SIGGMA

Job title: **Chemfix Pure Epoxy with post-installed rebars**

Report title: **Evaluation of Fire Resistance**

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chemfix
TOTAL SERVICE

Reviews

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1. Introduction

Chemfix Products LTD distributes the injection system Chemfix Pure Epoxy.

Chemfix performed additional tests to high temperature at the Testing Material Laboratory of the Politecnico di Milano (Italy), as detailed in Chapter 4. No test was carried out by the Manufacturer.

In Europe no specific provision (nor standard or guideline) exists so far for the evaluation of the fire resistance of post-installed rebars.
Therefore, the scope of this expert report is the evaluation of the fire resistance according to a procedure agreed with the manufacturer, that is responsible for the declared performances.

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

2. References and Symbols

2.1. References

[1] EOTA TR 023, Assessment of post-installed rebar connections (Edition November 2006)

[2] EN 1992- 1-2, Eurocode 2 - Design of concrete structures, Part 1-2: General rules - Structural fire design

[3] UNI 9502, Analytical fire resistance assessment of reinforced concrete and prestressed concrete structural elements

[R1] Imperial College London Consultants, Project report number: SPO/ICON-RT-09-07-Ver04

[R2] Test report “Tensile load tests on Chemfix post-installed rebar subject to high temperature exposure”, by the Laboratory of Material Testing (Laboratorio Prove Materiali) of Politecnico di Milano (Italy)

3. Description of the Bonded Anchors

A detailed description of the anchor, its installation procedure, its factory production control its and manufacturing process is int the documents provided by the manufacturer [R1].

4.Tests

4.1 Miscellaneous

The test procedure is described in [R2].

The test programme was drawn up jointly with the manufacturer. Ten temperature tests were performed.

The test program is illustrated in table 4.1.

Table 4.1 - Temperature tests on Pure Epoxy

Type	Number of tests	Rebar diameter	Temperature
Pure epoxy	5	12 mm	50 °C
Pure epoxy	5	12 mm	150 °C

5. Determination of the Characteristic Resistance

5.1 Assessment principle

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

From the results of the tension tests the average bond resistance is calculated according to [1], Equation (5.1).

$$f_{bm}^{t} = \frac{N_{u,m}}{\pi \cdot d \cdot l_v} \tag{5.1}$$

with:

f^t_{bm} = average bond resistance in the test series
$N_{u,m}$ = average value of the failure loads in the test series
d = rebar diameter
l_v = embedment length of the bar in the concrete

A relative rib area of the rebar equal to 0,08 is assumed.

If the average bond resistance f^t_{bm} determined according to Equation (5.1) reaches at least the required bond resistance $f_{req,bm}$ (10 N/mm²) then the post-installed rebar may be designed using the design value of the ultimate bond stress, f_{bd} = 2.3 N/mm² for ribbed bars according to Eurocode 2 for concrete strength class C20/25.
If the required bond resistance in C20/25 and/or C50/60 is not fulfilled, then the design bond strength f_{bd} shall be calculated as follow:

$$f_{bd} = f_{bm}^{t} \cdot 0.230 \tag{5.2}$$

with f^t_{bm} = average bond resistance in the test series limited to 10N/mm². The factor 0.230 already accounts for a partial safety factor of concrete γ_{Mc} equal to 1.5.

5.2 Evaluation of the design bond strength

Based on the test results reported in [R2], Table 1 reports the evaluation of the design bond strength for Pure Epoxy.

Table 1

Type	T (°C)	τ_{test}(Mpa)	f_{bd}(Mpa)
Epoxy	50	7,5	1,7
Epoxy	150	1,3	0,3

For the following evaluations Table 2 reports the values of design bond strength assumed in the different temperature ranges.

Table 2

Type	Range (°C)	f_{bd}(Mpa)
Epoxy	0 ÷ 20	2,3
Epoxy	20 ÷ 50	1,7
Epoxy	50÷150	0,3
Epoxy	>150	0,0

6. Resistance to Fire for Wall to Slab Connection

6.1 Temperature profiles

Table 3 reports the temperature profiles that can be assumed for a concrete slab according to [3] for different fire durations (from 30' to 240') as a function of the distance 'e' (in *cm*) from the exposed surfaces for calcareous aggregate.

Table 3 – Temperature profiles for a slab for different fire duration (according to [3])

e	30	60	90	120	180	240
0	661	824	907	963	1039	1092
1	482	661	758	824	914	977
2	326	490	595	669	770	840
3	222	370	466	541	648	723
3,5	191	325	415	486	594	671
4	161	286	372	439	544	622
4,5	135	252	334	398	498	577
5	114	223	301	362	458	534
6	82	175	246	302	390	460
7	60	138	202	254	335	399
8	45	109	166	213	289	350
9	35	86	136	180	251	308
10	29	69	112	152	218	271

The value reported in Table 3 are subsequently fitted by an exponential laws and extrapolated to account for a distance from the surface greater than 10 cm.
Figure 1 reports the obtained temperature profiles.
The conformity of the reported profiles to each specific design situation shall be verified by the designer.

6.2 Evaluation of basic anchorage length

Finally, as a function of the fire duration and of the distance of the rebar from the exposed surface, the basic anchorage length l_b [2] is evaluated for Pure Epoxy.
The results are reported in Annex 1. The following information are reported:

- Φ: diameter of the rebar;
- F_{Rd}: maximum force that can be transmitted by the rebar at ambient temperature, assuming a steel class B450C;
- e: distance from the exposed surface;
- l_b: basic anchorage length as a function of the fire durations F30, F60, F90, F120, F180 and F240. The basic anchorage length at ambient temperature F0 is also reported.

For values of the force to be transferred lower than the reported one, the basic anchorage lengths can be linearly reduced.

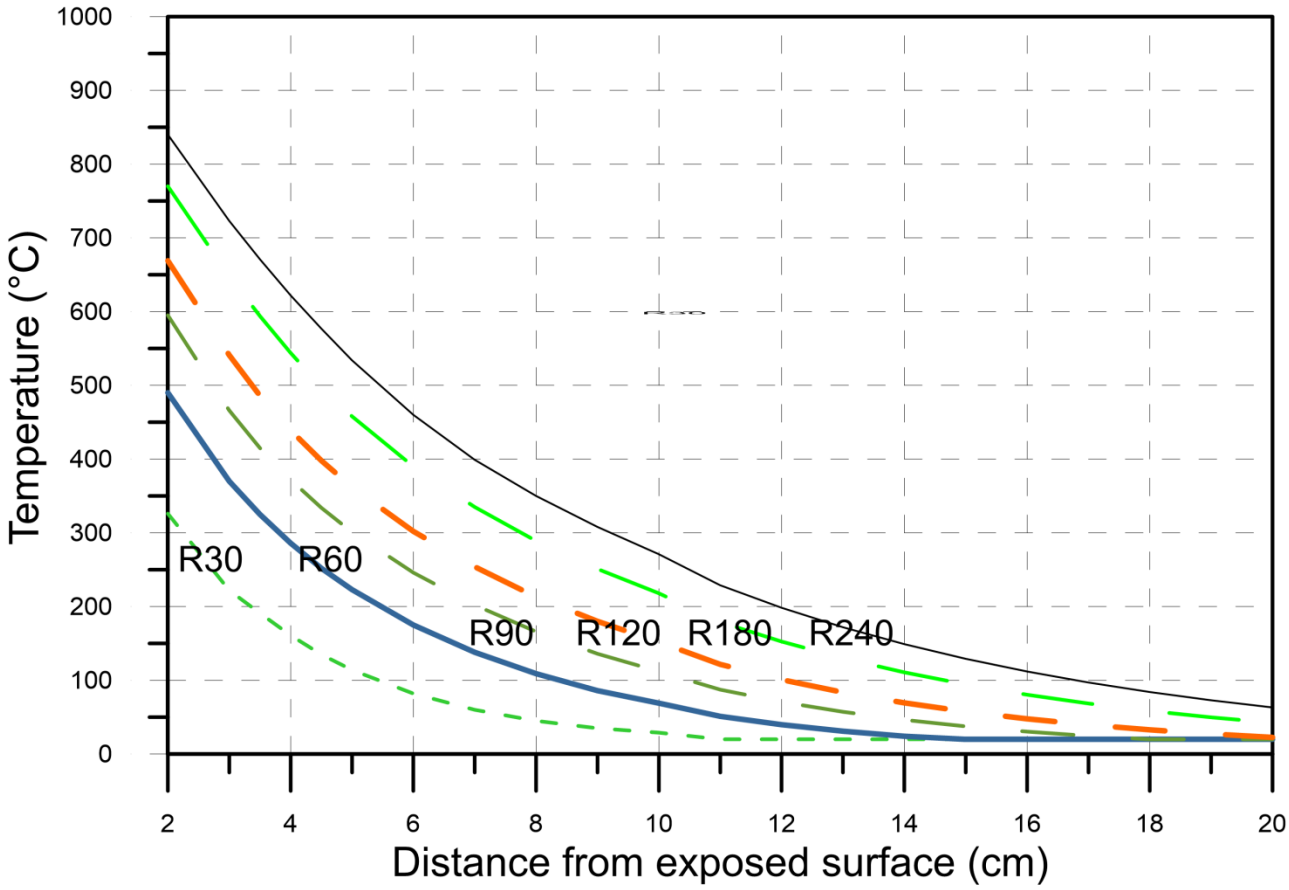


Figure 1 – Extrapolated temperature profiles for a slab for different fire durations

7. Resistance to Fire for a Reinforced Concrete Beam

7.1 Temperature profiles

Table 4 reports the temperature profiles that can be assumed for a concrete beam (calcareous aggregate) according to [4] for different fire durations (from 30' to 240')as a function of the distance 'e' (in *cm*) from both the bottom and the side surfaces.
A more conservative value of 145 °C is assumed for R=90' and e=9cm.

Table 4 - Temperature profiles for a beam for different fire duration (according to [4])

e	30	60	90	120	180	240
1	682	854	940	997	1073	1124
3	370	580	709	796	911	990
5	194	364	487	580	718	814
7	100	230	330	411	544	647
9	53	145	227	296	410	507
11	32	90	155	215	317	403
13	24	57	107	157	250	330
15	21	39	75	118	203	280
17	20	30	58	95	174	247

The value reported in Table 4 are subsequently fitted by an exponential laws and extrapolated to account for a distance from the surface greater than 17 cm.
Figure 2 reports the obtained temperature profiles.
The conformity of the reported profiles to each specific design situation shall be verified by the designer.

7.2 Evaluation of basic anchorage length

Finally, as a function of the fire duration and of the distance of the rebar from the corner of the beam, the basic anchorage length l_b [3] is evaluated for Pure Epoxy.
The results are reported in Annex 2. The following information are reported:

- Φ: diameter of the rebar;
- F_{Rd}: maximum force that can be transmitted by the rebar at ambient temperature, assuming a steel class B450C;
- e: distance from both the bottom and the side exposed surfaces;
- l_b: basic anchorage length as a function of the fire durations F30, F60, F90, F120, F180 and F240. The basic anchorage length at ambient temperature F0 is also reported.

For values of the force to be transferred lower than the reported one, the basic anchorage lengths can be linearly reduced.

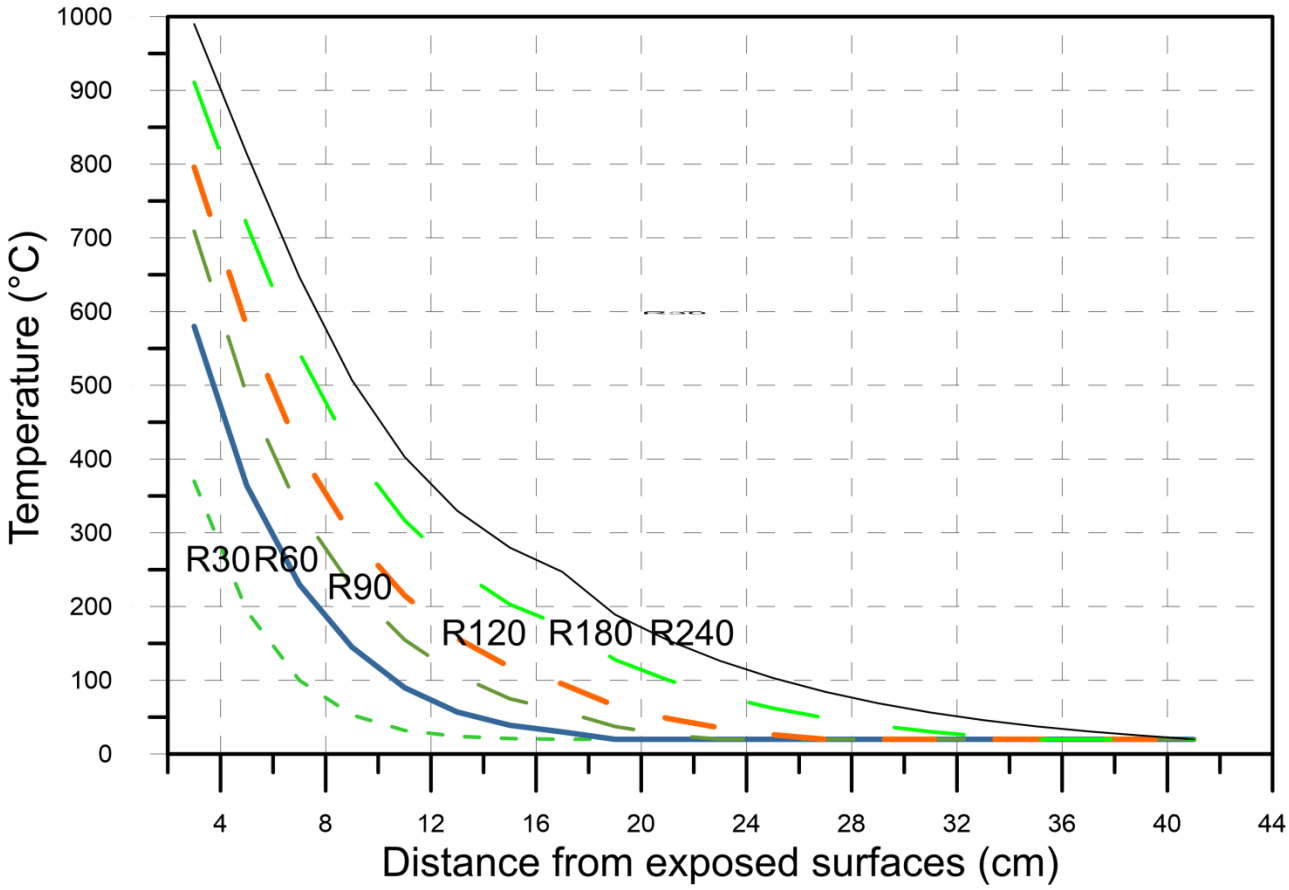
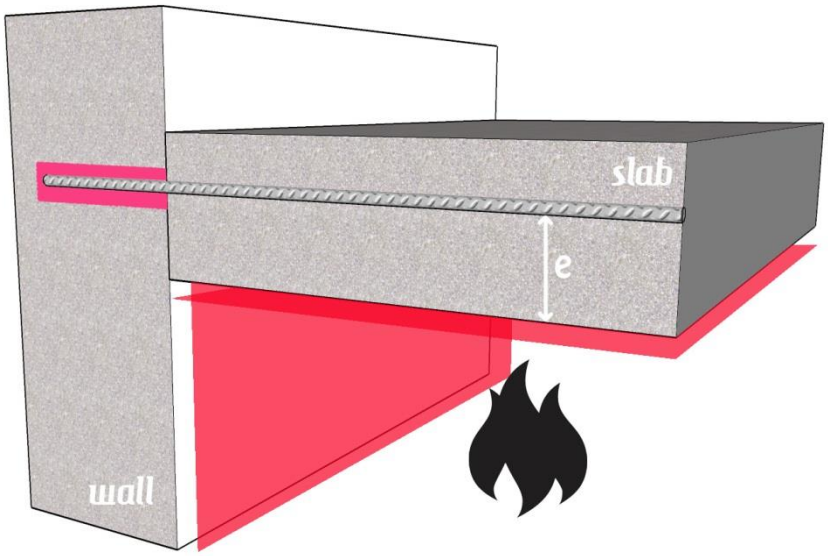


Figure 2 – Extrapolated temperature profiles for a slab for different fire durations

Annex 1



Wall to slab connection – Pure Epoxy (all the distances are in mm)

Rebar	F_{Rd}	Distance	R0	R30	R60	R90	R120	R180	R240
ϕ (mm)	(kN)	e (mm)	basic anchorage length l_b						
8	19,7	80	340	455					
		120		340	455				
		150		340	340	455			
		180		340	340	340	455		
		210		340	340	340	340	455	
		250		340	340	340	340	340	455
		290		340	340	340	340	340	340

Rebar	F_{Rd}	Distance	R0	R30	R60	R90	R120	R180	R240
ϕ (mm)	(kN)	e (mm)	basic anchorage length l_b						
10	30,7	80	425	569					
		120		425	569				
		150		425	425	569			
		180		425	425	425	569		
		210		425	425	425	425	569	
		250		425	425	425	425	425	569
		290		425	425	425	425	425	425

Rebar	F_{Rd}	Distance	R0	R30	R60	R90	R120	R180	R240
ϕ (mm)	(kN)	e (mm)	basic anchorage length l_b						
12	44,2	80	510	682					
		120		510	682				
		150		510	510	682			
		180		510	510	510	682		
		210		510	510	510	510	682	
		250		510	510	510	510	510	682
		290		510	510	510	510	510	510

Rebar	F_{Rd}	Distance	R0	R30	R60	R90	R120	R180	R240
ϕ (mm)	(kN)	e (mm)	basic anchorage length l_b						
14	60,2	80	595	796					
		120		595	796				
		150		595	595	796			
		180		595	595	595	796		
		210		595	595	595	595	796	
		250		595	595	595	595	595	796
		290		595	595	595	595	595	595

Rebar	F_{Rd}	Distance	R0	R30	R60	R90	R120	R180	R240
ϕ (mm)	(kN)	e (mm)	basic anchorage length l_b						
16	78,6	80	681	910					
		120		681	910				
		150		681	681	910			
		180		681	681	681	910		
		210		681	681	681	681	910	
		250		681	681	681	681	681	910
		290		681	681	681	681	681	681

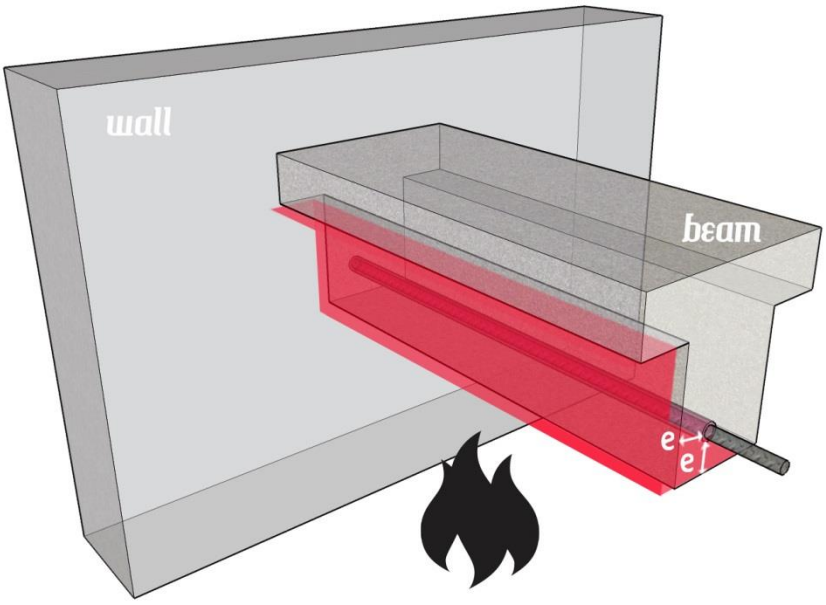
Rebar	F_{Rd}	Distance	R0	R30	R60	R90	R120	R180	R240
ϕ (mm)	(kN)	e (mm)	basic anchorage length l_b						
20	122,9	80	851	1137					
		120		851	1137				
		150		851	851	1137			
		180		851	851	851	1137		
		210		851	851	851	851	1137	
		250		851	851	851	851	851	1137
		290		851	851	851	851	851	851

Rebar	F_{Rd}	Distance	R0	R30	R60	R90	R120	R180	R240
ϕ (mm)	(kN)	e (mm)	basic anchorage length l_b						
24	176,9	80	1021	1365					
		120		1021	1365				
		150		1021	1021	1365			
		180		1021	1021	1021	1365		
		210		1021	1021	1021	1021	1365	
		250		1021	1021	1021	1021	1021	1365
		290		1021	1021	1021	1021	1021	1021

Rebar	F_{Rd}	Distance	R0	R30	R60	R90	R120	R180	R240
ϕ (mm)	(kN)	e (mm)	basic anchorage length l_b						
30	276,5	80	1276	1706					
		120		1276	1706				
		150		1276	1276	1706			
		180		1276	1276	1276	1706		
		210		1276	1276	1276	1276	1706	
		250		1276	1276	1276	1276	1276	1706
		290		1276	1276	1276	1276	1276	1276

Rebar	F_{Rd}	Distance	R0	R30	R60	R90	R120	R180	R240
ϕ (mm)	(kN)	e (mm)	basic anchorage length l_b						
32	314,5	80	1361	1820					
		120		1361	1820				
		150		1361	1361	1820			
		180		1361	1361	1361	1820		
		210		1361	1361	1361	1361	1820	
		250		1361	1361	1361	1361	1361	1820
		290		1361	1361	1361	1361	1361	1361

Annex 2



Reinforced Concrete Beam – Pure Epoxy (all the distances are in mm)

Rebar	F_{Rd}	Distance	R0	R30	R60	R90	R120	R180	R240
ϕ (mm)	(kN)	e (mm)	basic anchorage length l_b						
8	19,7	110	340	455					
		180		340	455				
		190		340	340	455			
		230		340	340	340	455		
		270		340	340	340	340	455	
		350		340	340	340	340	340	455
		410		340	340	340	340	340	340

Rebar	F_{Rd}	Distance	R0	R30	R60	R90	R120	R180	R240
ϕ (mm)	(kN)	e (mm)	basic anchorage length l_b						
10	30,7	110	425	569					
		180		425	569				
		190		425	425	569			
		230		425	425	425	569		
		270		425	425	425	425	569	
		350		425	425	425	425	425	569
		410		425	425	425	425	425	425

Rebar	F_{Rd}	Distance	R0	R30	R60	R90	R120	R180	R240
ϕ (mm)	(kN)	e (mm)	basic anchorage length l_b						
12	44,2	110	510	682					
		180		510	682				
		190		510	510	682			
		230		510	510	510	682		
		270		510	510	510	510	682	
		350		510	510	510	510	510	682
		410		510	510	510	510	510	510

Rebar	F_{Rd}	Distance	R0	R30	R60	R90	R120	R180	R240
ϕ (mm)	(kN)	e (mm)	basic anchorage length l_b						
14	60,2	110	595	796					
		180		595	796				
		190		595	595	796			
		230		595	595	595	796		
		270		595	595	595	595	796	
		350		595	595	595	595	595	796
		410		595	595	595	595	595	595

Rebar	F_{Rd}	Distance	R0	R30	R60	R90	R120	R180	R240
ϕ (mm)	(kN)	e (mm)	basic anchorage length l_b						
16	78,6	110	681	910					
		180		681	910				
		190		681	681	910			
		230		681	681	681	910		
		270		681	681	681	681	910	
		350		681	681	681	681	681	910
		410		681	681	681	681	681	681

Rebar	F_{Rd}	Distance	R0	R30	R60	R90	R120	R180	R240
ϕ (mm)	(kN)	e (mm)	basic anchorage length l_b						
20	122,9	110	851	1137					
		180		851	1137				
		190		851	851	1137			
		230		851	851	851	1137		
		270		851	851	851	851	1137	
		350		851	851	851	851	851	1137
		410		851	851	851	851	851	851

Rebar	F_{Rd}	Distance	R0	R30	R60	R90	R120	R180	R240
ϕ (mm)	(kN)	e (mm)	basic anchorage length l_b						
24	176,9	110	1021	1365					
		180		1021	1365				
		190		1021	1021	1365			
		230		1021	1021	1021	1365		
		270		1021	1021	1021	1021	1365	
		350		1021	1021	1021	1021	1021	1365
		410		1021	1021	1021	1021	1021	1021

Rebar	F_{Rd}	Distance	R0	R30	R60	R90	R120	R180	R240
ϕ (mm)	(kN)	e (mm)	basic anchorage length l_b						
30	276,5	110	1276	1706					
		180		1276	1706				
		190		1276	1276	1706			
		230		1276	1276	1276	1706		
		270		1276	1276	1276	1276	1706	
		350		1276	1276	1276	1276	1276	1706
		410		1276	1276	1276	1276	1276	1276

Rebar	F_{Rd}	Distance	R0	R30	R60	R90	R120	R180	R240
ϕ (mm)	(kN)	e (mm)	basic anchorage length l_b						
32	314,5	110	1361	1820					
		180		1361	1820				
		190		1361	1361	1820			
		230		1361	1361	1361	1820		
		270		1361	1361	1361	1361	1820	
		350		1361	1361	1361	1361	1361	1820
		410		1361	1361	1361	1361	1361	1361