The Passive Fire Protection Handbook I
Structural steel – Corrugated steel – Concrete

SAINT-GOBAIN

1. PROTECTION OF STRUCTURAL STEEL

FIRE PROTECTION INCREASE OF STRUCTURAL STEEL

Fire has become one of the greatest threats to buildings. It threatens and kills human beings, destroys properties and also leads to expensive production stoppages and high costs for consequential damage. The bearing capacity of a steel structure is substantially reduced if temperature rises due to fire. The temperature which the structure will reach in a fire will depends on the location, its size and a passive fire protection of structural steel members. ISOVER FireProtect® is a simple and reliable system that limits the temperature rise in the steel, therefore helps to save lives and protect property in the event of fire. Typical structures commonly designed using advantages of load-bearing capacities of steel are sports stadia, offices, industrial buildings, airport terminals, leisure centres, hospitals and shopping centres.

Fire protection cladding ISOVER FireProtect®

The ISOVER FireProtect system provides very efficient fire protection for structural steel. It is a quick, simple and secure system with easily worked materials and simple fixing equipment, which is assembled without complicated, expensive installation tools.

Fire classification

Fire protection system ISOVER FireProtect® was officially tested in PAVUS, a.s., authorized body AO 216. Based on proven modern and innovative system design it is possible to protect both steel columns and beams up to fire resistance R 180 within design temperatures 450–700 °C, for section factor up to $A_p/V = 645$ m^{-1}. Classification according to the latest standard EN 13501-2: 2016, testing based on EN 13381-4: 2013.

Why use ISOVER FireProtect®?

Features	Benefits
Fulfills EN 13381-4:2013	Superior fire resistance
Euroclass A1 fire rating according to EN 13501-1	Totally non-combustible, top level reaction to fire performance
Up to 5 times lighter than conventional solutions	Easy to handle
Easy to cut and fit	Standard insulators knife can be used
Fast installation	Dry way of assembly without need to use paint and glue
Off-cuts can be used	Minimises wastes on site
No need for pre-fabrication	Cost savings
High quality stone wool	Will not absorb moisture from the surrounding air and is chemically inert – will not accelerate corrosion of steel
	Performance will not deteriorate over time – long product life, no ageing of product
	Superior thermal insulation properties (low thermal conductivity)

2. SYSTEM ISOVER FIREPROTECT®

Fixing materials and tools:
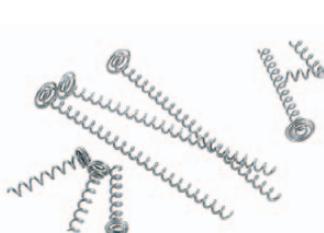
- slabs ISOVER FireProtect® 150
- Fire Screws
- stud-welded pins or pins and washers as required
- standard laggers knife
- screwdriver (preferably battery-powered) or equipment with welding gun
- rubber hammer

Fig. 1 Tools to be used for mounting ISOVER FireProtect®

Fire Screws

Fire Screw are available in different lengths. The screw must be at least twice as long as the insulation thickness.

Length (mm)	Pcs / Packing
40	1000
60	1000
80	1000
100	500
120	500
140	500
160	200
180	200
200	200

Stud-welded pins or pins and washers

Pins have a diameter of 2.7 mm and the washer's diameter is 30 mm.

Slabs ISOVER FireProtect® 150

The production of stone wool slabs is based on the defibering of molten raw materials consisting of minerals and different amounts of artificial resins as binders, mineral oils for dust suppression and hydrophobic means. Behaviour with stainless austenitic steels – AS quality for this application according to AGI Q 132, EN 13468 and ASTM C 795. Fibres are hydrophobic according to EN 1609.

Technical parameters:

Designation code: MW – EN 14303 – T5 – CS(10)20 – ST(+)700 – WS1 – CL10

| Thickness (mm)	Slabs are stored on a pallet		Packages on a pallet				
	Dimensions (mm)	m² / Pallet	Dimensions (mm)	m² / Pallet	m² / Package	Package / Pallet	Slabs / Package
20	1000 × 1200	72.00	600 × 1200	86.40	8.64	10	12
25	1000 × 1200	57.60	-	-	-	-	-
30	1000 × 1200	48.00	600 × 1200	60.48	5.04	12	7
40	1000 × 1200	36.00	600 × 1200	43.20	4.32	10	6
50	1000 × 1200	28.80	600 × 1200	34.56	2.88	12	4
60	1000 × 1200	24.00	600 × 1200	28.80	2.88	10	4
80*	1000 × 1200	19.20	600 × 1200	21.60	2.16	10	3
100*	1000 × 1200	14.40	600 × 1200	17.28	1.44	12	2

Other thicknesses and dimensions then stated can be produced at request when fulfilling minimum volume. Thickness tolerance: ±1 mm, width tolerance: ±5 mm, length tolerance: ±8 mm. * Minimal volume need to be consulted with a producer.

Parameter	Unit	Value													Standard						
THERMAL INSULATING PROPERTIES																					
Declared value of the thermal conductivity coefficient λ_D according to EN ISO 13787	°C	10	40	50	100	150	200	250	300	400	500	600	650	700							
	W·m⁻¹·K⁻¹	0.036	0.039	0.041	0.047	0.053	0.060	0.068	0.077	0.098	0.123	0.154	0.172	0.192							
Measured value of the thermal conductivity coefficient according to EN 12667	W·m⁻¹·K⁻¹	0.034	0.038	0.040	0.045	0.052	0.058	0.066	0.074	0.094	0.118	0.147	0.164	0.183							
Maximum service temperature	°C	700							EN 14706												
Specific heat capacity c_d	J·kg⁻¹·K⁻¹	800							-												
PHYSICAL PROPERTIES																					
Density (thickness 20 and 25 mm)	kg·m⁻³	165							EN 1602, EN 13470												
Density (thickness ≥ 30 mm)	kg·m⁻³	150							EN 1602, EN 13470												
Short term water absorption W_p	kg·m⁻²	<< 1							EN 1609												
Diffusion resistance factor	-	1,0							EN 12086												
Flow resistance Ξ	kPa·s·m⁻²	> 90							EN 29053												
FIRE SAFETY PROPERTIES																					
Reaction to fire	-	A1							EN 13501-1												
Melting temperature t_t	°C	≥ 1000							DIN 4102 part 17												

ADDITIONAL PROPERTIES

Acoustic absorption coefficient α for perpendicular impact of acoustic waves (-) according to EN ISO 354 and EN ISO 11654	Frequency		Hz	125	250	500	1000	2000	4000
	Thickness	20	mm	0.05	0.20	0.55	0.85	0.95	1.00
		40	mm	0.20	0.65	0.90	0.90	0.95	0.95
		60	mm	0.25	0.65	0.80	0.85	0.90	0.95
		100	mm	0.40	0.70	0.85	0.95	0.95	0.95

Definition of single number value according to EN ISO 11654	Single number value		-	α_w		NRC		Absorption class	
	Thickness	20	mm	0.50 (M, H)		0.65		D	
		40	mm	0.90		0.85		A	
		60	mm	0.85		0.90		B	
		100	mm	0.90		0.85		A	

FIXING

There are two possibilities how to fix slabs ISOVER FireProtect® 150 to the steel members:

- with Fire Screws in length corresponding to double the insulation thickness,
- with stud-welded pins or pins and washers, where diameter of the pin is 2.7 mm and diameter of the washer is 30 mm.

Both methods can be also combined.

Use of Fire Screws

Fixing of slabs to fitted pieces

Fixing of fire protective slabs ISOVER FireProtect® 150 is done with Fire Screws to fitted pieces from the same slab of width 100 mm and length corresponding to the distance between flanges plus 2–3 mm. However, a minimum slab thickness of 40 mm must be used for the fitted pieces. Maximum spacing is 600 mm. Maximum distance between Fire Screws and from axis of connected slab is 200 mm.

Fixing of slabs at the corners

Adjacent slabs are at the corners connected by Fire Screws at distances 150 mm, first Fire Screw is positioned at least 25 mm from edge of the slab.

Placement of the Fire Screws
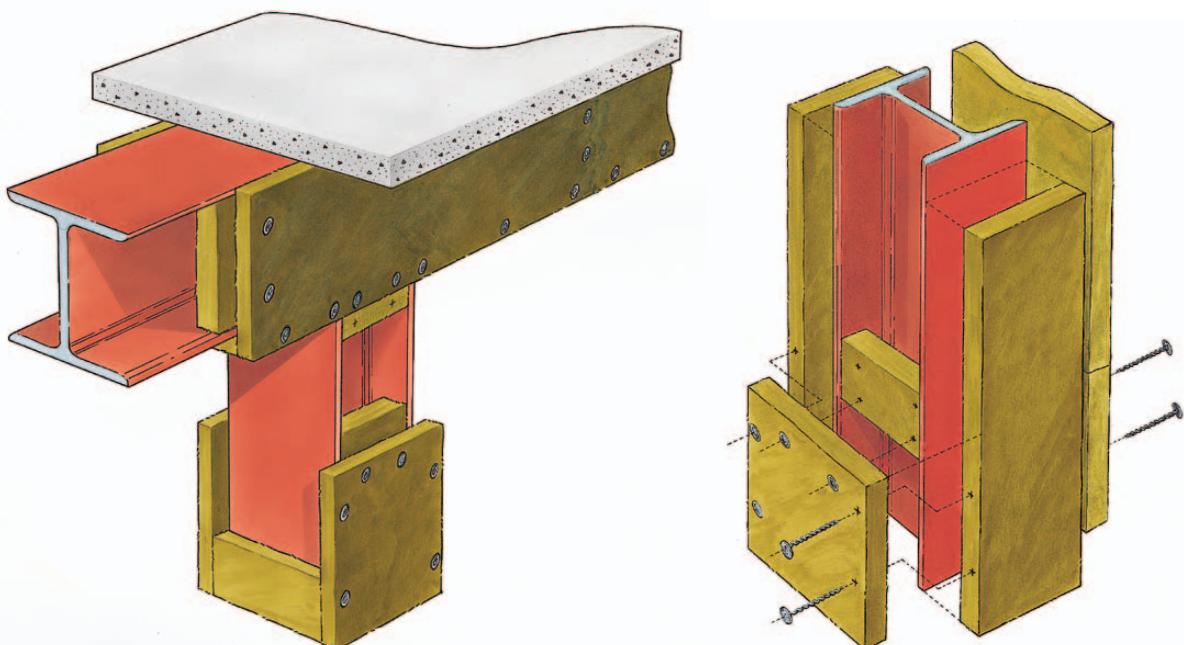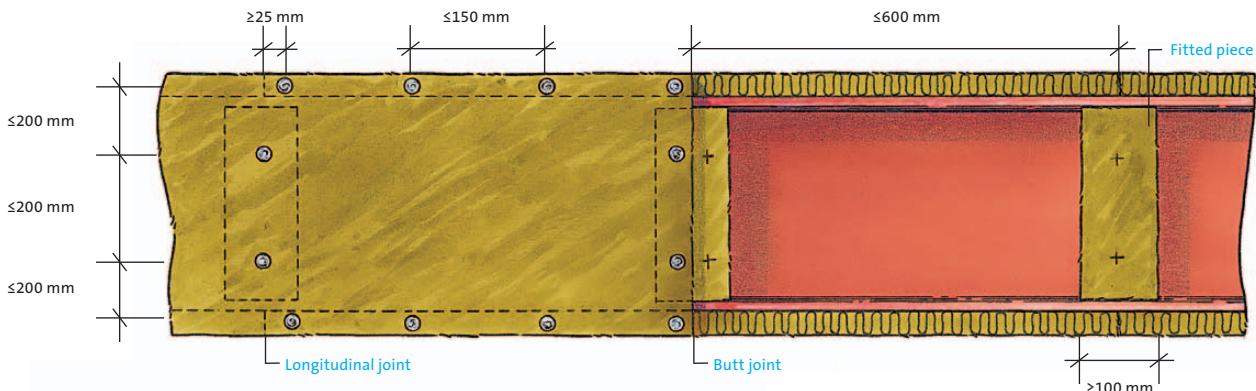
Fig. 2 Installation of ISOVER FireProtect® with Fire Screws

3. MOUNTING AND FIXING

4-sided fire loading	4-sided fire loading	3-sided fire loading	3-sided fire loading	Special shaping for 4-sided fire loading
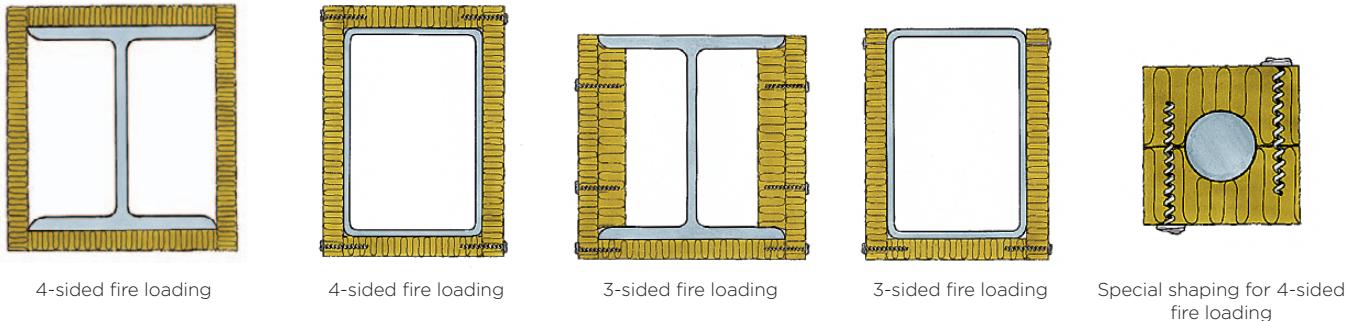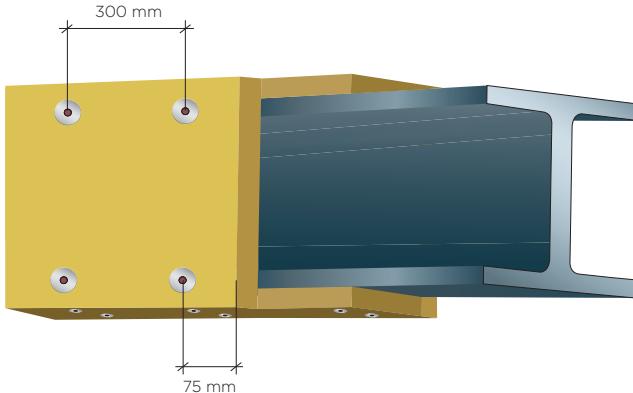
Fig. 3 Position of the fixations

In the case of closed beams insulated with 3-sided cladding the upper row of Fire Screws is replaced with pins fixed to the top flange of the beam. For I-beam it is possible to use pins or Fire Screws.

Use of pins

Slabs are fixed with welding pins in maximum distance of 300 mm. Maximum distance from the cladding's edges is 75 mm.

Fig. 4 Fixing of ISOVER FireProtect® with pins
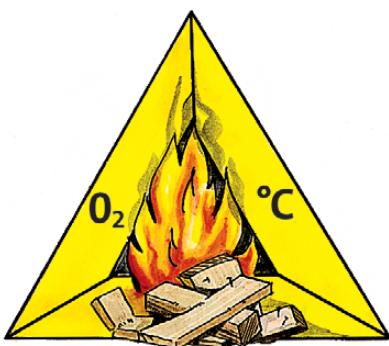
Fig. 5 Both methods can be also combined – important is to keep the distances (between pins 300 mm and between Fire Screws 150 mm)

What happens in a fire?

A fire is a blaze which is out of control. The design of steel structures must take account of the reduction in strength of the steel due to temperature loads in the event of fire.

Fire

Fire is a combustion process that liberates heat and light. Combustible material, oxygen and heat must be present to feed the fire. If one of the three is absent, the fire goes out.

Progress of a fire

The progress of a fire in a building is determined first and foremost by the quantity of combustible material. The oxygen supply is also highly significant. The progress of a normal fire can be described as shown in fig. 6.

The ignition phase is the most important phase from a safety point of view. It is during this phase that it is possible to make rescue efforts and extinguish the fire.

The temperature rises quickly, and combustible materials emit flammable gases and smoke. When the flammable gases reach their flashpoint, flashover can occur.

The flame phase starts when flashover occurs. People in the room at that time have little chance of leaving alive, and the rescue teams have little chance of extinguishing the fire. In the flame phase, the temperature reaches a maximum of around 1000 °C. Fire insulation of structural steelwork ensures that the building does not collapse.

In the cooling phase, or rather the glowing phase, the carbonised remnants and embers usually emit strong radiant heat. Even during this phase, the fire insulation protects the steel structures from harmful temperature rises.

Fire | Cooling
Ignition
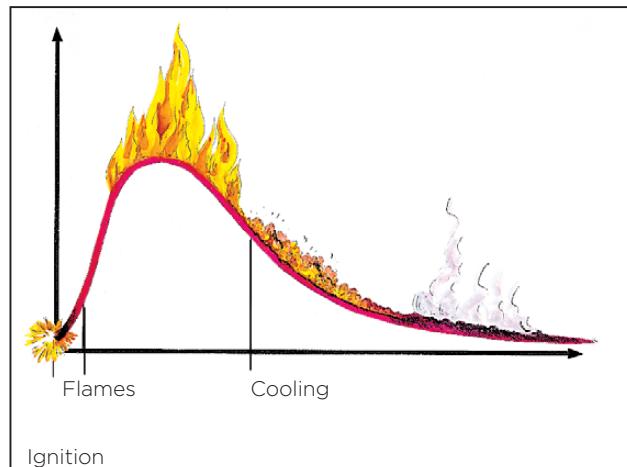
Fig. 6 Progression of a fire (in a building)

Non-combustible materials

The combustibility of a material is determined in accordance with an international fire testing method (EN ISO 1182 and EN ISO 1716).

Slabs ISOVER FireProtect® 150 contains so little flammable binder that in practice it does not contribute to the fire. Therefore, the material is classified as non-combustible with reaction to fire A1 according to EN 13501-1.

Steel strength

Steel strength is reduced at high temperatures. The critical temperature is the temperature at which yield stress occurs in the steel. The critical temperature of the steel therefore depends on the degree to which its strength is used structurally.
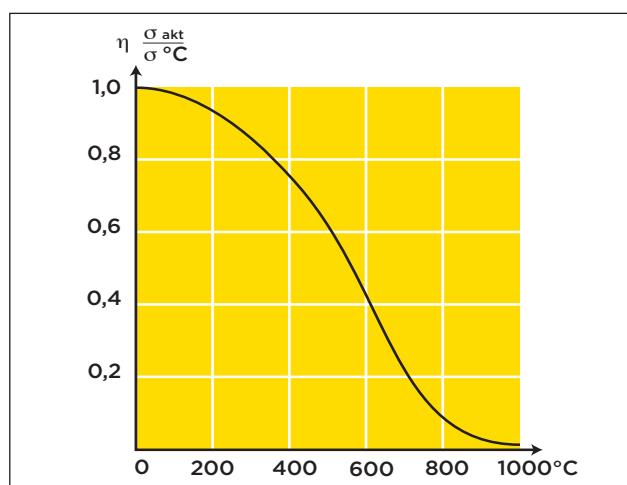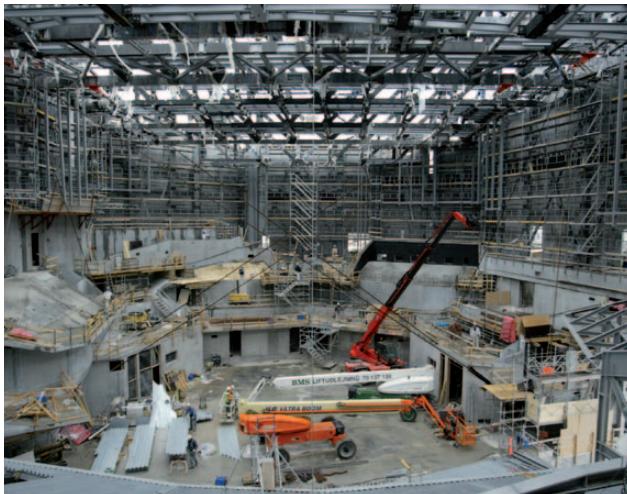
Fig. 7 The strength of the steel as a function of the temperature

Steel structures

In the design of a steel structure, consideration must be given to how the steel would be affected under the influence of fire, causing the tension in the steel to decrease with increasing temperature. ISOVER FireProtect® is a very efficient system for limiting temperature rise of the supporting steel structure, thus prolonging its fire resistance.

Fire resistance

Coarse structures have the best fire resistance. How quickly a steel structure is heated in a given fire is measured by the ratio of profile steel fire exposed surfaces and profile heat capacity. This relationship is expressed through the so-called section factor, A_p/V. Ap is the internal perimeter of the insulation in meters, V is the steel cross-sectional area in m^2. Examples of profiles with a low section factor are HEB and HEM. High section factor means quick heating of the steel. This means that slender structural steel requires thicker fire insulation.

Calculation

The fire resistance of a steel structure is calculated on the basis of the critical steel temperature. Calculation of the critical steel temperature is based on steel cross-section load ratio.

Normally, you can calculate the required insulation thickness at the critical steel temperature of 500 °C. You can check with the designer for that project on the critical steel temperature for the different structures and find out if it is higher compared to the amount of steel used in a normal situation. A higher critical steel temperature of the steel will require thinner insulation thickness. More information can be found in EN 1993-1-2: Eurocode 3: Design of steel structures – Part 1-2: General rules - Structural fire design.

$$A_p = 2b + 2h$$
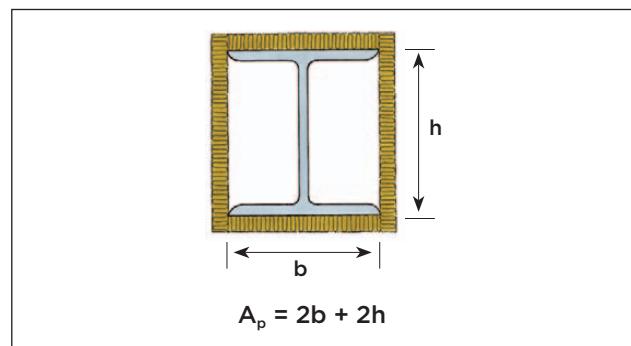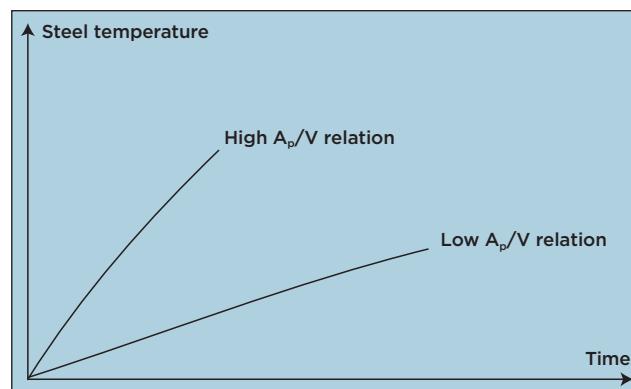
Fig. 8 Examples of profiles with a low section factor are HEB and HEM. High section factor means quick heating of the steel. This means that slender structural steel requires thicker fire insulation.

Section factor
A_p = internal perimeter of the insulation (m)
V = steel cross-sectional area (m^2)

Rising of steel temperature

Design table of maximum section factors for all fire resistances

Fire resistance classification (min)	Protection thickness (min)	Maximum section factor [m⁻¹] to maintain steel temperature below design temperature								
		Critical steel temperature [°C]								
		450	500	525	550	560	600	620	650	700
R 30	20	357	558	645	645	645	645	645	645	645
	25	440	645	645	645	645	645	645	645	645
	30	544	645	645	645	645	645	645	645	645
	40	645	645	645	645	645	645	645	645	645
R 45	20	227	327	357	357	357	357	394	477	645
	25	269	357	357	357	357	398	446	536	645
	30	316	357	357	357	364	449	501	596	645
	40	357	357	393	441	462	560	618	645	645
	50	360	446	496	552	576	645	645	645	645
	60	465	565	622	645	645	645	645	645	645
	80	645	645	645	645	645	645	645	645	645
R 60	20	128	165	187	214	225	281	316	357	357
	25	149	190	215	243	256	317	354	357	357
	30	171	216	243	274	288	353	357	357	357
	40	218	272	303	339	355	357	357	357	394
	50	272	333	357	357	357	357	357	389	451
	60	333	357	357	357	357	390	411	445	507
	80	362	411	436	461	471	512	532	564	616
	100	522	568	590	610	619	645	645	645	645
R 90	20	69	83	91	99	103	118	127	141	167
	25	79	94	103	112	116	133	142	157	185
	30	89	106	115	125	129	147	157	173	203
	40	110	130	141	152	157	177	188	205	237
	50	133	155	167	180	185	207	218	237	270
	60	157	182	195	208	214	237	249	268	301
	80	211	239	254	268	274	298	310	329	357
	100	274	303	317	332	338	357	357	357	357
R 120	20			60	65	67	75	79	86	99
	25		63	68	73	75	84	89	96	110
	30	60	70	76	81	84	93	98	106	121
	40	74	85	92	98	101	112	117	126	142
	50	88	101	108	115	118	130	136	146	163
	60	103	118	125	133	136	149	156	166	184
	80	135	152	160	169	173	187	194	205	223
	100	170	188	198	207	210	225	232	243	261
R 180	25									61
	30								60	67
	40				57	59	64	67	71	79
	50		60	63	67	69	75	78	83	91
	60	61	69	73	77	79	85	89	94	103
	80	78	88	92	97	99	107	111	117	126
	100	97	107	113	118	120	128	133	139	149

Design table for fire resistance **30 min**

Section factor (m⁻¹)	Design temperature (°C)								
	450	**500**	**525**	**550**	**560**	**600**	**620**	**650**	**700**
	Fire protection thickness (mm) to keep steel temperature under design temperature								
≤ 50	20	20	20	20	20	20	20	20	20
60	20	20	20	20	20	20	20	20	20
70	20	20	20	20	20	20	20	20	20
80	20	20	20	20	20	20	20	20	20
90	20	20	20	20	20	20	20	20	20
100	20	20	20	20	20	20	20	20	20
110	20	20	20	20	20	20	20	20	20
120	20	20	20	20	20	20	20	20	20
130	20	20	20	20	20	20	20	20	20
140	20	20	20	20	20	20	20	20	20
150	20	20	20	20	20	20	20	20	20
160	20	20	20	20	20	20	20	20	20
170	20	20	20	20	20	20	20	20	20
180	20	20	20	20	20	20	20	20	20
190	20	20	20	20	20	20	20	20	20
200	20	20	20	20	20	20	20	20	20
210	20	20	20	20	20	20	20	20	20
220	20	20	20	20	20	20	20	20	20
230	20	20	20	20	20	20	20	20	20
240	20	20	20	20	20	20	20	20	20
250	20	20	20	20	20	20	20	20	20
260	20	20	20	20	20	20	20	20	20
270	20	20	20	20	20	20	20	20	20
280	20	20	20	20	20	20	20	20	20
290	20	20	20	20	20	20	20	20	20
300	20	20	20	20	20	20	20	20	20
310	20	20	20	20	20	20	20	20	20
320	20	20	20	20	20	20	20	20	20
330	20	20	20	20	20	20	20	20	20
340	20	20	20	20	20	20	20	20	20
350	20	20	20	20	20	20	20	20	20
360	20	20	20	20	20	20	20	20	20
370	25	20	20	20	20	20	20	20	20
380	25	20	20	20	20	20	20	20	20
390	25	20	20	20	20	20	20	20	20
400	25	20	20	20	20	20	20	20	20
410	25	20	20	20	20	20	20	20	20
420	25	20	20	20	20	20	20	20	20
430	25	20	20	20	20	20	20	20	20
440	25	20	20	20	20	20	20	20	20
450	30	20	20	20	20	20	20	20	20
460	30	20	20	20	20	20	20	20	20
470	30	20	20	20	20	20	20	20	20
480	30	20	20	20	20	20	20	20	20
490	30	20	20	20	20	20	20	20	20
500	30	20	20	20	20	20	20	20	20
510	30	20	20	20	20	20	20	20	20
520	30	20	20	20	20	20	20	20	20
530	30	20	20	20	20	20	20	20	20
540	30	20	20	20	20	20	20	20	20
550	30	20	20	20	20	20	20	20	20
560	40	20	20	20	20	20	20	20	20
570	40	20	20	20	20	20	20	20	20
580	40	25	20	20	20	20	20	20	20
590	40	25	20	20	20	20	20	20	20
600	40	25	20	20	20	20	20	20	20
610	40	25	20	20	20	20	20	20	20
620	40	25	20	20	20	20	20	20	20
630	40	25	20	20	20	20	20	20	20
640	40	25	20	20	20	20	20	20	20
645	40	25	20	20	20	20	20	20	20

Design table for fire resistance **45 min**

Section factor (m⁻¹)	Design temperature (°C)								
	450	500	525	550	560	600	620	650	700
	Fire protection thickness (mm) to keep steel temperature under design temperature								
≤ 50	20	20	20	20	20	20	20	20	20
60	20	20	20	20	20	20	20	20	20
70	20	20	20	20	20	20	20	20	20
80	20	20	20	20	20	20	20	20	20
90	20	20	20	20	20	20	20	20	20
100	20	20	20	20	20	20	20	20	20
110	20	20	20	20	20	20	20	20	20
120	20	20	20	20	20	20	20	20	20
130	20	20	20	20	20	20	20	20	20
140	20	20	20	20	20	20	20	20	20
150	20	20	20	20	20	20	20	20	20
160	20	20	20	20	20	20	20	20	20
180	20	20	20	20	20	20	20	20	20
180	20	20	20	20	20	20	20	20	20
190	20	20	20	20	20	20	20	20	20
200	20	20	20	20	20	20	20	20	20
210	20	20	20	20	20	20	20	20	20
220	20	20	20	20	20	20	20	20	20
230	20	20	20	20	20	20	20	20	20
240	25	20	20	20	20	20	20	20	20
250	25	20	20	20	20	20	20	20	20
260	25	20	20	20	20	20	20	20	20
270	25	20	20	20	20	20	20	20	20
280	30	20	20	20	20	20	20	20	20
290	30	20	20	20	20	20	20	20	20
300	30	20	20	20	20	20	20	20	20
310	30	20	20	20	20	20	20	20	20
320	30	20	20	20	20	20	20	20	20
330	40	20	20	20	20	20	20	20	20
340	40	25	20	20	20	20	20	20	20
350	40	25	20	20	20	20	20	20	20
360	50	50	40	40	30	25	20	20	20
370	60	50	40	40	40	25	20	20	20
380	60	50	40	40	40	25	20	20	20
390	60	50	40	40	40	25	20	20	20
400	60	50	50	40	40	25	25	20	20
410	60	50	50	40	40	30	25	20	20
420	60	50	50	40	40	30	25	20	20
430	60	50	50	40	40	30	25	20	20
440	60	50	50	40	40	30	25	20	20
450	60	50	50	50	40	30	25	20	20
460	60	60	50	50	40	40	30	20	20
470	60	60	50	50	50	40	30	20	20
480	80	60	50	50	50	40	30	20	20
490	80	60	50	50	50	40	30	25	20
500	80	60	50	50	50	40	30	25	20
510	80	60	60	50	50	40	40	25	20
520	80	60	60	50	50	40	40	25	20
530	80	60	60	50	50	40	40	25	20
540	80	60	60	50	50	40	40	25	20
550	80	60	60	50	50	40	40	30	20
560	80	60	60	60	50	40	40	30	20
570	80	60	60	60	50	50	40	30	20
580	80	80	60	60	50	50	40	30	20
590	80	80	60	60	60	50	40	30	20
600	80	80	60	60	60	50	40	30	20
610	80	80	60	60	60	50	40	40	20
620	80	80	60	60	60	50	40	40	20
630	80	80	80	60	60	50	50	40	20
640	80	80	80	60	60	50	50	40	20
645	80	80	80	60	60	50	50	40	20

Design table for fire resistance **60 min**

Section factor (m⁻¹)	Design temperature (°C)								
	450	500	525	550	560	600	620	650	700
	Fire protection thickness (mm) to keep steel temperature under design temperature								
≤ 50	20	20	20	20	20	20	20	20	20
60	20	20	20	20	20	20	20	20	20
70	20	20	20	20	20	20	20	20	20
80	20	20	20	20	20	20	20	20	20
90	20	20	20	20	20	20	20	20	20
100	20	20	20	20	20	20	20	20	20
110	20	20	20	20	20	20	20	20	20
120	20	20	20	20	20	20	20	20	20
130	20	20	20	20	20	20	20	20	20
140	25	20	20	20	20	20	20	20	20
150	25	20	20	20	20	20	20	20	20
160	30	20	20	20	20	20	20	20	20
170	30	25	20	20	20	20	20	20	20
180	40	25	20	20	20	20	20	20	20
190	40	25	20	20	20	20	20	20	20
200	40	30	25	20	20	20	20	20	20
210	40	30	25	20	20	20	20	20	20
220	40	40	30	25	20	20	20	20	20
230	50	40	30	25	25	20	20	20	20
240	50	40	30	25	25	20	20	20	20
250	50	40	40	30	25	20	20	20	20
260	50	40	40	30	30	20	20	20	20
270	50	40	40	30	30	20	20	20	20
280	60	50	40	40	30	25	20	20	20
290	60	50	40	40	30	25	20	20	20
300	60	50	40	40	40	25	20	20	20
310	60	50	50	40	40	25	20	20	20
320	60	50	50	40	40	25	25	20	20
330	60	50	50	40	40	30	25	20	20
340	80	60	50	40	40	30	25	20	20
350	80	60	50	50	40	30	25	20	20
360	80	80	80	80	80	60	60	50	40
370	100	80	80	80	80	60	60	50	40
380	100	80	80	80	80	60	60	50	40
390	100	80	80	80	80	60	60	50	40
400	100	80	80	80	80	80	60	60	50
410	100	80	80	80	80	80	60	60	50
420	100	100	80	80	80	80	80	60	50
430	100	100	80	80	80	80	80	60	50
440	100	100	100	80	80	80	80	60	50
450	100	100	100	80	80	80	80	80	50
460	100	100	100	80	80	80	80	80	60
470	100	100	100	100	80	80	80	80	60
480	100	100	100	100	100	80	80	80	60
490	100	100	100	100	100	80	80	80	60
500	100	100	100	100	100	80	80	80	60
510	100	100	100	100	100	80	80	80	80
520	100	100	100	100	100	100	80	80	80
530	100	100	100	100	100	100	80	80	80
540		100	100	100	100	100	100	80	80
550		100	100	100	100	100	100	80	80
560		100	100	100	100	100	100	80	80
570		100	100	100	100	100	100	100	80
580		100	100	100	100	100	100	100	80
590			100	100	100	100	100	100	80
600			100	100	100	100	100	100	80
610				100	100	100	100	100	80
620				100	100	100	100	100	100
630					100	100	100	100	100
640						100	100	100	100
645						100	100	100	100

Design table for fire resistance **90 min**

Section factor (m⁻¹)	Design temperature (°C)								
	450	**500**	**525**	**550**	**560**	**600**	**620**	**650**	**700**
	Fire protection thickness (mm) to keep steel temperature under design temperature								
≤ 50	20	20	20	20	20	20	20	20	20
60	20	20	20	20	20	20	20	20	20
70	25	20	20	20	20	20	20	20	20
80	30	20	20	20	20	20	20	20	20
90	40	25	25	20	20	20	20	20	20
100	40	30	25	20	20	20	20	20	20
110	40	40	30	25	25	20	20	20	20
120	50	40	40	30	30	25	20	20	20
130	50	40	40	40	30	25	25	20	20
140	60	50	40	40	40	30	25	25	20
150	60	50	50	40	40	40	30	25	20
160	80	60	50	50	50	40	40	30	20
170	80	60	60	50	50	40	40	30	25
180	80	60	60	50	50	50	40	40	25
190	80	80	60	60	60	50	50	40	30
200	80	80	80	60	60	50	50	40	30
210	80	80	80	80	60	60	50	50	40
220	100	80	80	80	80	60	60	50	40
230	100	80	80	80	80	60	60	50	40
240	100	80	80	80	80	80	60	60	50
250	100	100	80	80	80	80	60	60	50
260	100	100	100	80	80	80	80	60	50
270	100	100	100	100	80	80	80	80	50
280		100	100	100	100	80	80	80	60
290		100	100	100	100	80	80	80	60
300		100	100	100	100	100	80	80	60
310			100	100	100	100	80	80	80
320			100	100	100	100	100	80	80
330				100	100	100	100	80	80
340					100	100	100	100	80
350						100	100	100	80

4. DESIGN

Design table for fire resistance **120 min**

Section factor (m⁻¹)	Design temperature (°C)								
	450	500	525	550	560	600	620	650	700
	Fire protection thickness (mm) to keep steel temperature under design temperature								
≤ 50	25	20	20	20	20	20	20	20	20
60	30	25	20	20	20	20	20	20	20
70	40	30	30	25	25	20	20	20	20
80	50	40	40	30	30	25	20	20	20
90	60	50	40	40	40	30	30	25	20
100	60	50	50	50	40	40	40	30	20
110	80	60	60	50	50	40	40	40	25
120	80	80	60	60	60	50	50	40	30
130	80	80	80	60	60	50	50	50	40
140	100	80	80	80	80	60	60	50	40
150	100	80	80	80	80	80	60	60	50
160	100	100	80	80	80	80	80	60	50
170	100	100	100	80	80	80	80	80	60
180		100	100	100	100	80	80	80	60
190		100	100	100	100	100	80	80	80
200			100	100	100	100	100	80	80
210					100	100	100	100	80
220					100	100	100	100	80
230							100	100	100
240								100	100
250									100
260									100

Design table for fire resistance **180 min**

Section factor (m⁻¹)	Design temperature (°C)								
	450	500	525	550	560	600	620	650	700
	Fire protection thickness (mm) to keep steel temperature under design temperature								
≤ 50	50	40	40	40	40	30	25	25	20
60	60	50	50	50	50	40	40	30	25
70	80	80	60	60	60	50	50	40	40
80	100	80	80	80	80	60	60	50	50
90	100	100	80	80	80	80	80	60	50
100		100	100	100	100	80	80	80	60
110			100	100	100	100	80	80	80
120					100	100	100	100	80
130							100	100	100
140								100	100
150									100

Design table for critical steel temperature 450 °C

A_p/V (m^{-1})	Fire resistance period (min)						
	30	45	60	90	120	150	180
	Protection thickness (mm)						
50	20	20	20	20	25	40	50
60	20	20	20	20	30	50	60
70	20	20	20	25	40	60	80
80	20	20	20	30	50	80	100
90	20	20	20	40	60	80	100
100	20	20	20	40	60	100	
110	20	20	20	40	80	100	
120	20	20	20	50	80	100	
130	20	20	25	50	80		
140	20	20	25	60	100		
150	20	20	30	60	100		
160	20	20	30	80	100		
170	20	20	30	80	100		
180	20	20	40	80			
190	20	20	40	80			
200	20	20	40	80			
210	20	20	40	80			
220	20	20	50	100			
230	20	25	50	100			
240	20	25	50	100			
250	20	25	50	100			
260	20	25	50	100			
270	20	30	50	100			
280	20	30	60				
290	20	30	60				
300	20	30	60				
310	20	30	60				
320	20	40	60				
330	20	40	60				
340	20	40	80				
350	20	40	80				
360	25	50	80				
370	25	60	100				
380	25	60	100				
390	25	60	100				
400	25	60	100				
410	25	60	100				
420	25	60	100				
430	25	60	100				
440	30	60	100				
450	30	60	100				
460	30	60	100				
470	30	80	100				
480	30	80	100				
490	30	80	100				
500	30	80	100				
510	30	80	100				
520	30	80	100				
530	30	80					
540	30	80					
550	40	80					
560	40	80					
570	40	80					
580	40	80					
590	40	80					
600	40	80					
610	40	80					
620	40	80					
630	40	80					
640	40	80					
645	40	80					

Design table for critical steel temperature 500 °C

A_p/V (m^{-1})	Fire resistance period (min)						
	30	45	60	90	120	150	180
	Protection thickness (mm)						
50	20	20	20	20	20	30	40
60	20	20	20	20	25	40	60
70	20	20	20	20	30	50	80
80	20	20	20	20	40	60	80
90	20	20	20	25	50	80	100
100	20	20	20	30	50	80	100
110	20	20	20	40	60	80	
120	20	20	20	40	80	100	
130	20	20	20	40	80	100	
140	20	20	20	50	80		
150	20	20	20	50	80		
160	20	20	20	60	100		
170	20	20	25	60	100		
180	20	20	25	60	100		
190	20	20	30	80			
200	20	20	30	80			
210	20	20	30	80			
220	20	20	40	80			
230	20	20	40	80			
240	20	20	40	100			
250	20	20	40	100			
260	20	20	40	100			
270	20	20	40	100			
280	20	20	50	100			
290	20	20	50	100			
300	20	20	50	100			
310	20	20	50				
320	20	20	50				
330	20	25	50				
340	20	25	60				
350	20	25	60				
360	20	50	80				
370	20	50	80				
380	20	50	80				
390	20	50	80				
400	20	50	80				
410	20	50	80				
420	20	50	100				
430	20	50	100				
440	20	50	100				
450	20	60	100				
460	20	60	100				
470	20	60	100				
480	20	60	100				
490	20	60	100				
500	20	60	100				
510	20	60	100				
520	20	60	100				
530	20	60	100				
540	20	60	100				
550	20	60	100				
560	25	60	100				
570	25	80					
580	25	80					
590	25	80					
600	25	80					
610	25	80					
620	25	80					
630	25	80					
640	25	80					
645	25	80					

Design table for critical steel temperature 525 °C

A_p/V (m^{-1})	Fire resistance period (min)						
	30	45	60	90	120	150	180
	Protection thickness (mm)						
50	20	20	20	20	20	25	40
60	20	20	20	20	25	40	50
70	20	20	20	20	30	50	60
80	20	20	20	20	40	60	80
90	20	20	20	20	40	60	80
100	20	20	20	25	50	80	100
110	20	20	20	30	60	80	100
120	20	20	20	40	60	100	
130	20	20	20	40	80	100	
140	20	20	20	40	80	100	
150	20	20	20	50	80		
160	20	20	20	50	80		
170	20	20	20	60	100		
180	20	20	20	60	100		
190	20	20	25	60	100		
200	20	20	25	80			
210	20	20	25	80			
220	20	20	30	80			
230	20	20	30	80			
240	20	20	30	80			
250	20	20	40	80			
260	20	20	40	100			
270	20	20	40	100			
280	20	20	40	100			
290	20	20	40	100			
300	20	20	40	100			
310	20	20	50	100			
320	20	20	50				
330	20	20	50				
340	20	20	50				
350	20	20	50				
360	20	40	80				
370	20	40	80				
380	20	40	80				
390	20	40	80				
400	20	50	80				
410	20	50	80				
420	20	50	80				
430	20	50	80				
440	20	50	100				
450	20	50	100				
460	20	50	100				
470	20	50	100				
480	20	50	100				
490	20	50	100				
500	20	60	100				
510	20	60	100				
520	20	60	100				
530	20	60	100				
540	20	60	100				
550	20	60	100				
560	20	60	100				
570	20	60	100				
580	20	60	100				
590	20	60					
600	20	60					
610	20	60					
620	20	60					
630	20	80					
640	20	80					
645	20	80					

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Design table for critical steel temperature 550 °C

A_p/V (m⁻¹)	Fire resistance period (min)						
	30	45	60	90	120	150	180
	Protection thickness (mm)						
50	20	20	20	20	20	25	40
60	20	20	20	20	20	30	50
70	20	20	20	20	25	40	60
80	20	20	20	20	30	50	80
90	20	20	20	20	40	60	80
100	20	20	20	25	50	80	100
110	20	20	20	25	50	80	100
120	20	20	20	30	60	80	
130	20	20	20	40	60	100	
140	20	20	20	40	80	100	
150	20	20	20	40	80	100	
160	20	20	20	50	80		
170	20	20	20	50	100		
180	20	20	20	60	100		
190	20	20	20	60	100		
200	20	20	20	60	100		
210	20	20	20	80			
220	20	20	25	80			
230	20	20	25	80			
240	20	20	25	80			
250	20	20	30	80			
260	20	20	30	80			
270	20	20	30	100			
280	20	20	40	100			
290	20	20	40	100			
300	20	20	40	100			
310	20	20	40	100			
320	20	20	40	100			
330	20	20	40	100			
340	20	20	50				
350	20	20	50				
360	20	40	80				
370	20	40	80				
380	20	40	80				
390	20	40	80				
400	20	40	80				
410	20	40	80				
420	20	40	80				
430	20	40	80				
440	20	40	80				
450	20	50	80				
460	20	50	80				
470	20	50	100				
480	20	50	100				
490	20	50	100				
500	20	50	100				
510	20	50	100				
520	20	50	100				
530	20	50	100				
540	20	50	100				
550	20	50	100				
560	20	60	100				
570	20	60	100				
580	20	60	100				
590	20	60	100				
600	20	60	100				
610	20	60	100				
620	20	60					
630	20	60					
640	20	60					
645	20	60					

Design table for critical steel temperature 560 °C

A_p/V (m^{-1})	Fire resistance period (min)						
	30	45	60	90	120	150	180
	Protection thickness (mm)						
50	20	20	20	20	20	25	40
60	20	20	20	20	20	30	50
70	20	20	20	20	25	40	60
80	20	20	20	20	30	50	80
90	20	20	20	20	40	60	80
100	20	20	20	20	40	80	100
110	20	20	20	25	50	80	100
120	20	20	20	30	60	80	
130	20	20	20	40	60	100	
140	20	20	20	40	80	100	
150	20	20	20	40	80	100	
160	20	20	20	50	80		
170	20	20	20	50	80		
180	20	20	20	50	100		
190	20	20	20	60	100		
200	20	20	20	60	100		
210	20	20	20	60	100		
220	20	20	20	80			
230	20	20	25	80			
240	20	20	25	80			
250	20	20	25	80			
260	20	20	30	80			
270	20	20	30	80			
280	20	20	30	100			
290	20	20	40	100			
300	20	20	40	100			
310	20	20	40	100			
320	20	20	40	100			
330	20	20	40	100			
340	20	20	40				
350	20	20	40				
360	20	30	80				
370	20	40	80				
380	20	40	80				
390	20	40	80				
400	20	40	80				
410	20	40	80				
420	20	40	80				
430	20	40	80				
440	20	40	80				
450	20	40	80				
460	20	40	80				
470	20	50	80				
480	20	50	100				
490	20	50	100				
500	20	50	100				
510	20	50	100				
520	20	50	100				
530	20	50	100				
540	20	50	100				
550	20	50	100				
560	20	50	100				
570	20	50	100				
580	20	60	100				
590	20	60	100				
600	20	60	100				
610	20	60	100				
620	20	60					
630	20	60					
640	20	60					
645	20	60					

Design table for critical steel temperature 600 °C

A_p/V (m⁻¹)	Fire resistance period (min)						
	30	45	60	90	120	150	180
	Protection thickness (mm)						
50	20	20	20	20	20	20	30
60	20	20	20	20	20	25	40
70	20	20	20	20	20	40	50
80	20	20	20	20	25	40	60
90	20	20	20	20	30	50	80
100	20	20	20	20	40	60	80
110	20	20	20	20	40	80	100
120	20	20	20	25	50	80	100
130	20	20	20	25	50	80	
140	20	20	20	30	60	100	
150	20	20	20	40	80	100	
160	20	20	20	40	80	100	
170	20	20	20	40	80		
180	20	20	20	50	80		
190	20	20	20	50	100		
200	20	20	20	50	100		
210	20	20	20	60	100		
220	20	20	20	60	100		
230	20	20	20	60			
240	20	20	20	80			
250	20	20	20	80			
260	20	20	20	80			
270	20	20	20	80			
280	20	20	20	80			
290	20	20	25	80			
300	20	20	25	100			
310	20	20	25	100			
320	20	20	30	100			
330	20	20	30	100			
340	20	20	30	100			
350	20	20	30	100			
360	20	25	60				
370	20	25	60				
380	20	25	60				
390	20	25	80				
400	20	30	80				
410	20	30	80				
420	20	30	80				
430	20	30	80				
440	20	30	80				
450	20	40	80				
460	20	40	80				
470	20	40	80				
480	20	40	80				
490	20	40	80				
500	20	40	80				
510	20	40	80				
520	20	40	100				
530	20	40	100				
540	20	40	100				
550	20	40	100				
560	20	50	100				
570	20	50	100				
580	20	50	100				
590	20	50	100				
600	20	50	100				
610	20	50	100				
620	20	50	100				
630	20	50	100				
640	20	50	100				
645	20	50	100				

Design table for critical steel temperature 620 °C

A_p/V (m^{-1})	Fire resistance period (min)						
	30	45	60	90	120	150	180
	Protection thickness (mm)						
50	20	20	20	20	20	20	25
60	20	20	20	20	20	25	40
70	20	20	20	20	20	30	50
80	20	20	20	20	25	40	60
90	20	20	20	20	30	50	80
100	20	20	20	20	40	60	80
110	20	20	20	20	40	60	80
120	20	20	20	20	50	80	100
130	20	20	20	25	50	80	100
140	20	20	20	25	60	80	
150	20	20	20	30	60	100	
160	20	20	20	40	80	100	
170	20	20	20	40	80		
180	20	20	20	40	80		
190	20	20	20	50	80		
200	20	20	20	50	100		
210	20	20	20	50	100		
220	20	20	20	60	100		
230	20	20	20	60	100		
240	20	20	20	60			
250	20	20	20	80			
260	20	20	20	80			
270	20	20	20	80			
280	20	20	20	80			
290	20	20	20	80			
300	20	20	20	80			
310	20	20	20	80			
320	20	20	25	100			
330	20	20	25	100			
340	20	20	25	100			
350	20	20	25	100			
360	20	20	60				
370	20	20	60				
380	20	20	60				
390	20	20	60				
400	20	25	60				
410	20	25	60				
420	20	25	80				
430	20	25	80				
440	20	25	80				
450	20	30	80				
460	20	30	80				
470	20	30	80				
480	20	30	80				
490	20	30	80				
500	20	30	80				
510	20	40	80				
520	20	40	80				
530	20	40	80				
540	20	40	100				
550	20	40	100				
560	20	40	100				
570	20	40	100				
580	20	40	100				
590	20	40	100				
600	20	40	100				
610	20	40	100				
620	20	50	100				
630	20	50	100				
640	20	50	100				
645	20	50	100				

Design table for critical steel temperature 650 °C

A_p/V (m^{-1})	Fire resistance period (min)						
	30	45	60	90	120	150	180
	Protection thickness (mm)						
50	20	20	20	20	20	20	25
60	20	20	20	20	20	20	30
70	20	20	20	20	20	30	40
80	20	20	20	20	20	40	50
90	20	20	20	20	25	40	60
100	20	20	20	20	30	50	80
110	20	20	20	20	40	60	80
120	20	20	20	20	40	60	100
130	20	20	20	20	50	80	100
140	20	20	20	20	50	80	
150	20	20	20	25	60	100	
160	20	20	20	30	60	100	
170	20	20	20	30	80	100	
180	20	20	20	40	80		
190	20	20	20	40	80		
200	20	20	20	40	80		
210	20	20	20	50	100		
220	20	20	20	50	100		
230	20	20	20	50	100		
240	20	20	20	60	100		
250	20	20	20	60			
260	20	20	20	60			
270	20	20	20	80			
280	20	20	20	80			
290	20	20	20	80			
300	20	20	20	80			
310	20	20	20	80			
320	20	20	20	80			
330	20	20	20	100			
340	20	20	20	100			
350	20	20	20	100			
360	20	20	50				
370	20	20	50				
380	20	20	50				
390	20	20	60				
400	20	20	60				
410	20	20	60				
420	20	20	60				
430	20	20	60				
440	20	20	60				
450	20	20	80				
460	20	20	80				
470	20	20	80				
480	20	25	80				
490	20	25	80				
500	20	25	80				
510	20	25	80				
520	20	25	80				
530	20	25	80				
540	20	30	80				
550	20	30	80				
560	20	30	80				
570	20	30	100				
580	20	30	100				
590	20	30	100				
600	20	40	100				
610	20	40	100				
620	20	40	100				
630	20	40	100				
640	20	40	100				
645	20	40	100				

Design table for critical steel temperature 700 °C

A_p/V (m^{-1})	Fire resistance period (min)						
	30	45	60	90	120	150	180
	Protection thickness (mm)						
50	20	20	20	20	20	20	20
60	20	20	20	20	20	20	25
70	20	20	20	20	20	20	40
80	20	20	20	20	20	30	50
90	20	20	20	20	20	40	50
100	20	20	20	20	25	40	60
110	20	20	20	20	30	50	80
120	20	20	20	20	30	60	80
130	20	20	20	20	40	60	100
140	20	20	20	20	40	80	100
150	20	20	20	20	50	80	
160	20	20	20	20	50	80	
170	20	20	20	25	60	100	
180	20	20	20	25	60	100	
190	20	20	20	30	80		
200	20	20	20	30	80		
210	20	20	20	40	80		
220	20	20	20	40	80		
230	20	20	20	40	100		
240	20	20	20	50	100		
250	20	20	20	50	100		
260	20	20	20	50	100		
270	20	20	20	60			
280	20	20	20	60			
290	20	20	20	60			
300	20	20	20	60			
310	20	20	20	80			
320	20	20	20	80			
330	20	20	20	80			
340	20	20	20	80			
350	20	20	20	80			
360	20	20	40				
370	20	20	40				
380	20	20	40				
390	20	20	40				
400	20	20	50				
410	20	20	50				
420	20	20	50				
430	20	20	50				
440	20	20	50				
450	20	20	50				
460	20	20	60				
470	20	20	60				
480	20	20	60				
490	20	20	60				
500	20	20	60				
510	20	20	80				
520	20	20	80				
530	20	20	80				
540	20	20	80				
550	20	20	80				
560	20	20	80				
570	20	20	80				
580	20	20	80				
590	20	20	80				
600	20	20	80				
610	20	20	80				
620	20	20	100				
630	20	20	100				
640	20	20	100				
645	20	20	100				

Fire protection of trapezoidal roofs with fire resistance REI 60 and REI 90 according to EN 13501-2

Trapezoidal roof systems are very cost effective, lightweight and suited to a wide variety of applications, including new build and refurbishment. The load-bearing capacity of corrugated steel without fire protection is 15–45 minutes depending on the structure and insulation used on the top of the steel sheet. The steel sheet bends and if the anchoring to the support is good enough if uses advantages of membrane and the load-bearing capability remains for a significant amount of time.

Fire classification

Fire protection system ISOVER FireProtect® was officially tested in PAVUS, a.s., authorized body AO 216. It is possible to protect roof made of corrugated steel for fire resistances REI 60 and REI 90. Classification according to the latest standard EN 13501-2: 2016, testing based on EN 1365-2: 2015.

Fire resistance (min)	Thickness of fire protection cladding ISOVER FireProtect® 150
REI 60	30
REI 90	60

When there is no insulation used on top of the corrugated steel sheet, the heat goes through the metal and dissipates upwards and the steel temperature rises slower.

When corrugated steel is used as a load-bearing structure for the roof construction and insulation is installed on top of the corrugated steel board, the temperature of the metal rises very quickly. ISOVER FireProtect® is a simple and reliable system that limits the temperature rise in the steel sheet and helps roof to withstand longer from collapse.

Fig. 10 Sample after 30 minutes – fire protection system ISOVER FireProtect® fulfils its function for 100 %, roof is without any deformation (bending stress, the same as would be under cold conditions)

Fig. 9 System ISOVER FireProtect® for fire protection of corrugated steel is characterized by light weight and small height, but also a direct fixing to the corrugated steel without need of help of suspension construction

Fig. 11 Sample after 90 minutes – roof deformation protected with ISOVER FireProtect® is close to limit deformation given by test standard EN 1365-2 (fluent transition from bending stress to membrane)

Design guide of trapezoidal roof

Trapezoidal profiled steel sheet was tested as a simply supported beam with span 6 m. Total area load in accidental design situation under fire conditi ons, according to EN 1990 and EN 1991-1-2, was 1.0 kN/m². The corresponding maximum bending moment in the middle of the roof span was $M_{fi,A}$ = 4.5 kNm/m and shear forces in the support were $V_{fi,1}$ = 3.0 kN/m. The similar constructions will have the same fire resistant classification in case when calculated values of stress (internal forces) will be lower or equal to the stated values.
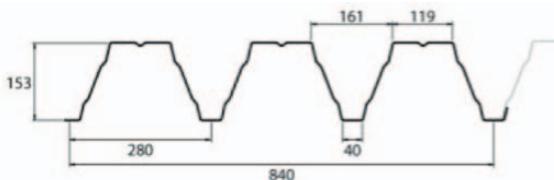
Fig. 12 The supporting structure shall consist of trapezoidal profiled steel sheets TR 150/280/0.75 mm and with a thickness of 0.75 mm.

Mounting and fixing must be according to the metal sheet manufacturer recommendations and instructions. The trapezoidal profiles are fixed to the supports by two self-drilling screws Ø 5.5 mm x 19 mm (galvanized carbon steel, hardened) in each wave. The trapezoidal steel sheets are fixed to each other by self-drilling screws Ø 4.8 mm × 19 mm (galvanized carbon steel), in spacing of 500 mm.

Fire protection cladding

Assembly of slabs ISOVER FireProtect® 150 in thickness 30 mm (REI 60) or 60 mm (REI 90) is quick, simple and secure with easily worked materials and simple fixing – stud-welded pins (Ø 2,7 mm, washer Ø 30 mm, length 32–33 mm for REI 60 or 62–63 mm for REI 90) or pins and washers (with the same dimension as described for stud-welded pins) in maximal distance

Fig. 13 View to finished fire protection cladding of trapezoidal metal sheet, dimension 1 × 1,2 m of slab ISOVER FireProtect® 150 highlighted by red line

of 300 mm to the bottom waves of the trapezoidal steel profile. Maximum distance from the cladding joints (edges of slabs) is 75 mm. Approximate pin's quantity is 13 pcs/m².

Trapezoidal roofs carried by steel beams

Fire protection of steel beams carrying a trapezoidal roof is often required in practice. Protection of steel beams is carried out using ISOVER FireProtect® with the thickness given by the section factor A_p/V and critical steel temperature. The trapezoidal roof protection is provided by slabs ISOVER FireProtect® 150 with the thickness of 30 mm or 60 mm.

Fig. 14 The four side fire protection of a steel beam (using the ISOVER FireProtect® 150 slabs to backfill a trapezoidal profile)

Fig. 15 The three side fire protection of a steel member in combination with the fire protection of a trapezoidal profile sheet. The thickness of the fire protection cladding ISOVER FireProtect® on the metal sheet corresponds to:
- **the thickness of the fire protection cladding on the steel member (in case there is no fire resistance requirement to the metal sheet),**
- **the thickness of 30 mm (in case of the fire resistance requirement REI 60 to the trapezoidal metal roof) or 60 mm (REI90),**
- **the thickness of the fire protection cladding as stated in the design tables on page 26 (in case of the concrete ceiling poured in trapezoidal metal sheets).**

Cladding of floors made of concrete poured in trapezoidal metal sheets with fire resistance up to REI 60

Trapezoidal metal sheet is a standard component used in industrial buildings and recently also in private buildings. The principle of the use of trapezoidal sheet has been known for years. Due to its shape, it usually has very good load characteristics and it is widely used for its favourable price-performance ratio.

Steel structures have a much higher load bearing capacity than concrete structures, but there is a problem with their stability and stiffness. On the other hand, concrete structures show high stiffness but low tensile strength. This means that by combining these two materials you can benefit from the above-mentioned advantages of both materials. Concrete floors cast into the trapezoidal sheet are preferably used in structures with a supporting steel structure and in the reconstruction of old buildings.

In terms of structural analysis, a concrete slab can be designed in two ways - either as a slab of constant thickness over the trapezoidal sheet where the reinforcement is only placed over the trapezoidal wave (see Fig. 16) or the reinforcement can be placed into the waves where a higher static height of the slab is to be considered (Fig. 17). In both cases, however, the load capacity of the trapezoidal sheet itself is not taken into account, as it is only used as permanent shuttering.

Fig. 16 According to EN 1992-1-1, the thickness of the concrete slab h_1 is considered the load-bearing thickness, while the filled trapezoidal sheet ribs only represent extra weight. The thickness of the distribution layers h_f can be included in I criterion in individual cases.

Calculation of the effective thickness of a concrete slab in terms of fire resistance

$$h_{eff} = h_1 + 0,5 \cdot h_2 \cdot \left(\frac{l_1 + l_2}{l_1 + l_3} \right) \qquad \text{for } h_2 / h_1 \leq 1,5 \text{ a } h_1 > 40 \text{ mm}$$

$$h_{eff} = h_1 \cdot \left[1 + 0,75 \cdot \left(\frac{l_1 + l_2}{l_1 + l_3} \right) \right] \qquad \text{for } h_2 / h_1 > 1,5 \text{ a } h_1 > 40 \text{ mm}$$

Cross-section dimensions h_1, h_2, l_1, l_2 a l_3 are provided in fig. 16.
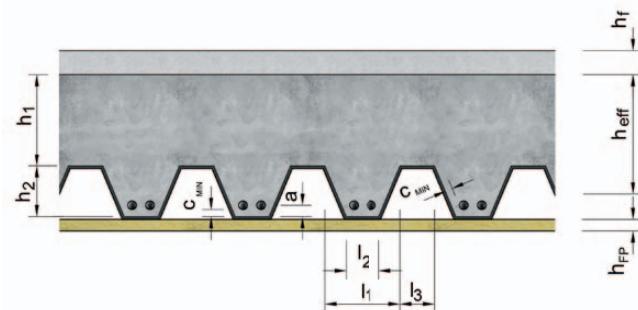
Fig. 17 If the reinforcement is placed in the trapezoidal sheet waves, a ribbed ceiling with a bearing "T-section" will be formed and therefore a statically optimal use of the height of the concrete slab will be achieved. When establishing the insulation capacity criterion I, you can consider the height h_1 or the so-called effective height of h_{eff}; the thickness of the distribution layers h_f can also be included in I criterion in individual cases.

As increased temperatures affect the steel material characteristics (yield strength, strength limit, modulus of elasticity) and the concrete layer over the reinforcement is insufficient in this case, these structures may require additional fire protection. ISOVER FireProtect® cladding is a proven solution and it can be mounted on a trapezoidal sheet without an auxiliary suspension structure, which is both fast and convenient. Additionally, it is a type of slabs characterized by low weight, low construction height and the possibility of mounting to existing structures.

Mounting

The installation of slabs ISOVER FireProtect ® 150 is very fast and simple and it is done using stud-welded pins attached by semi-automatic welding guns. The recommended spacing of the pins is 300 mm throughout the area of the slab and 75 mm from the edge of the slab. Approximate consumption of the pins is about 13 pcs/m².

Fire classification

ISOVER FireProtect® system is designed for the fire protection of floors from trapezoidal sheet with a concrete layer in accordance with ČSN 73 0810 (applied test methodology EN 1365-2: 2015), the fire protection thickness being determined according to EN 1991-1-2, EN 1992-1-2, EN 1993-1-2 and EN 1994-1-2. Using the mechanically fixed ISOVER FireProtect® system fire resistance in the range up to R(EI) 60 can be achieved. The required insulation thickness h_{FP} is taken from the table based on the determination of the concrete thickness equivalent to increase the tensile reinforcement coverage and the dimensional parameters of the concrete elements calculated according to the dimension tables.

Reinforcement spacing a is considered the smallest distance of the lower layer of the reinforcement from the lower exposed surface of the slab. Typically the concrete cover c_{min} given by EN 1992-1-1 is decisive.

Design table

Thickness of ISOVER FireProtect® 150 h_{FP} (mm)	Fire protection REI xx			
	Thickness of concrete slab h_1* (mm)			
	40	45	50	60
20	REI 45	REI 45	REI 60	REI 60
25	REI 45	REI 60	REI 60	REI 60
30	REI 60	REI 60	REI 60	REI 60

* Thickness of the concrete slab h_1 is considered the smallest value that may be rectified by replacing the effective thickness h_{eff}.

Fire resistance increase of concrete members and slabs according to EN 13501-2

Concrete is specified in buildings and civil engineering projects for several reasons, sometimes cost, and sometimes speed of construction or architectural appearance, but one of concrete's major inherent benefits is its performance in fire, which may be overlooked in the race to consider all the factors affecting design decisions. Concrete usually performs well in building fires, however, concrete structures must still be designed for fire effects. Structural components still must be able to withstand dead and live loads without collapse even though the rise in temperature causes a decrease in the strength and modulus of elasticity for concrete and steel reinforcement. In addition, fully developed fires cause expansion of structural components and the resulting stresses and strains must be resisted. This rise in temperature dramatically reduces the mechanical properties of concrete and steel.

ORDEXAL® B system is designed to increase the fire resistance of concrete slabs (decks) up to R 360 and of concrete beams up to R 240 according to EN 13381-3: 2015. The additional fire protection of the hollow core or massive concrete slabs/beams slows down the temperature rise of reinforcing steels. The goal is to maintain the bearing capability in the side on tension.

Composition

ORDEXAL® B system consists of mineral wool slabs ISOVER PYRO of 20 mm thickness and heat-resistant cement-based adhesive Dexaflamm B. The slabs are glued in their full surface to the reinforced concrete structure by the heat-resistant adhesive.

Fire protection slabs

Mineral wool slabs of 20 mm thickness, with nominal density 190 kg/m^3, supplied in basic dimensions 500 x 1000 mm, pack of 10 pieces in foil. The slabs can be cut by a standard laggers knife, circular saw with sintered carbide blade and extraction or a hand saw with fine teeth.

Adhesive description

The heat resistant adhesive Dexaflamm B is supplied in 15 or 50 kg plastic barrels or 25 kg paper bags. The cement is prepared by mixing the content of the barrel of dry mixture (50 kg) to about 12 litres of clean water by a stirrer, drill extender or mixer with forced mixing. The mixing time is 2-5 min. After mixing let the compound leave to stand for about 5 minutes and then mix briefly again. When mixing small quantities, observe the ratio of dry mixture and water. Time of processability is about 90 minutes.

Design tables

1. Rectangular **reinforced concrete columns** protected with system ORDEXAL® B in thickness 20 mm exposed to fire from one or more sides.
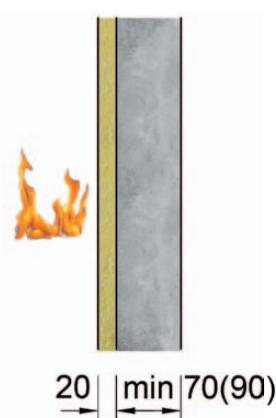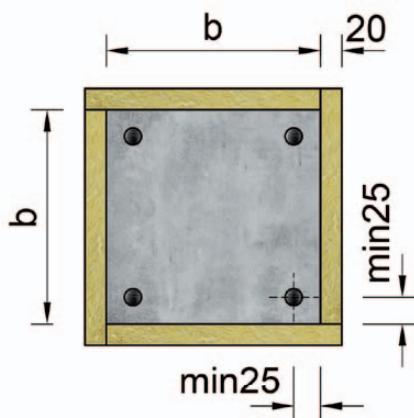
Fire resistance (min)	Minimum dimension of column (mm) Width of diameter of column b	Axial distance of reinforcement a
R 60	b = 200	a = 25
R 120	b = 250	a = 25
R 180	b = 350	a = 25

2. Concrete non-bearing walls with or without **reinforcement,** protected with system ORDEXAL® B in thickness 20 mm exposed to fire from one side

Fire resistance (min)	Minimum thickness of the concrete wall d (mm)
EI 120	70
EI 180	90

Note: When exposed to fire from one or the other side, fire protection system has to be applied from both sides of the wall

**3.** **Reinforced concrete walls** protected with system ORDEXAL® B in thickness 20 mm exposed to fire from one side.
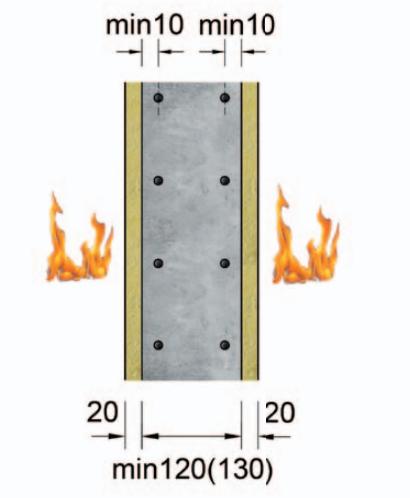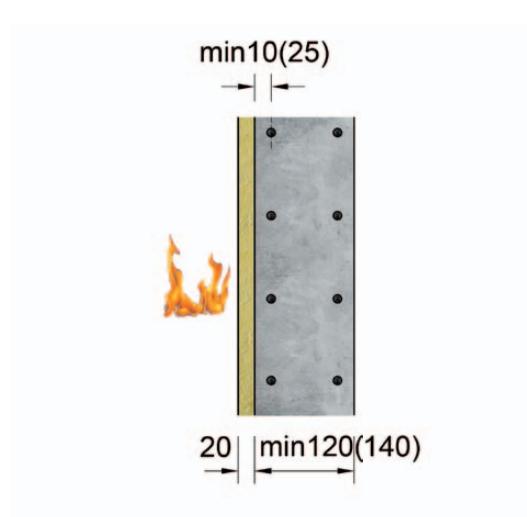
| Fire resistance (min)	Minimum thickness of the wall d (mm) / Axial distance of reinforcement a (mm)
REI 120	120/10
REI 180	140/25

Note: When exposed to fire from one or the other side, fire protection system has to be applied from both sides of the wall

4. **Reinforced concrete walls** protected with system ORDEXAL® B in thickness 20 mm exposed to fire from both sides.

Fire resistance (min)	Minimum thickness of the wall d (mm) / Axial distance of reinforcement a (mm)
R 120	120/10
R 180	130/10

5. **Simply supported reinforced concrete or prestressed concrete beams,** protected from three sides with system ORDEXAL® B in thickness 20 mm.
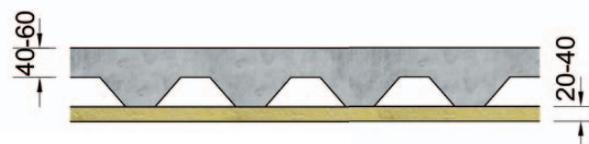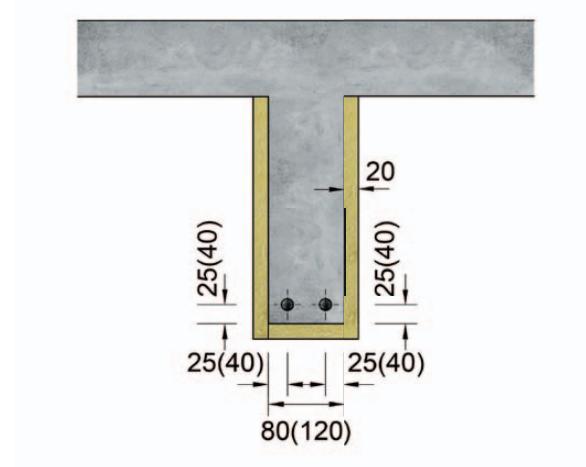
Fire resistance (min)	Minimum width of beam b (mm)/ Average axial distance of reinforcement a (mm)
R 120	80/25
R 180	120/40

6. **Floors from trapezoidal metal sheet with a concrete layer 40 to 60 mm,** protected with system ORDEXAL® ZLB in thickness 20 and 40 mm.

Fire resistance (min)	Minimal thickness of concrete slab (mm)	Thickness of ISOVER PYRO (mm)
REI 60	40	20
REI 90	50	20
REI 180	60	40
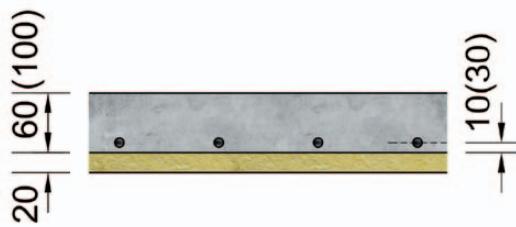
* Thickness of the concrete slab h_1 is considered the smallestvalue that may be rectified by replacing the effective thickness h_{eff}.
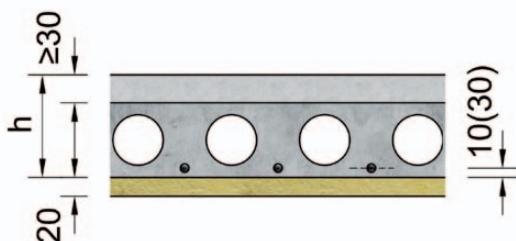
7. Simply supported reinforcement concrete or prestressed concrete slabs with reinforcement in one direction, protected from bottom side with system ORDEXAL® B in thickness 20 mm.

Fire resistance (min)	Minimum thickness of the slab h_s (mm) / Axial distance of reinforcement a (mm)
REI 120	60/10
REI 180	100/30

Note: Table is valid also for hollow slab panels with effective thickness $h_s = h \cdot [A_c/(b \cdot h)]^{0.5}$
Where: h is actual thickness of the panel, topping included (countable layer thickness ≥ 30 mm)
A_c is area of concrete cross-section, topping included
b width of the panel
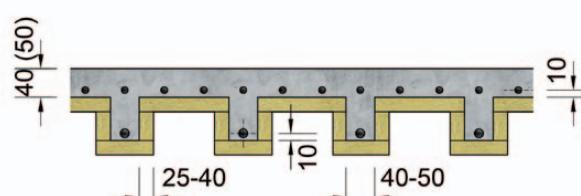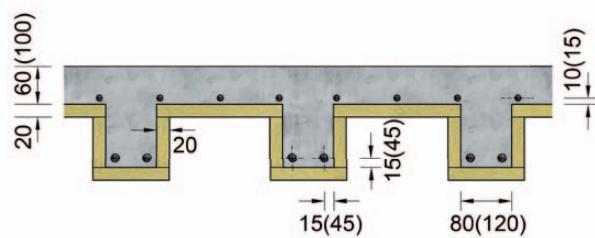
9. Thin slabs (fixed) with thickness 40 mm and 50 mm from reinforced concrete with reinforcement in one or two directions, protected with system ORDEXAL® B in thickness 20 mm, 30 mm or 40 mm.

Fire resistance (min)	Minimum thickness of reinforced slab h_s (mm)/ Axial distance of reinforcement a (mm)	Fire protection thickness of ORDEXAL® B (mm) applied from the bottom side
REI 60	40/10	20
REI 90	50/10	20
REI 90	40/10	30
REI 120	50/10	30
REI 120	40/10	40
REI 120	50/10	40

Values are not valid for prestressed concrete!
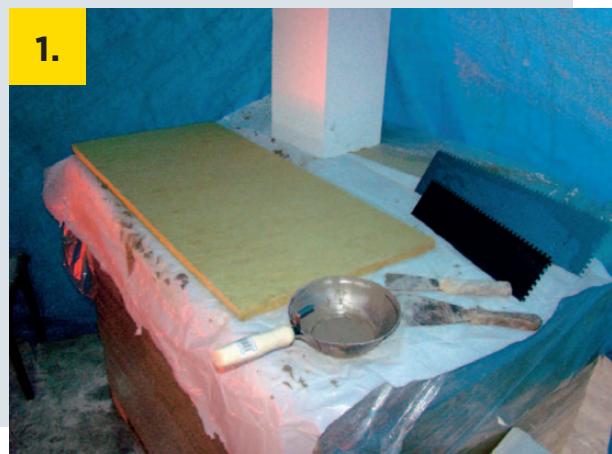
8. Simply supported reinforcement concrete or prestressed concrete ribbed slabs, protected with system ORDEXAL® B in thickness 20 mm.

Fire resistance (min)	Minimum thickness of reinforced slab h_s (mm)/ Axial distance of reinforcement a (mm)	Minimum width of the rib b (mm)/ Axial distance of reinforcement a (mm)
REI 120	60/10	80/15
REI 180	100/15	120/45

Pictorial instructions for the installation of system ORDEXAL® B

1.

Inspect the slab and the tools used

2.

Prepare Dexaflamm B adhesive

3.

Apply an adequate amount of the adhesive on the slab

4.

Spread the adhesive with a notched trowel over the entire surface of the slab

5.

Press the first slab to the baseline and remove any excessive adhesive

6.

Check the bonding over the entire surface - Dexaflamm B adhesive is slightly pushed out and visible
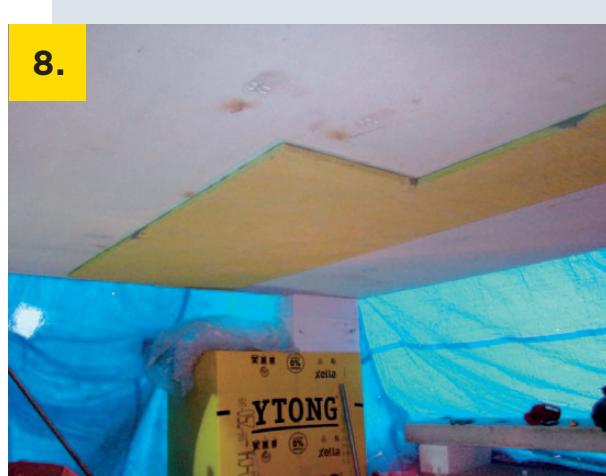
7. FIRE PROTECTION OF CONCRETE

7. Installation of the first row of slabs - inspect the straightness of the row

8. Install other slabs by pressing them against the edge of the already installed slabs (the edges are not glued)
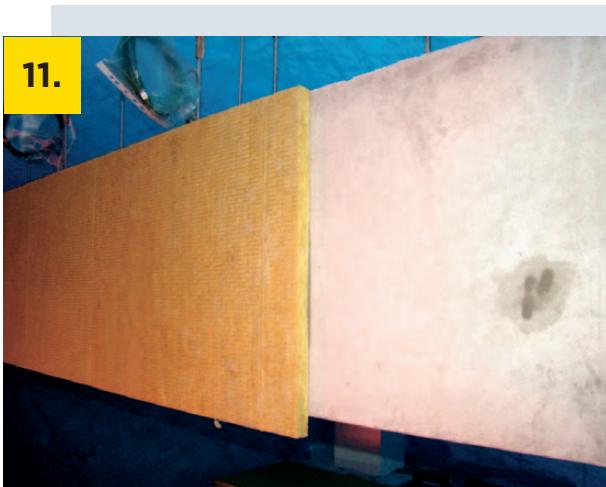
9. Check the system thickness, 20 mm slab, 3-4 mm layer of adhesive
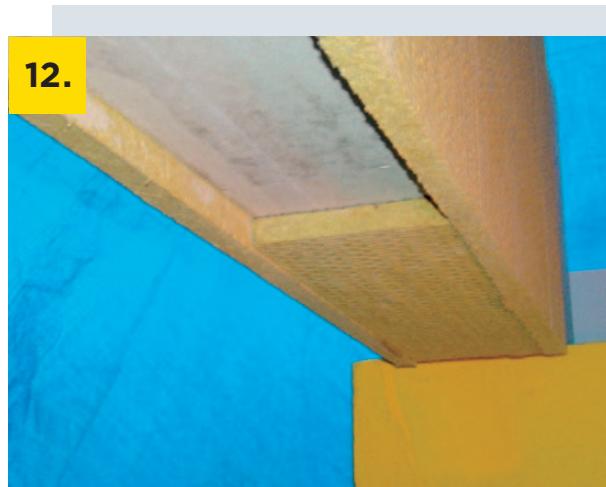
10. Finished ORDEXAL® B lining

11. In case of a beam, the sides are glued first

12. The flange is glued in the end

ORDEXAL® KARBON ALB is designed to increase the fire resistance of carbon fibre lamellas reinforcing and strengthening concrete structures. With a suitable design you can achieve the reinforcing function of a carbon fibre lamella **in the range of 30 to 120 minutes with reduced demands for the space needed for the protective material.** The design is developed according to the dimension table, depending on the heat resistance of the adhesive used.

Use

The application of ORDEXAL® KARBON ALB is suitable:
in all common heated and unheated interiors (according to EAD environment types Z1, Z2 and Y). The fire protective insulation does not overload the structure, does not crack and reduce vibrations and dynamic impacts.

The application of ORDEXAL® KARBON ALB is not suitable:
without additional surface treatment in highly aggressive environment (aromates and organic vapours) and places with flowing or dripping water, or in non-ventilated spaces with a relative humidity above 80 %.

> **WARNING - the size and installation of ORDEXAL® KARBON ALB cladding on the reinforcing carbon lamellas depend on the dimensions of the reinforced concrete structures and the distance of the lamella from its edges. The minimum lateral overlap of the lamella cladding is always 100 mm. If the lamella is located at the edge of a beam or closer than 100 mm from an opening, its sides have to be clad as well! It is advisable to consult the design in advance with our experts.**

Design table

According to the tests carried out in PAVUS test laboratory, a dimension table of the thickness of ORDEXAL® KARBON ALB fire protective slab was developed for individual thicknesses required to observe the maximum allowable temperatures on the surface of a carbon lamella depending on time.

Prescribed thickness of the ORDEXAL® KARBON ALB cladding

Fire resistance[x] (minutes)	Thickness of the cladding [xx] (mm) ORDEXAL® KARBON ALB for fire protection of strengthening carbon fibre lamellas with critical temperature 50 to 90 °C				
R – load-bearing capacity	50°C	60°C	70°C	80°C	90°C
30	40	40	40	40	40
45	40	40	40	40	40
60	60	60	40	40	40
90	80	80	60	60	40
120	100	100	80	80	60

[x] The concrete structure itself must have at least the same fire resistance before fire protection.

[xx] The final thickness of the cladding is about 6 - 12 mm higher than the values given in the table (with the thickness of the adhesive).

Fig. 17 Carbon fiber reinforced lamellas before fire protection

Fig. 18 Semifinished fire protective cladding ORDEXAL® KARBON ALB without final surface layer
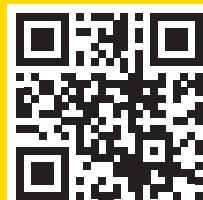
Fig. 19 Final appearance after applying white paint to the insulation surface

FURTHER INFORMATION ABOUT ISOVER FIREPROTECT

For more information about ISOVER FireProtect, please contact the local ISOVER representative in your country.

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