2. CONCRETE STRUCTURAL ELEMENTS

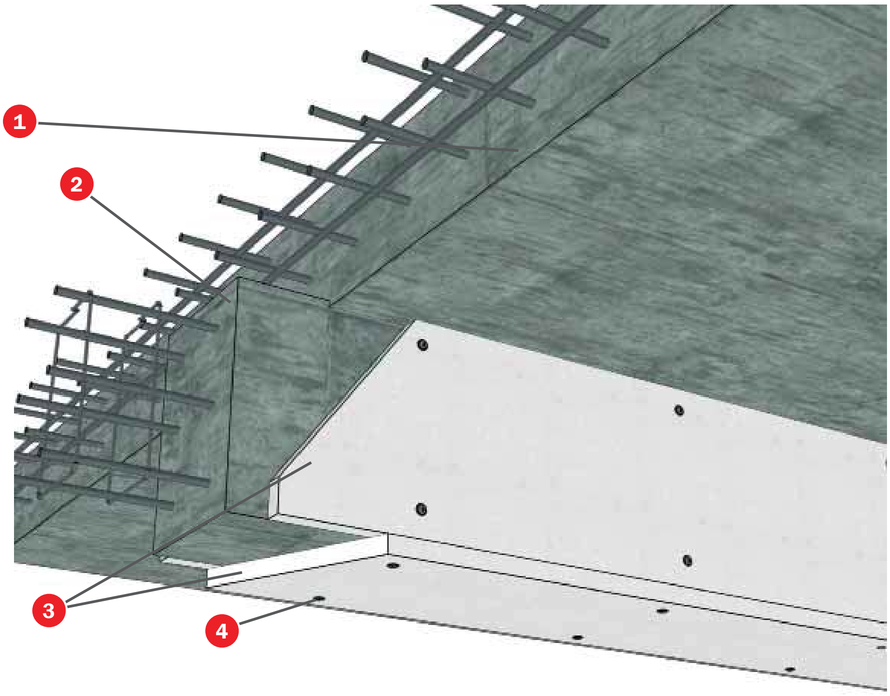
Despite its lack of combustibility and low thermal conductivity, the concrete experiences during the fire the formation of porous pressures and ductile internal tensiones which generate explosives splinters. This results in the loss of sections and the exposure of the reinforcement steel to extremely high temperatures.

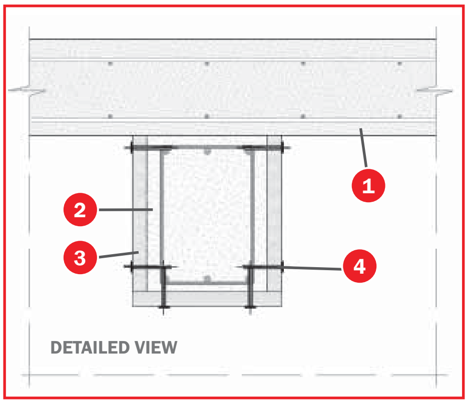
Furthermore, due to the warming, in particular to temperatures higher than 300 ºC, the concrete losses its resistance. These problams can be faced through the passive fire protection of concrete structural elements.

The fire protection of the concrete structural elements is used to prevent the chip explosion, which a higher degree of concrete is much more sensitive to.

Overall, the passive fire protection has become a priority issue anywhere where a combination with the follwing aspects is presented: chip explosion prevention; reinforcement and steel protection; so it doesn't exceed critical temperatures, protection so that the concrete doesn't exceed excesive temperatures.

2.1 PROTECTION OF BEAMS AND CONCRETE SLABS TECBOR® A R-30 - R-240





TEST

Standard: UNE EN 13381-3.

Laboratory: APPLUS.

Test Nº: 12-3550-541 M-1 and 12-3550-656.

SOLUTION

1. Slab
2. Concrete beam
3. **Tecbor®** boards
4. DBZ 6/35 metal anchors

DESCRIPTION OF ASSEMBLY

As minimum and maximum thickness were tested depending on the requested REI, we will need a determined number of layers to be installed. The boards will be directly fixed to the concrete with metal impact anchors HIlti DBZ type. Boards layout will be butt joint with no need of bonding paste. In the case where the gap between joints is bigger than 3 mm, **Tecsel®** mastic will be needed.

SPALLING EFFECT

This explosion is the violent break of the concrete layers or pieces of the surface of a structural element when exposed to a fast increase of temperatures, as it happens during a fire.

It usually takes place during the first 20 or 30 minutes in a conflagration. Many materials, (for example: permeability, saturation level, size and type of aggregate, presence of breakage and reinforcement); the geometrical shapes (as the section size) and the environment (resistance level, or heating and profile rate), have been factors influencing the splinters during a fire, as it has been identified from the researches.

The main factors which impact on the splinters are: the rate of warning (mainly over 2° or 3°C/minute), permeability of the material, degree of saturation of the pores (mainly over 2 or 3% of the moisture content by weight of the concrete), presence of reinforcement and level of external applied resistence.

Concrete's low permeability shows a greater tendency to splinter than one with concrete's average resistance,despite its greater resistance to tension.

This is because greater preassures on the pores are formed during the heating, due to the low permeability of the material. Furthermore, the highest preassure point on the pores happens closer to the surface for concrete.

PROTECTION WITH TECBOR® BOARDS

Fire resistance of concrete structural elements varies according to its density, moisture content, composition, size factors and distance to the shaft edge of the metal framework.

With the calculation methods contained in ENV 1992- 1-2 1955 standard, Eurocode 2 part 1-2 can be designed the concrete structural elements with the required bearing and compartment capacity for normalized thermal action.

Nevertheless, in order to improve the resistance capacity of the concrete, the **Tecbor®** boards offer a very effective and economic technical solution, increasing the fire resistance of the concrete structural elements.

EUROCODE 2, establishes the possibility of using protection and improvement systems with the corresponding test to determine both the equivalent thickness of the material and its capacity to remain cohesive and consistent with the slab.

CTE in its annex C also collects these specifications.

Tecbor® boards have their corresponding test according to UNE ENV 13381-3:2004 standard. The equivalent factors in concrete of the **Tecbor®** boards for different fire resistances have been tested through this test. The thicknesses to be applied are determined according to these factors.

Mercor tecresa® has carried out the study to calculate the minimum thickness of the **Tecbor®** boards to obtain different critic T at different coating thickness both on slabs.

Study to find the minimum thickness of the Tecbor® A boards to obtain certain critic T at different coating thickness on concrete beams

Data have been obtained from the test results shown in the 12/3550-656, 12/3550-200, 12/3550-201 reports and assuming a linear correlation between the protection thickness of "**Tecbor® A**" and its fire performance.

Boxes without numeric value indicate that the corresponding value is higher than the maximum tested value (40 mm).

Boxes with value 0 indicate that it is not necessary the application of protection due to the concrete beam's own fire resistance.

	350 ºC	400 ºC	450 ºC	500 ºC	550 ºC	600 ºC	650 ºC
Coating thickness "g" (mm)	Minimum protection thickness (mm) for R30						
≥5	0	0	0	0	0	0	0

	350 °C	400 °C	450 °C	500 °C	550 °C	600 °C	650 °C
Coating thickness “g” (mm)	Minimum thickness of protection (mm) for R60						
5-9	10	0	0	0	0	0	0
≥10	0	0	0	0	0	0	0

	350 °C	400 °C	450 °C	500 °C	550 °C	600 °C	650 °C
Coating thickness “g” (mm)	Minimum thickness of protection (mm) for R90						
5-9	18	13	10	10	10	0	0
10-14	11	10	10	0	0	0	0
15-19	10	0	0	0	0	0	0
≥20	0	0	0	0	0	0	0

	350 °C	400 °C	450 °C	500 °C	550 °C	600 °C	650 °C
Coating thickness “g” (mm)	Minimum thickness of protection (mm) for R120						
5-9	28	26	23	21	18	16	16
10-14	24	21	17	14	11	10	10
15-19	17	12	10	10	0	0	0
20-24	11	10	0	0	0	0	0
25-29	10	10	0	0	0	0	0
30-34	10	10	0	0	0	0	0
35-39	10	10	0	0	0	0	0
40-44	10	0	0	0	0	0	0
45-49	10	0	0	0	0	0	0
50-54	10	0	0	0	0	0	0
55-59	10	0	0	0	0	0	0
≥60	0	0	0	0	0	0	0

R180 and R240 tables have been obtained with data only from the 12/3550-200 maximum thickness test.

	350 °C	400 °C	450 °C	500 °C	550 °C	600 °C	650 °C
Coating thickness “g” (mm)	Minimum thickness of protection (mm) for R180						
≥5	40	40	40	40	40	40	40

	350 °C	400 °C	450 °C	500 °C	550 °C	600 °C	650 °C
Coating thickness “g” (mm)	Minimum thickness of protection (mm) for R240						
5-9	-	-	-	-	-	40	40
10-14	-	-	-	-	40	40	40
15-19	-	-	-	40	40	40	40
20-24	-	-	40	40	40	40	40
25-29	-	40	40	40	40	40	40
30-34	-	40	40	40	40	40	40
35-39	-	40	40	40	40	40	40
40-44	-	40	40	40	40	40	40
45-49	-	40	40	40	40	40	40
≥50	40	40	40	40	40	40	40

Study to find the minimum thickness of the Tecbor® A boards to obtain certain critic T at different coating thickness on concrete slabs

Data have been obtained from the test results shown in the 12/3550-541, 12/3550-167, 12/3550-199 reports and assuming a linear correlation between the protection thickness of "**Tecbor® A**" and its fire performance.

Boxes without numeric value indicate that the corresponding value is higher than the maximum tested value (40 mm).

Boxes with value 0 indicate that it is not necessary the application of protection due to the concrete slab's own fire resistance.

	350 ºC	400 ºC	450 ºC	500 ºC	550 ºC	600 ºC	650 ºC
Coating thickness "g" (mm)	Espesor mínimo de protección (mm) para R30						
≥5	0	0	0	0	0	0	0

	350 ºC	400 ºC	450 ºC	500 ºC	550 ºC	600 ºC	650 ºC
Coating thickness "g" (mm)	Espesor mínimo de protección (mm) para R60						
≥5	0	0	0	0	0	0	0

	350 ºC	400 ºC	450 ºC	500 ºC	550 ºC	600 ºC	650 ºC
Coating thickness "g" (mm)	Espesor mínimo de protección (mm) para R90						
5-9	27	24	22	19	17	14	12
10-14	21	18	15	11	10	10	10
15-19	14	10	10	0	0	0	0
20-24	10	0	0	0	0	0	0
≥25	0	0	0	0	0	0	0

	350 ºC	400 ºC	450 ºC	500 ºC	550 ºC	600 ºC	650 ºC
Coating thickness "g" (mm)	Minimum coating thickness (mm) for R120						
5-9	30	28	26	24	22	20	17
10-14	27	25	22	20	17	15	13
15-19	24	21	18	15	12	10	10
20-24	22	18	15	11	10	10	10
25-29	19	15	11	10	10	0	0
30-34	16	12	10	10	0	0	0
35-39	10	10	10	0	0	0	0
40-44	10	10	0	0	0	0	0
≥45	0	0	0	0	0	0	0

	350 ºC	400 ºC	450 ºC	500 ºC	550 ºC	600 ºC	650 ºC
Coating thickness "g" (mm)	Minimum thickness of protection (mm) for R180						
5-9	-	-	-	-	-	-	36
10-14	-	-	-	38	34	29	25
15-19	-	37	33	29	25	22	18
20-24	36	32	28	24	20	16	12
25-29	33	29	25	21	17	13	10
30-34	30	26	22	17	13	10	10
35-39	27	22	18	14	10	10	10
40-44	23	18	14	10	10	0	0
45-49	20	15	10	10	0	0	0
50-54	17	11	10	10	0	0	0
55-59	14	10	10	0	0	0	0
60-64	10	10	0	0	0	0	0
65-69	10	0	0	0	0	0	0
≥70	0	0	0	0	0	0	0

	350 ºC	400 ºC	450 ºC	500 ºC	550 ºC	600 ºC	650 ºC
Coating thickness "g" (mm)	Minimum thickness of protection (mm) for R240						
5-9	-	-	-	-	-	-	-
10-14	-	-	-	-	-	-	-
15-19	-	-	-	-	-	-	-
20-24	-	-	-	-	-	-	38
25-29	-	-	-	-	-	38	28
30-34	-	-	-	-	38	28	19
35-39	-	-	-	38	29	19	10
40-44	-	-	38	29	19	10	10
45-49	-	40	31	21	12	10	0
50-54	-	33	23	14	10	0	0
55-59	36	27	18	10	0	0	0
60-64	30	21	12	10	0	0	0
65-69	25	15	10	0	0	0	0
70-74	20	11	10	0	0	0	0
75	15	10	0	0	0	0	0

Note: values for R240 cannot be found for depths greater than 75 mm, as there is no temperature value at greater depths since the maximum depth at which the thermocouples must be placed is 75 mm (s. UNE EN 13381-3:2004)