FIRE PROTECTION GUIDE 2/CONCRETE

LOADBEARING CONCRETE SLABS, HOLLOW-CORE SLABS AND BEAMS

OWENS CORNING® PAROC®

CONTENT:

DETERMINE THE NEEDED FIRE RESISTANCE PERIOD

Even if concrete have advantages over other building materials by is its inherent fire-resistive properties, concrete structures must still be designed for fire performance. Structural components must be able to withstand self-weight/imposed 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 concrete structures fully developed fires cause expansion of structural components and the resulting stresses and strains must be resisted.

The resistance of reinforced concrete to fire depends on type of aggregate used to make the concrete, fire loading and moisture content. In general, lightweight concrete performs better at elevated temperatures than normal weight concrete. Pre-stressed concrete is stronger than reinforced concrete but have greater tendency to spall.

The fire resistance requirement for a building is defined in terms of fire resistance period and stated in terms of minutes (15, 30, 45, 60, 75, 90 or 120 minutes). This information is usually given in local building regulations and it depends on the height, occupants and type of the building. In practice it means that building frame has to maintain its load bearing capacity during complete endurance of the fire including the decay phase. It is the responsibility of the design engineer, using design codes such as EN 1992 Eurocode 2 (Design of concrete structures) to specify the appropriate limiting or failure temperature for a given structure.

Materials are usually tested by using standard fire curve which demonstrates development of real fire. The temperature in a standard fire rises rather quickly and then increases indefinitely. In real life fire will decay after all combustible material has burned so it is extremely unlikely that constructions will collapse after one hour if they have passed fire resistance test for 60 minutes.

Fire resistance test results are expressed in terms of time of failure against one or more of three criteria:

- **Load bearing capacity (R)**
- **Integrity (passage of hot gases/flames) (E)**
- **Insulation (temperature raise) (I)**
- **Only R-type bearing requirements are set for beams and pillars. REI-type bearing requirements can also be used for walls and slabs.**

In load-bearing structural elements such as beams, columns, walls and slabs, the resistance R prevents the structure from collapsing. In general, the separating function (E and I) applies to elements that form an integral part of the walls and envelope of the compartment: i.e. the walls and slabs.

To avoid a fire-resistance test being necessary for each construction product, calculation methods have been perfected to define the thermal and mechanical stresses and thereby evaluate the resistance to fire of structures made from concrete, steel mixed steel/concrete, wood, brick and aluminium. These calculation methods can be found in the section of the Eurocodes on fire behavior.

Deformation criteria shall be applied where the means of protection, or the design criteria for separating elements, require consideration of the deformation of the load bearing structure. Consideration of the deformation of the load bearing structure is not necessary if the efficiency of the means of protection has been evaluated according to EN1992-1-2 (4.7).

DETERMINE PROTECTION METHOD

The fire part of the Eurocodes presents three ways to design fire resistance of concrete structures:

1. **Calculations by tabulated values; cold dimensioning**

For reinforced or pre-stressed concrete girders, columns, walls and slabs Eurocode 2 gives tables which defines the minimum dimensions of sections as well as the distance from the axis of reinforcement to the nearest facing.

2. **Simplified calculation models:**

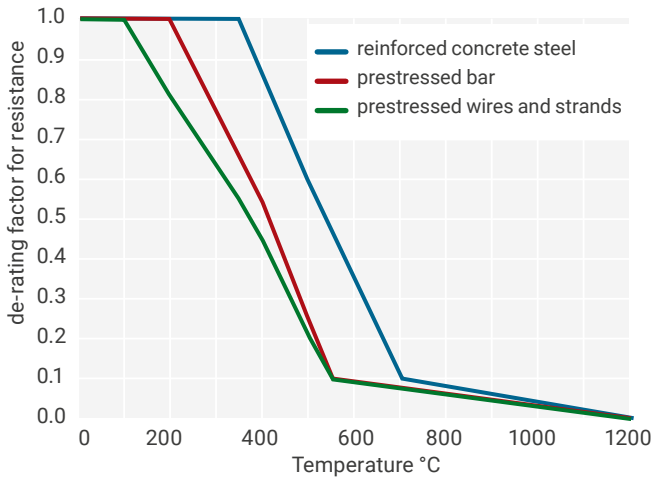
This method is similar than cold method. It also integrates the loss of resistance of the concrete and reinforcements as a function of their temperature. This model needs thorough knowledge of FSE.

3. **Advanced calculation models:**

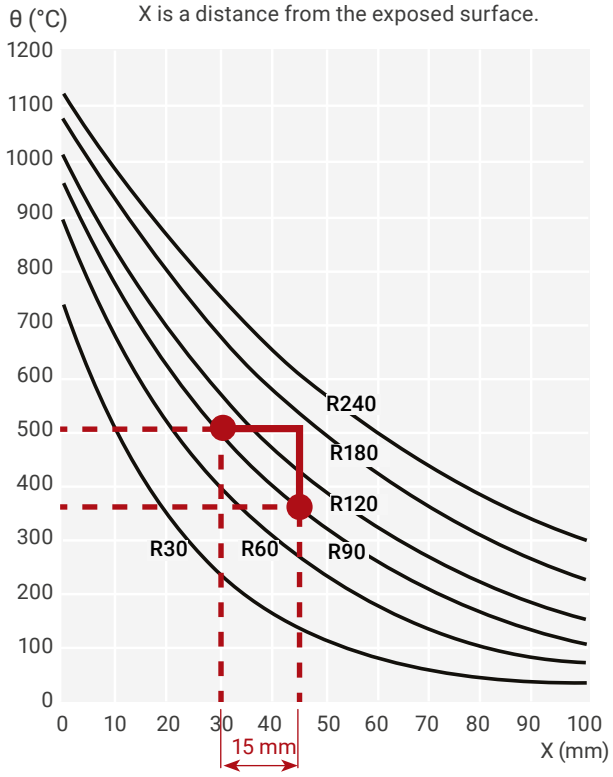
Can be used on a case-by-case basis and needs sophisticated calculation programs and high-level knowledge.

Tabulated values method is based on hypothesis of siliceous aggregates. Depending on the required fire duration, and possibly the loading level, the Eurocode tables give pairs of values of the type 200/35. The first value corresponds to the minimum dimension of the transversal section of the piece (bmin). The second value corresponds to ”a”, the distance from the axis of the longitudinal reinforcement to the nearest facing.

The tables are based on a critical temperature of the steel: 500 °C for reinforced concrete steels, 400 °C for pre-stressed rods, 350 °C for pre-stressed wires and strands. The de-rating factor of the characteristic strength of steels in reinforced and pre-stressed concrete as a function of the critical temperature θ_{cr} to be used with the tables is illustrated by the reference curves in the figure below.



The graph below shows temperature profiles for slabs (height h = 200 mm) for R60 – R240 (EC2). These same curves are also used for hollow-core slabs.



This means that temperature of a point situated 30 mm from the surface after 90 minutes exposure of the element is 500 °C. The point situated 15 mm deeper has temperature 350 °C.

Example of application:

A 200 mm thick reinforced concrete floor (C25/30) on simple supports intended for an office block. What is the practical height of the spacers for reinforcements to obtain a fire resistance of 2 hours? The main lower reinforcement consists of steel rods 12 mm in diameter.

The height of the spacers is the nominal cover of the reinforcements. It is simply the one that should be indicated on the plans.

The critical temperature for the steel will be 500 °C. The nominal cover of the reinforcements is immediately deduced from the previous figure: on curve R 120 the abscissa x = a = 35 mm corresponds to the ordinate of 500 °C.

The nominal cover is therefore c_{nom} = a – diam/2 = 35 – 12/2 = 29 mm.

PAROC FireSAFE SYSTEM – PAROC FPS 17

Design tools for prediction of thickness of single layer fire protection system with passive fire protection material PAROC FPS 17 applied to concrete members in a Standard Fire Exposure. Tested insulation thicknesses were 20 and 60 mm. The concrete in the test specimens was of type C30/37 XC4 according to EN 206 and EN 1992-1-1.
The steel reinforcement ribbed bars used were of grade B500B (to EN 10080) with f_{yk} = 500 MPa.

Test method: EN 13381-3:2015 (E) Test methods for determining the contribution to the fire resistance of structural members – Part 3: Applied protection to concrete members.

The results of the assessment from the fire protection system tested in horizontal orientation on **concrete slabs** are applicable to all concrete slabs and walls with fire exposure from one side only, in both horizontal and vertical orientation.

The results of the assessment from the fire protection system tested in horizontal orientation on **concrete beams** are applicable, as tested, to all beams and columns exposed to fire from more than one side, in use in both horizontal and vertical orientation provided that the method of fixing and application is the same as that tested.

The results of the assessment are applicable only to single layer fire protection systems with following boundaries:

- **Normal weight 2016 – 2769 kg/m³ slabs and walls.**
- **Normal weight 2026 – 2762 kg/m³ beams and columns.**
- **To the concrete strength which is equal to or one strength grade higher than that tested, i.e. C30/37 and C35/45 according to EN 206.**
- **Applicable to pre-stressed structures provided that rules indicated in EN 1992-1-2 are respected.**
- **Applicable to concrete members with concrete prepared from any type of aggregate (siliceous, non-siliceous).**
- **Are applicable to all concrete beams with an equal or higher width as that tested (150 mm) and with an equal or higher height as that tested (450 mm). It is possible to decrease the height provided the section surface remains the same or is higher, by increasing the width.**
- **Only applicable to fire protection systems where the fixing and jointing systems are the same as that tested.**
- **Valid for 19 mm – 63 mm PAROC FPS 17 thicknesses.**

The assessment for insulation carried out according to EN 13381-3: 13.4 and EN 1363-1:
The results of equivalent thickness of concrete versus fire protection thickness and fire resistance (test duration) for slabs and beams were determined according to EN 13381-3: Annex C.

Basic data relating to the temperature within an unprotected concrete slab or beam were derived by reference to EN 1992-1-2:

- Sunprotected slab with thickness of 200 mm – temperature profiles given in EN 1992-1-2: Figure A.2;
- unprotected beam with section of 300 mm (w) x 600 mm (h) – temperature profiles given in EN 1992-1-2: Figure A.7, A.8.

PAROC FPS 17 equivalent thickness of concrete

	Thickness of PAROC FPS 17 (mm)	Equivalent thickness of concrete (mm)					
		30 min	60 min	90 min	120 min	180 min	240 min
Slabs and walls	**20**	49	62	71	74	75	72
	25	54	66	76	79	82	81
	30	59	70	80	85	89	89
	35	63	74	85	90	96	98
	40	68	79	89	95	103	106
	45	73	83	94	100	110	115
	50	78	87	98	106	117	123
	55	82	91	103	111	124	132
	60	87	95	107	116	131	140
Beams and columns	**20**	51	67	70	69	62	49
	25	55	70	75	75	70	59
	30	58	73	79	81	78	70
	35	62	76	84	87	86	80
	40	66	80	88	93	95	90
	45	69	83	93	99	103	100
	50	73	86	97	105	111	111
	55	76	89	102	111	119	121
	60	80	92	106	117	127	131

From the table above you can find equivalent thickness of concrete according to EN 13381-3. In practice this means that in 30 minutes fire protection of concrete you can either use 49 mm thick protective layer of concrete or 20 mm of stone wool in case where steels are in the depth of 15 mm.

DESIGN TABLES OF CONCRETE SLABS AND WALLS

Critical temperature of steel of steel 300°C

Minimum depth of protective concrete (mm)*	PAROC FPS 17, Fire protection thickness, mm					
	30 min	60 min	90 min	120 min	180 min	240 min
10	20	20	20	20	20	20
15	20	20	20	20	20	20
20	20	20	20	20	20	20
25	0	20	20	20	20	20
30	0	20	20	20	20	20
35	0	20	20	20	20	20
40	0	20	20	20	20	20
45	0	0	20	20	20	20
50	0	0	20	20	20	20
55	0	0	0	20	20	20
60	0	0	0	20	20	20
65	0	0	0	0	20	20
70	0	0	0	0	20	20

Critical temperature of steel 350°C

Minimum depth of protective concrete (mm)*	PAROC FPS 17, Fire protection thickness, mm					
	30 min	60 min	90 min	120 min	180 min	240 min
10	20	20	20	20	20	20
15	20	20	20	20	20	20
20	0	20	20	20	20	20
25	0	20	20	20	20	20
30	0	20	20	20	20	20
35	0	0	20	20	20	20
40	0	0	20	20	20	20
45	0	0	20	20	20	20
50	0	0	0	20	20	20
55	0	0	0	20	20	20
60	0	0	0	0	20	20
65	0	0	0	0	20	20
70	0	0	0	0	20	20

Critical temperature of steel 400°C

Minimum depth of protective concrete (mm)*	PAROC FPS 17, Fire protection thickness, mm					
	30 min	60 min	90 min	120 min	180 min	240 min
10	20	20	20	20	20	20
15	20	20	20	20	20	20
20	0	20	20	20	20	20
25	0	20	20	20	20	20
30	0	0	20	20	20	20
35	0	0	20	20	20	20
40	0	0	0	20	20	20
45	0	0	0	20	20	20
50	0	0	0	0	20	20
55	0	0	0	0	20	20
60	0	0	0	0	20	20
65	0	0	0	0	0	20
70	0	0	0	0	0	20

Critical temperature of steel 450°C

Minimum depth of protective concrete (mm)*	PAROC FPS 17, Fire protection thickness, mm					
	30 min	60 min	90 min	120 min	180 min	240 min
10	20	20	20	20	20	20
15	0	20	20	20	20	20
20	0	20	20	20	20	20
25	0	20	20	20	20	20
30	0	0	20	20	20	20
35	0	0	0	20	20	20
40	0	0	0	20	20	20
45	0	0	0	0	20	20
50	0	0	0	0	20	20
55	0	0	0	0	20	20
60	0	0	0	0	0	20
65	0	0	0	0	0	20
70	0	0	0	0	0	0

Critical temperature of steel 500°C

Minimum depth of protective concrete (mm)*	PAROC FPS 17, Fire protection thickness, mm					
	30 min	60 min	90 min	120 min	180 min	240 min
10	20	20	20	20	20	20
15	0	20	20	20	20	20
20	0	20	20	20	20	20
25	0	0	20	20	20	20
30	0	0	0	20	20	20
35	0	0	0	20	20	20
40	0	0	0	0	20	20
45	0	0	0	0	20	20
50	0	0	0	0	0	20
55	0	0	0	0	0	20
60	0	0	0	0	0	0
65	0	0	0	0	0	0
70	0	0	0	0	0	0

Critical temperature of steel 550°C

Minimum depth of protective concrete (mm)*	PAROC FPS 17, Fire protection thickness, mm					
	30 min	60 min	90 min	120 min	180 min	240 min
10	0	20	20	20	20	20
15	0	20	20	20	20	20
20	0	0	20	20	20	20
25	0	0	20	20	20	20
30	0	0	0	20	20	20
35	0	0	0	0	20	20
40	0	0	0	0	20	20
45	0	0	0	0	0	20
50	0	0	0	0	0	20
55	0	0	0	0	0	0
60	0	0	0	0	0	0
65	0	0	0	0	0	0
70	0	0	0	0	0	0

Critical temperature of steel 600°C

Minimum depth of protective concrete (mm)*	PAROC FPS 17, Fire protection thickness, mm					
	30 min	60 min	90 min	120 min	180 min	240 min
10	0	20	20	20	20	20
15	0	20	20	20	20	20
20	0	0	20	20	20	20
25	0	0	0	20	20	20
30	0	0	0	0	20	20
35	0	0	0	0	20	20
40	0	0	0	0	0	20
45	0	0	0	0	0	20
50	0	0	0	0	0	0
55	0	0	0	0	0	0
60	0	0	0	0	0	0
65	0	0	0	0	0	0
70	0	0	0	0	0	0

*measured from the middle of the steel

Critical temperature of steel 650°C

Minimum depth of protective concrete (mm)*	PAROC FPS 17, Fire protection thickness, mm					
	30 min	60 min	90 min	120 min	180 min	240 min
10	0	20	20	20	20	20
15	0	0	20	20	20	20
20	0	0	0	20	20	20
25	0	0	0	0	20	20
30	0	0	0	0	20	20
35	0	0	0	0	0	20
40	0	0	0	0	0	20
45	0	0	0	0	0	0
50	0	0	0	0	0	0
55	0	0	0	0	0	0
60	0	0	0	0	0	0
65	0	0	0	0	0	0
70	0	0	0	0	0	0

*measured from the middle of the steel

DESIGN TABLES OF CONCRETE BEAMS AND COLUMNS

Critical temperature of steel 300°C

Minimum depth of protective concrete (mm)*	PAROC FPS 17, Fire protection thickness, mm					
	30 min	60 min	90 min	120 min	180 min	240 min
25	20	20	20	25	45	55
30	20	20	20	20	40	55
35	20	20	20	20	40	50
40	0	20	20	20	35	50
45	0	20	20	20	30	45
50	0	20	20	20	30	45
55	0	20	20	20	25	40
60	0	20	20	20	20	40
65	0	0	20	20	20	35
70	0	0	20	20	20	35
75	0	0	20	20	20	30
80	0	0	0	20	20	30
85	0	0	0	20	20	30

Critical temperature of steel 350°C

Minimum depth of protective concrete (mm)*	PAROC FPS 17, Fire protection thickness, mm					
	30 min	60 min	90 min	120 min	180 min	240 min
25	20	20	20	20	40	50
30	20	20	20	20	35	50
35	0	20	20	20	30	45
40	0	20	20	20	30	45
45	0	20	20	20	25	40
50	0	20	20	20	20	35
55	0	20	20	20	20	35
60	0	0	20	20	20	35
65	0	0	20	20	20	30
70	0	0	0	20	20	30
75	0	0	0	20	20	25
80	0	0	0	20	20	25
85	0	0	0	20	20	20

Critical temperature of steel 400°C

Minimum depth of protective concrete (mm)*	PAROC FPS 17, Fire protection thickness, mm					
	30 min	60 min	90 min	120 min	180 min	240 min
25	20	20	20	20	40	45
30	20	20	20	20	35	45
35	0	20	20	20	30	40
40	0	20	20	20	30	40
45	0	20	20	20	25	35
50	0	20	20	20	20	35
55	0	0	20	20	20	30
60	0	0	20	20	20	30
65	0	0	0	20	20	25
70	0	0	0	20	20	25
75	0	0	0	20	20	20
80	0	0	0	0	20	20
85	0	0	0	0	20	20

Critical temperature of steel 450°C

Minimum depth of protective concrete (mm)*	PAROC FPS 17, Fire protection thickness, mm					
	30 min	60 min	90 min	120 min	180 min	240 min
25	20	20	20	20	30	40
30	0	20	20	20	30	40
35	0	20	20	20	25	35
40	0	20	20	20	20	35
45	0	0	20	20	20	30
50	0	0	20	20	20	30
55	0	0	20	20	20	25
60	0	0	0	20	20	25
65	0	0	0	20	20	20
70	0	0	0	20	20	20
75	0	0	0	0	20	20
80	0	0	0	0	20	20
85	0	0	0	0	20	20

Critical temperature of steel 500°C

Minimum depth of protective concrete (mm)*	PAROC FPS 17, Fire protection thickness, mm					
	30 min	60 min	90 min	120 min	180 min	240 min
25	0	20	20	20	20	35
30	0	20	20	20	20	30
35	0	20	20	20	20	30
40	0	20	20	20	20	25
45	0	0	20	20	20	25
50	0	0	20	20	20	20
55	0	0	0	20	20	20
60	0	0	0	20	20	20
65	0	0	0	20	20	20
70	0	0	0	0	20	20
75	0	0	0	0	20	20
80	0	0	0	0	0	20
85	0	0	0	0	0	20

Critical temperature of steel 550°C

Minimum depth of protective concrete (mm)*	PAROC FPS 17, Fire protection thickness, mm					
	30 min	60 min	90 min	120 min	180 min	240 min
25	0	20	20	20	20	35
30	0	20	20	20	20	30
35	0	20	20	20	20	30
40	0	0	20	20	20	25
45	0	0	20	20	20	25
50	0	0	0	20	20	20
55	0	0	0	20	20	20
60	0	0	0	20	20	20
65	0	0	0	0	20	20
70	0	0	0	0	20	20
75	0	0	0	0	20	20
80	0	0	0	0	0	20
85	0	0	0	0	0	20

Critical temperature of steel 600°C

Minimum depth of protective concrete (mm)*	PAROC FPS 17, Fire protection thickness, mm					
	30 min	60 min	90 min	120 min	180 min	240 min
25	0	20	20	20	20	30
30	0	20	20	20	20	25
35	0	0	20	20	20	25
40	0	0	20	20	20	20
45	0	0	0	20	20	20
50	0	0	0	20	20	20
55	0	0	0	0	20	20
60	0	0	0	0	20	20
65	0	0	0	0	20	20
70	0	0	0	0	20	20
75	0	0	0	0	0	20
80	0	0	0	0	0	20
85	0	0	0	0	0	20

*measured from the middle of the steel

Critical temperature of steel 650°C

Minimum depth of protective concrete (mm)*	PAROC FPS 17, Fire protection thickness, mm					
	30 min	60 min	90 min	120 min	180 min	240 min
25	0	20	20	20	20	25
30	0	0	20	20	20	25
35	0	0	20	20	20	20
40	0	0	0	20	20	20
45	0	0	0	20	20	20
50	0	0	0	0	20	20
55	0	0	0	0	20	20
60	0	0	0	0	20	20
65	0	0	0	0	20	20
70	0	0	0	0	0	20
75	0	0	0	0	0	20
80	0	0	0	0	0	20
85	0	0	0	0	0	0

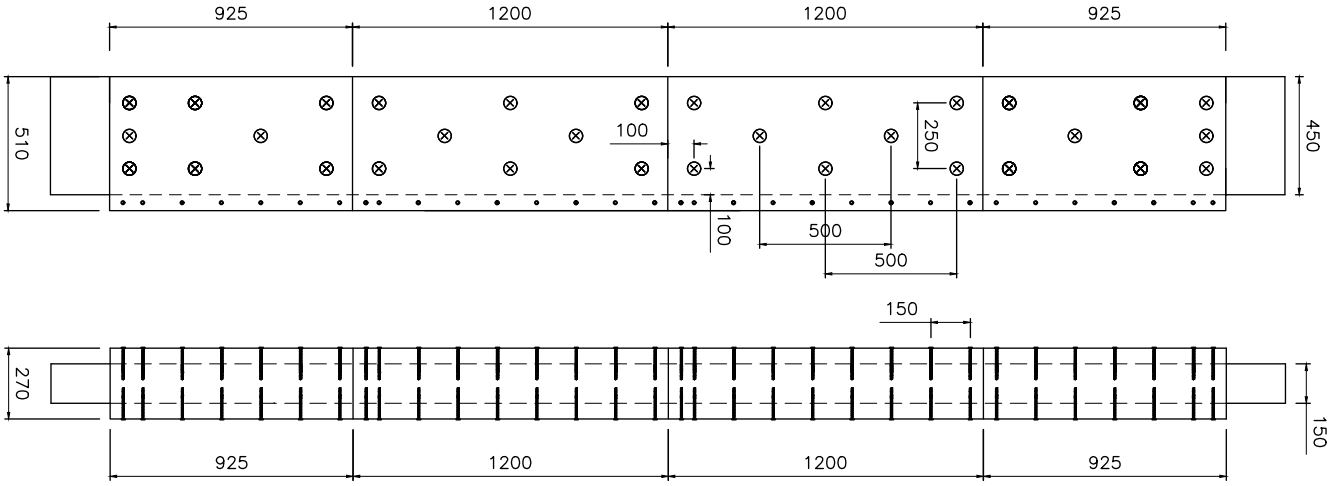
*measured from the middle of the steel

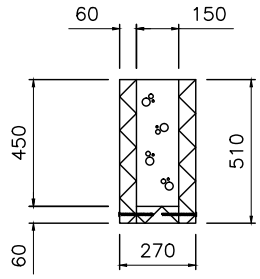
PAROC FPS 17 INSTALLATION

CONCRETE BEAMS AND COLUMNS

- Install the PAROC FPS 17 fire protection according to drawing below. In the picture you can see installation of 60 mm thick PAROC FPS 17 slab to concrete beam. Joints have to be tight – no gaps are allowed.
- Use at least 8 fasteners/slab (600 x 1200). Notice, that fire protection slabs on sides of the beam have to cover the slab on the bottom surface.
- The PAROC FPS 17 slab on the bottom surface of the beam is connected to the the sides with PAROC XFS 001 fire springs (c 150 mm). The length of the fire spring is 2 x thickness of the fire protection slab.

Fire protected concrete beam.





Cross-section of concrete beam with fire protection.

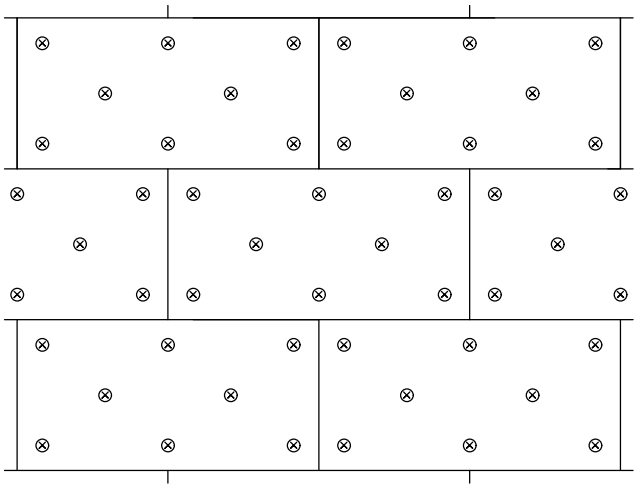
PAROC XFS 001 Fire spring.

Fire protection on the bottom surface of the beam.

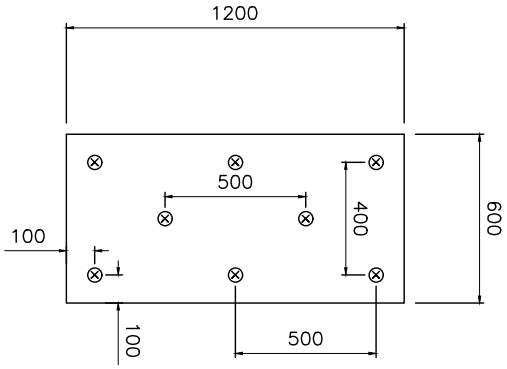
CONCRETE SLABS AND WALLS

- Install the PAROC FPS 17 slabs according to drawing. Joints have to be tight – no gaps are allowed.
- Use at least 8 fasteners / slab (600 x 1200). Minimum distance from the edges ≤100 mm.

Fire protected concrete slab.



Installation of PAROC FPS 17 fire protection to concrete slab. The joints are staggered.



Distance of fasteners.

INSTALLATION OF FASTENER

- Drill a 8 mm hole to the concrete through insulation. The hole should be 10 mm deeper than length of fastener.
- In case of 60 mm thick fire protection layer use EJOT DMH-8x110-V fastener with EJOT DMT-80V washer. The depth of the hole is in this case normal installation depth 50 mm + 10 mm = 60 mm.
- Install fastener by using hammer.
- Joints between fire protection slabs have to be tight – no gaps are allowed.

Fastener + washer

EJOT DMH-8x110-V (for 60 mm thick fire protection slab)
+ EJOT DMT-80V washer, Ø 80 mm (or similar)

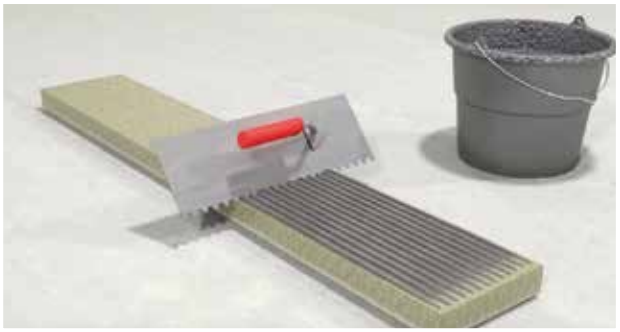
EJOT DMH-8x80-V (for 20 mm thick fire protection slab)
+ EJOT DMT-80V washer, Ø 80 mm (or similar)

PAROC FireSAFE SYSTEM – PAROC CGL 20

Loadbearing concrete floors (solid reinforced concrete slab): CGL 20		
50 mm	R180	Normal weight concrete, minimum thickness of the slab = 100 mm Minimum axis distance of reinforced steel bars from the exposed side = 25 mm. Critical temperature of steel 450°C
60 mm	R240	

Beams (solid reinforced concrete beam): CGL 20		
50 mm	R180	Normal weight concrete, minimum width of beam – b_w = 150 mm Minimum axis distance of reinforced steel bars from the exposed side –am = 25 mm. Critical temperature of steel 450°C
60 mm	R240	

Hollow-core slabs: CGL 20		
50 mm	R120	Normal weight concrete, minimum thickness of hollow-core slab = 150 mm. Minimum axis distance of reinforced steel bars from the exposed side = 25 mm. Minimum thickness of topping concrete layer (directly on the slabs), reinforced with steel mesh 150/150/4/4 mm = 40 mm. Critical temperature of steel 450°C
60 mm	R180	
100 mm	R240	



PAROC CGL 20 INSTALLATION

FIRE PROTECTION WITH PAROC CGL 20

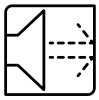
- Prepare the glue-plaster. Clue should be non-organic mineral clue based on cement binder (Bautechnik Ceresit CT 190 WM or CAPAROL Capatect Klebe- und Spachtelmasse 190 grau) prepared to application by adding water. Consumption of glue 4,5 kg/m^2.
- Applicable for insulation thicknesses 50–200 mm.
- Apply the glue-plaster onto the rear surface of lamella with trowel.
- Mount the lamella onto ceiling, always remember to use a trowel.
- PAROC CGL 20cy surface is ready for painting. Paint can be applied by spraying. Finishing material; non-organic water based silicate paint applied to the pre-painted surface (0,2 l/m^2).

Fire protection made by inorganic stone wool is very durable. Maintenance is only needed in case of impact damage, but it is important to exchange the damaged product, to maintain the designed fire protection. Damage is very easy to repair just by changing the current part of the insulation.

PAROC FireSAFE system shall be used in indoor spaces with normal indoor temperature and moisture conditions.

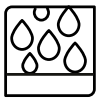
DURABLE

REUSABLE



SOUND REDUCING

FIRE PROOF



MOISTURE PROOF

SAFE

ENERGY EFFICIENT

PAROC® stands for energy-efficient and fire safe insulation solutions of stone wool for new and renovated buildings, marine and offshore, acoustics and other industrial applications. Behind those products, there is an 80-year history of stone wool production knowhow backed with technical insulation expertise and innovation.

Building Insulation offering covers a wide range of products and solutions for all traditional building insulation. The building insulation products are mainly used for the thermal, fire and sound insulation of exterior walls, roofs, floors and basements, intermediate floors and partitions. Sound absorbing ceilings and wall panels for interior acoustic control, as well as industrial noise control products, are available in the range.

Technical Insulation offering includes thermal, fire and sound insulation in HVAC systems, industrial processes and pipework, industrial equipment as well as shipbuilding and offshore industry.

For more information please visit ***www.paroc.com***

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