168.2
	740						177.0
28	310	94.1	94.1	94.1	92.4	76.5	62.8
	370	112.3	112.3	112.3	110.6	94.7	81.0
	420	127.5	127.5	127.5	125.8	109.9	96.2
	480	145.7	145.7	145.7	144.0	128.1	114.4
	540	163.9	163.9	163.9	162.2	146.3	132.6
	600	182.1	182.1	182.1	180.4	164.5	150.8
	660	200.3	200.3	200.3	198.6	182.7	169.0
	680	205.3	205.3	205.3	204.7	188.8	175.1
	700				205.3	194.9	181.2
	740					205.3	193.3
	780						205.3
32	350	121.4	121.4	121.4	119.5	101.3	85.7
	400	138.7	138.7	138.7	136.8	118.7	103.0
	460	159.5	159.5	159.5	157.6	139.5	123.8
	520	180.4	180.4	180.4	178.5	160.3	144.6
	580	201.2	201.2	201.2	199.3	181.1	165.4
	640	222.0	222.0	222.0	220.1	201.9	186.2
	700	242.8	242.8	242.8	240.9	222.7	207.1
	760	263.6	263.6	263.6	261.7	243.5	227.9
	780	268.1	268.1	268.1	268.1	250.5	234.8
	840					268.1	255.6
	880						268.1

The table continues to the next page.

Concrete Cover = 160 mm		Fire Design Load Resistance $N_{Rd,Fire}$ [kN]					
Diameter [mm]	length l_v [mm]	R30	R60	R90	R120	R180	R240
40	480	190.0	190.0	190.0	188.7	168.9	151.2
	540	213.8	213.8	213.8	212.5	192.6	174.9
	600	237.5	237.5	237.5	236.2	216.4	198.7
	660	261.3	261.3	261.3	260.0	240.1	222.4
	720	285.0	285.0	285.0	283.7	263.9	246.2
	780	308.8	308.8	308.8	307.5	287.6	269.9
	840	332.5	332.5	332.5	331.2	311.4	293.7
	900	356.3	356.3	356.3	355.0	335.1	317.4
	960	380.0	380.0	380.0	378.7	358.9	341.2
	1020	403.8	403.8	403.8	402.5	382.6	364.9
	1060	418.9	418.9	418.9	418.3	398.5	380.8
	1080				418.9	406.4	388.7
	1120					418.9	404.5
	1160						418.9

8 THE EFFECT OF INCLUDING STEEL REBAR IN THE 3-D MODEL

As stated in §4.5, the effect of the presence of a steel rebar in the model of end anchoring of beams in beam-wall connections is investigated in this study. For this purpose, a steel bar with square cross section 10 x 10 mm was included in two additional models, first one with concrete cover thickness of 30mm and second one of 70mm. The steel bar is considered equivalent to a rebar with 12mm diameter, even though the cross-section area of the model bar is 13% lower than that of the 12mm diameter bar. The specific heat and the thermal conductivity of the steel is modelled as temperature dependent as shown in Figure 8.1 and Figure 8.2. The emissivity of steel is taken as 0.9 and the density of steel is taken as 7900 kg/m³. The rest of the parameters are the same as the models without steel for both concrete cover thickness values.

The temperature distribution for models with and without steel for concrete cover thickness values of 30mm and 70mm are plotted in Figure 8.3 and Figure 8.4, respectively for each ISO 834-1 fire duration, and illustrated in Figure 8.5 for a 240 min ISO 834-1 fire duration.

The fire design load resistance values for models with and without steel and the difference between them for various anchorage lengths and fire durations are tabulated in Table 8.1 for concrete cover 30 mm and in Table 8.2 for concrete cover 70 mm. The same comparison is plotted in Figure 8.6 for 30 mm concrete cover and Figure 8.7 for 70 mm concrete cover.

The following results can be drawn in the light of the data that has been obtained:

- The differences between the models with and without steel become greater for smaller concrete thickness.
- For large anchorage lengths, and hence fire design resistance loads closer to steel design yielding load, the difference between the models with and without steel in terms of fire resistance loads are negligible.
- However, for smaller anchorage lengths, i.e., fire design resistance loads at around 50% of steel design yielding load, a reduction of 10% is observed in the fire design resistance load capacities for same anchorage length values if steel rebar is included in the model.
- Therefore, to account for the reduction of the fire resistance capacity when the steel rebar is included in the model, it is suggested that, in the tables from Table 7.3 to Table 7.10 which are based on models without steel, if the declared fire design resistance load for a given anchorage length is less than 70% of the steel design yielding load, a reduction factor of 0.90 should be applied to the declared fire design resistance load. Additionally, more detailed evaluations are suggested when the force to transfer is below 25% of the steel design yielding load, given the non-negligible impact provided by the presence of the steel bar for short anchorage lengths.

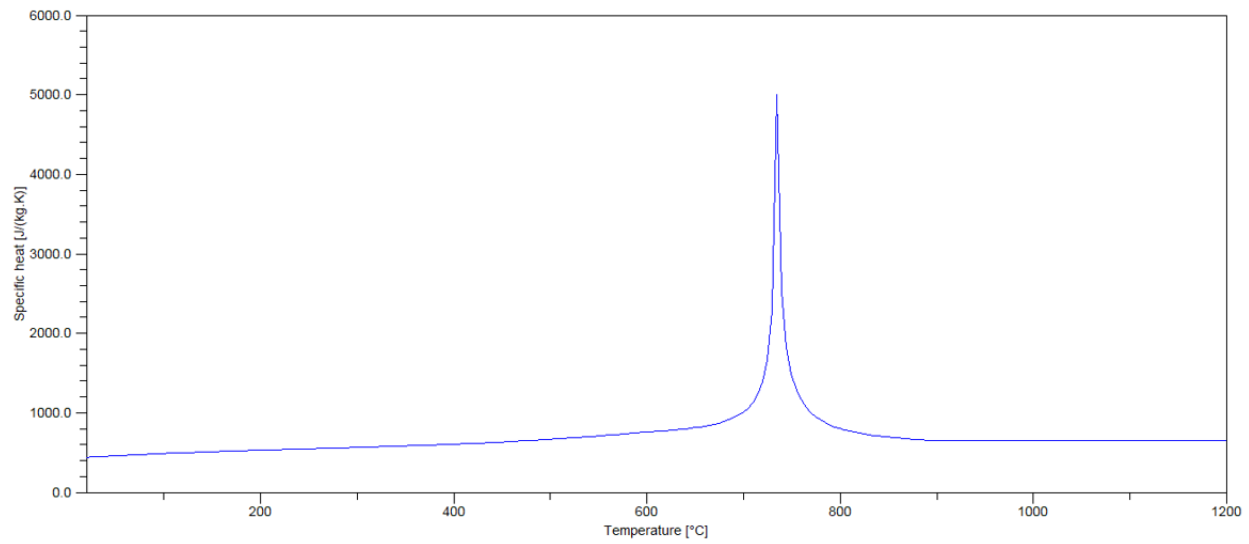


Figure 8.1 The specific heat vs temperature function of steel as modelled in VOLTRA

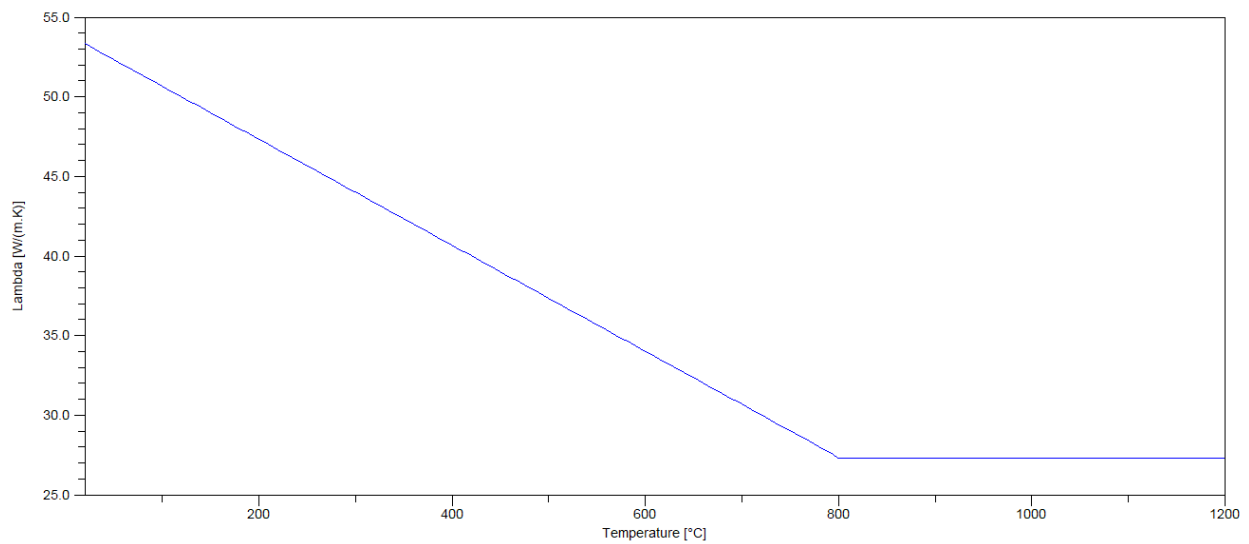


Figure 8.2 The thermal conductivity vs temperature function of steel as modelled in VOLTRA

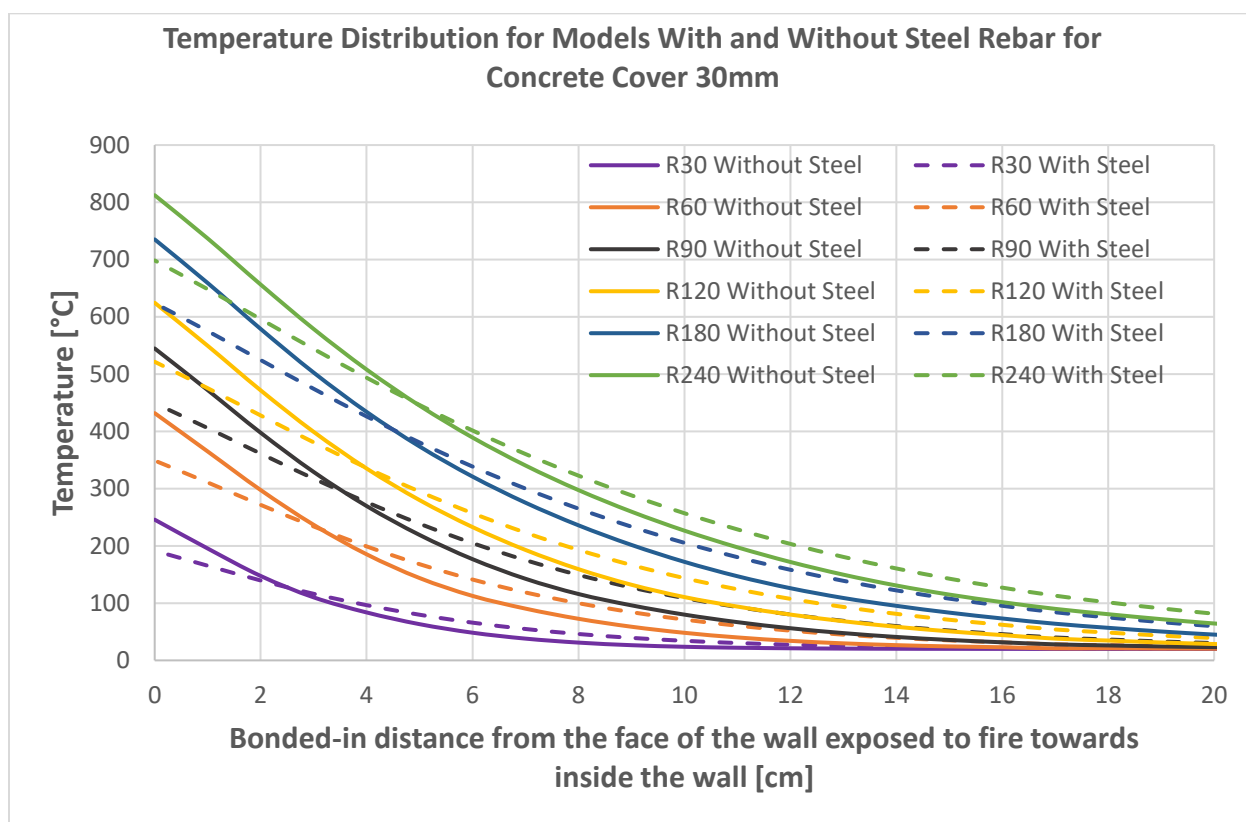


Figure 8.3 Temperature distribution for models with and without steel rebar for concrete cover 30mm

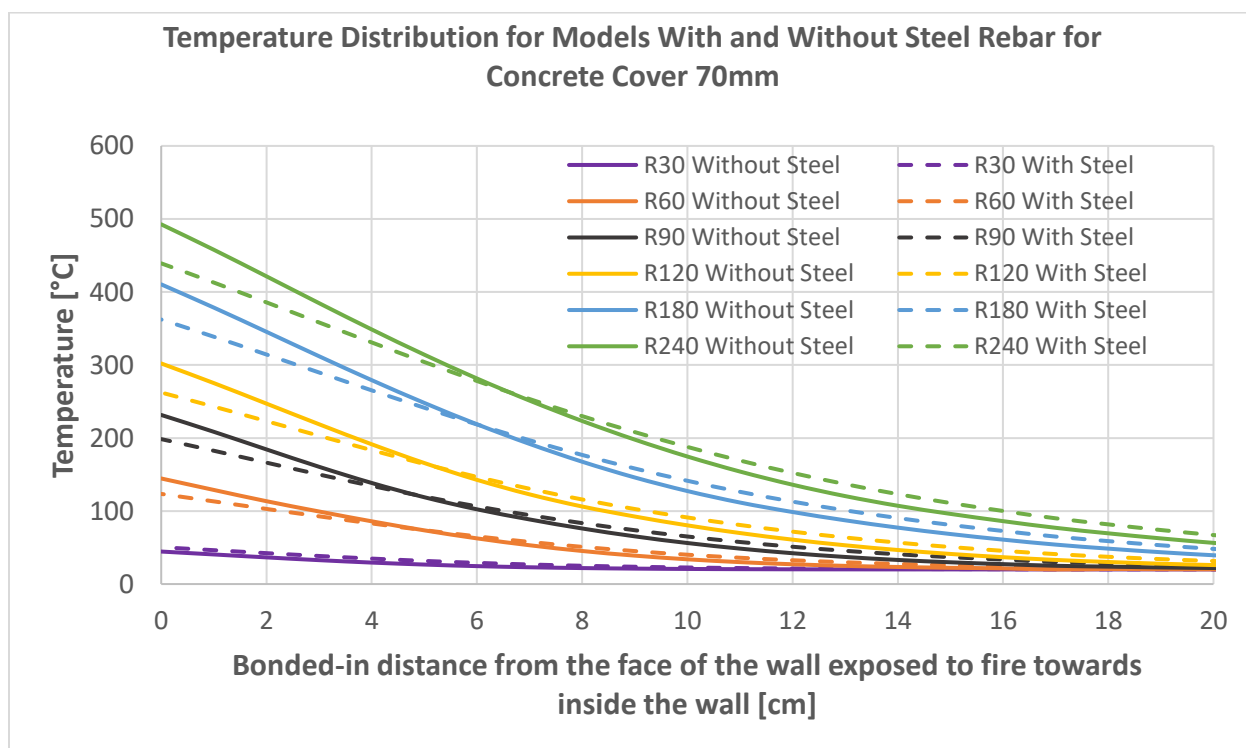


Figure 8.4 Temperature distribution for models with and without steel rebar for concrete cover 30mm

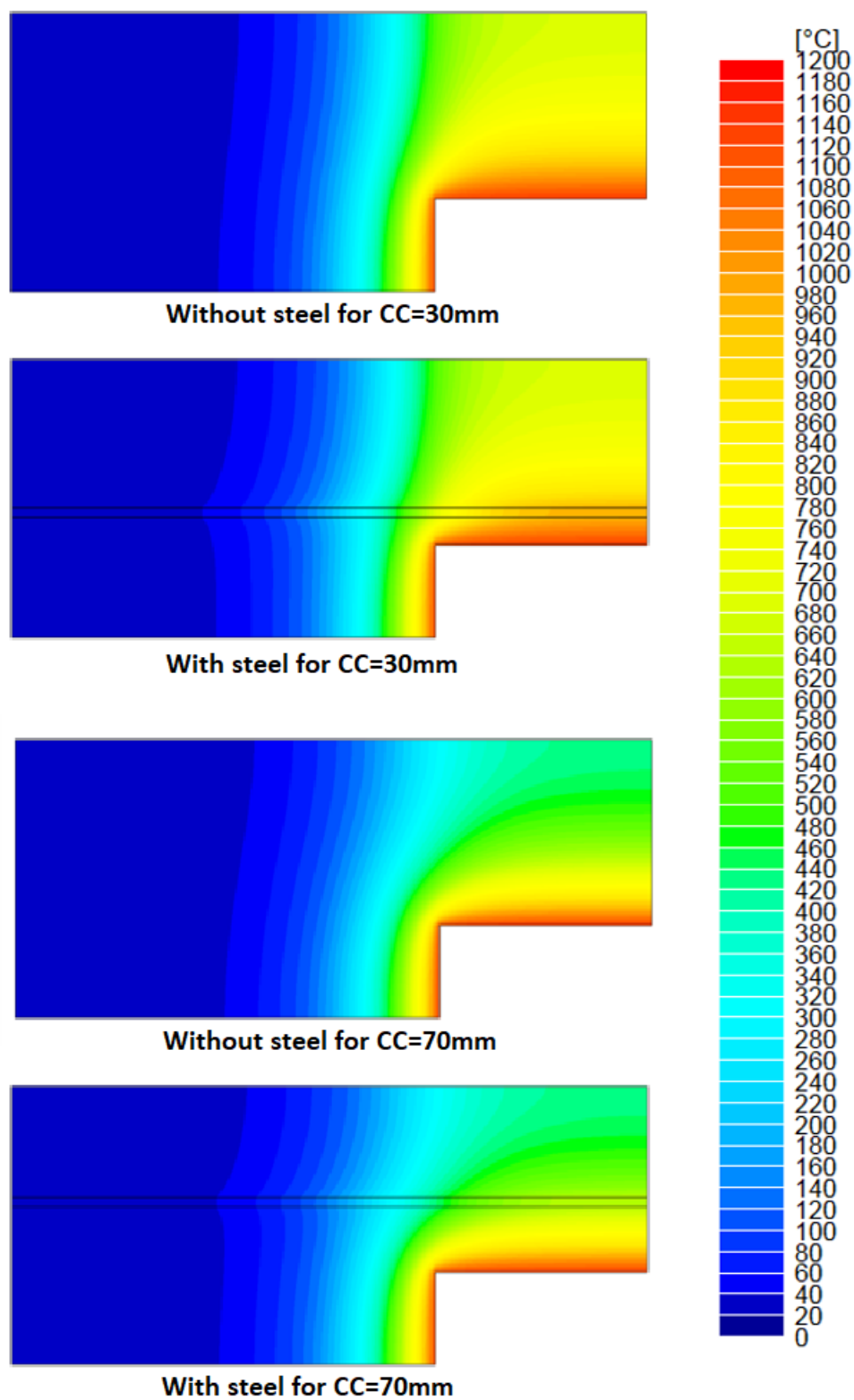


Figure 8.5 Temperature distribution at the horizontal cross-section of the position of the bar for 240 minutes of ISO 834-1 fire exposure (for concrete cover thickness 30mm, the section at 30 mm away from the bottom surface of the beam is clipped and displayed; while for concrete cover thickness 70mm, the section at 70 mm away from the bottom surface of the beam is clipped and displayed)

Table 8.1 The fire design load resistance values for 30 mm concrete cover for given bond lengths and fire durations, for models with and without steel, and their difference.

Concrete Cover = 30 mm	Without Steel $\phi 12$ Fire Design Load Resistance $N_{Rd,Fire}$ [kN]						Concrete Cover = 30 mm	With Steel $\phi 12$ Fire Design Load Resistance $N_{Rd,Fire}$ [kN]						Difference between fire design load resistances of models without and with steel rebar: (Without-With)/Without									
	length l_v [mm]	R30	R60	R90	R120	R180		R240	length l_v [mm]	R30	R60	R90	R120	R180	R240	length l_v [mm]	R30	R60	R90	R120	R180	R240	
	130	12.0	7.4	4.2	1.9	0.6	0.2		130	10.8	5.1	2.0	1.0	0.2	0.0		130	9%	31%	52%	50%	61%	100%
	170	17.2	12.6	9.4	6.8	2.7	1.2		170	16.0	10.3	6.7	4.0	1.4	0.6		170	6%	18%	29%	41%	48%	49%
	210	22.4	17.8	14.6	12.0	7.6	4.0		210	21.2	15.5	11.9	9.2	4.7	2.3		210	5%	13%	18%	23%	38%	43%
	250	27.6	23.0	19.8	17.2	12.8	9.1		250	26.5	20.7	17.1	14.4	9.9	6.3		250	4%	10%	14%	16%	23%	31%
	290	32.8	28.2	25.0	22.4	18.0	14.3		290	31.7	25.9	22.3	19.6	15.1	11.5		290	3%	8%	11%	12%	16%	20%
	330	37.7	33.4	30.2	27.6	23.2	19.5		330	36.9	31.1	27.5	24.8	20.3	16.7		330	2%	7%	9%	10%	13%	14%
	340		34.7	31.5	28.9	24.5	20.8		340	37.7	32.4	28.8	26.1	21.6	18.0		340		7%	9%	10%	12%	14%
	370		37.7	35.4	32.8	28.4	24.7		370		36.3	32.7	30.0	25.5	21.9		370		4%	8%	8%	10%	11%
	390			37.7	35.4	31.0	27.3		390		37.7	35.3	32.6	28.1	24.5		390			6%	8%	9%	10%
	420				37.7	34.9	31.2		420			37.7	36.5	32.0	28.4		420				3%	8%	9%
	440					37.5	33.8		440				37.7	34.6	31.0		440					8%	8%
	460					37.7	36.4		460					37.2	33.6		460					1%	8%
	480						37.7		480					37.7	36.2		480						4%
	500								500						37.7		500						

Table 8.2 The fire design load resistance values for 70 mm concrete cover for given bond lengths and fire durations, for models with and without steel, and their difference.

Concrete Cover = 70 mm	Without Steel $\phi 12$ Fire Design Load Resistance $N_{Rd,Fire}$ [kN]						
	length l_v [mm]	R30	R60	R90	R120	R180	R240
	130	16.8	11.4	7.2	4.1	1.3	0.5
	170	22.0	16.6	12.4	9.3	4.5	2.0
	210	27.2	21.8	17.6	14.5	9.7	5.7
	250	32.4	27.0	22.8	19.7	14.9	10.9
	290	37.6	32.2	28.0	24.9	20.1	16.1
	300	37.7	33.5	29.3	26.2	21.4	17.4
	340		37.7	34.5	31.4	26.6	22.6
	370			37.7	35.3	30.5	26.5
	380				36.6	31.8	27.8
	390				37.7	33.1	29.1
	400					34.4	30.4
	440					37.7	35.6
	460						37.7
	480						

Concrete Cover = 70 mm	With Steel $\phi 12$ Fire Design Load Resistance $N_{Rd,Fire}$ [kN]						
	length l_v [mm]	R30	R60	R90	R120	R180	R240
	130	16.9	11.3	6.4	3.0	1.0	0.3
	170	22.1	16.5	11.6	8.0	3.1	1.4
	210	27.3	21.7	16.8	13.2	7.8	4.0
	250	32.5	26.9	22.0	18.4	13.0	8.9
	290	37.7	32.1	27.2	23.6	18.2	14.1
	300		33.4	28.5	24.9	19.5	15.4
	340		37.7	33.7	30.1	24.7	20.6
	370			37.6	34.0	28.6	24.5
	380			37.7	35.3	29.9	25.8
	390				36.6	31.2	27.1
	400				37.7	32.5	28.4
	440					37.7	33.6
	460						36.2
	480						37.7

Difference between fire design load resistances of models without and with steel rebar: (Without-With)/Without						
length l_v [mm]	R30	R60	R90	R120	R180	R240
130	-1%	1%	12%	26%	23%	34%
170	-1%	0%	7%	15%	30%	30%
210	-1%	0%	5%	9%	19%	30%
250	0%	0%	4%	7%	12%	18%
290	0%	0%	3%	5%	9%	12%
300		0%	3%	5%	9%	11%
340		0%	3%	4%	7%	9%
370			0%	4%	6%	7%
380				4%	6%	7%
390				3%	6%	7%
400					5%	7%
440					0%	6%
460						4%
480						

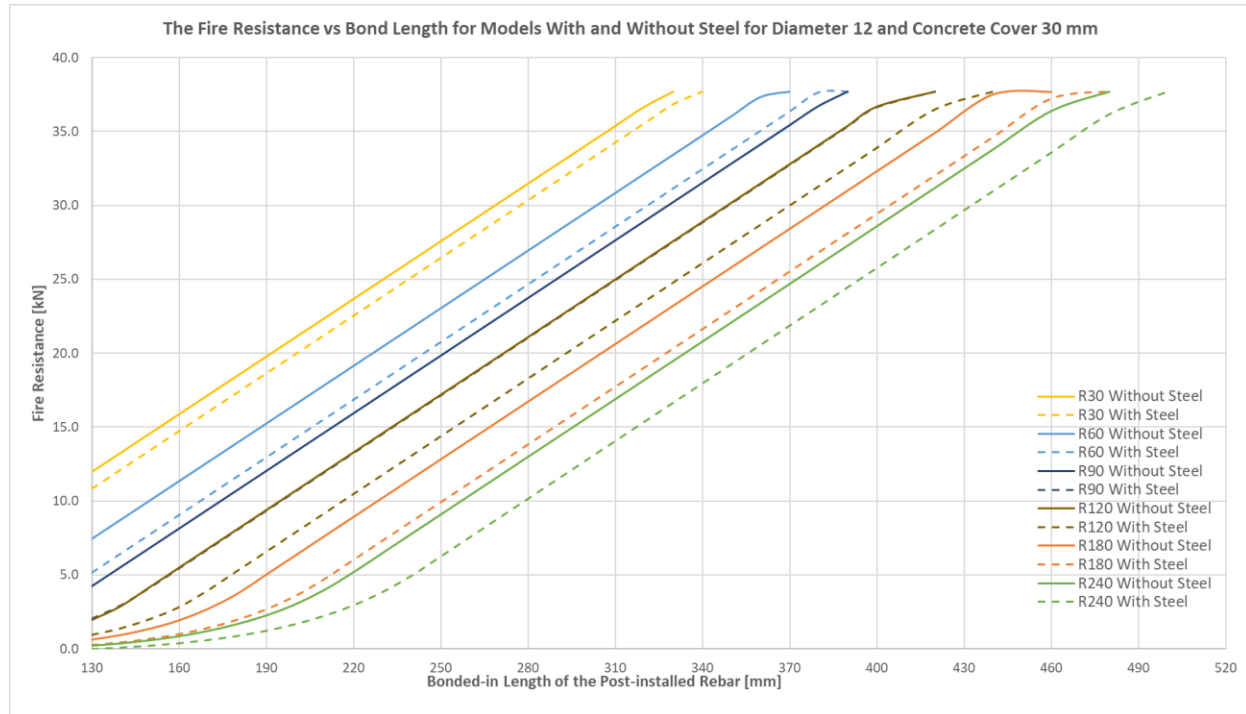


Figure 8.6 Comparison of models with and without steel for various anchorage lengths and ISO 834-1 fire durations for 30 mm concrete cover

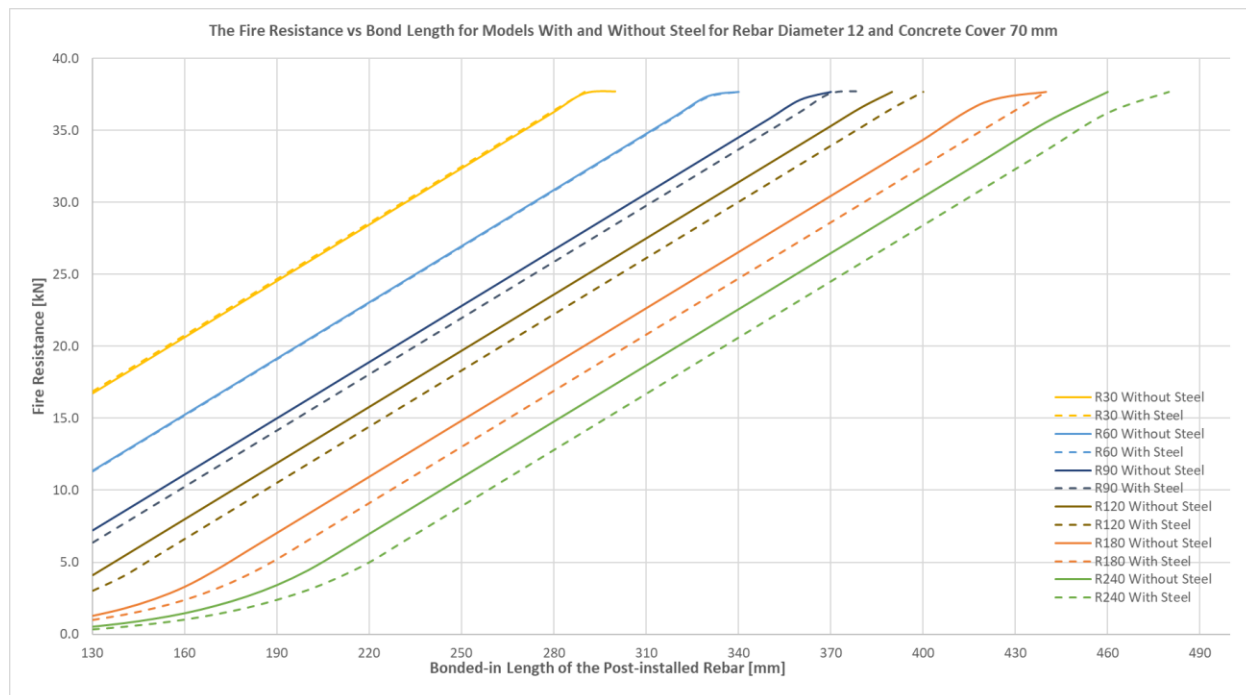


Figure 8.7 Comparison of models with and without steel for various anchorage lengths and ISO 834-1 fire durations for 70 mm concrete cover