MFPA Leipzig GmbH
Testing, Inspection and Certification Authority for Construction Products and Construction Types

Leipzig Institute for Materials Research and Testing
Business Division III - Structural Fire Protection
Dipl.-Ing. Sebastian Hauswaldt

Work Group 3.2 - Fire Behaviour of Building Components and special Constructions

Dipl.-Wirtsch.-Ing. S. Kramer
Tel.: +49 (0) 341-6582-194
s.kramer@mfpa-leipzig.de

Advisory Opinion No. GS 3.2/16-369-3

11 August 2017
No. Copy 1

Subject matter:	Rawlplug injection system R-KER-II-S as a system for post-installed rebar connections Fire protection assessment concept for the Rawlplug injection system R-KER-II-S in conjunction with reinforcing steel for concrete BSt 500 S corresponding to EAD 330087-00-0601 (Draft Mai 2016)
Client:	Rawlplug SA. ul. Kwidzyńska 6 51-416 Wrocław Poland
Date of order:	25 January 2017
Person in charge:	Dipl.-Wirtsch.-Ing. S. Kramer
Validity:	10. August 2022

This document consists of 9 text pages and 2 enclosures.

Gesellschaft für Materialforschung und Prüfungsanstalt für das Bauwesen Leipzig mbH (MFPA Leipzig GmbH)

Head Office: Hans-Weigel-Str. 2b – 04319 Leipzig/Germany
Managing Director: Prof. Dr.-Ing. Frank Dehn
Comm. Register: Local Court Leipzig HRB 17719
VAT-ID: DE 813200649
Tel.: +49 (0) 341-6582-0
Fax: +49 (0) 341-6582-135

1 Objective and request

On 25 January 2017, Rawlplug SA. commissioned MFPA Leipzig GmbH to prepare an advisory opinion on the fire behaviour of the Rawlplug injection system R-KER-II-S, i.e. the Rawlplug injection mortar R-KER-II-S in conjunction with reinforcing steel for overlap joints and wall-slab connections with a one-sided exposure to fire.

2 Description of the construction to be assessed

For the Rawlplug rebar connection reinforcing bars with a diameter d_s from 8 to 32 mm and the injection mortar R-KER-II-S are used. The steel element is placed into a drilled hole filled with injection mortar and is anchored via the bond between embedded element, injection mortar and concrete. Variable anchoring depths are permissible for construction.

3 Basic information for the assessment concept

3.1 Temperatures at the reinforcement

In accordance with DIN EN 13381-3: 2015-06 [1] temperature curves were taken as a basis for the advisory opinion, in particular for the heating behaviour of reinforced concrete elements made of normal concrete with quartzite aggregates to determine the temperatures at the reinforcement. Fig. 1 shows the temperatures graphically as a function of the duration of heating and the depth of concrete for solid structural components exposed to fire on one side with the standard temperature-time curve (ETK) according to DIN EN 1363-1: 2012-10 [2].

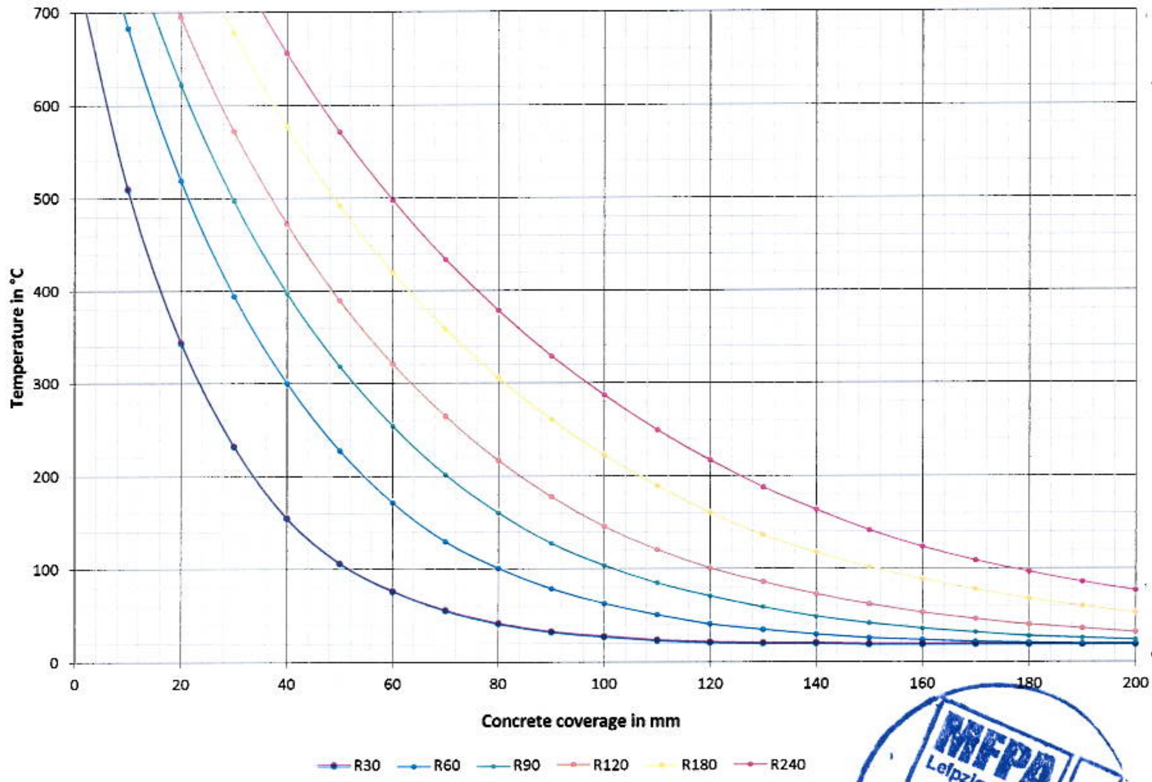

Fig. 1 Temperatures in reinforced concrete structural components after 30, 60, 90, 120, 180 and 240 minutes exposure to fire on one side in accordance with EN 1363-1, data from DIN EN 13381-3: 2015-06 [1]

3.2 Bond resistance

To assess, the reduction factor for temperature stresses of $k_{fi}(\theta)$ was also taken as a basis for the calculations. This reduction factor depends on the temperature and was determined as follows:

The tests for the injection system Rawlplug R-KER-II-S took place in May and June 2017 at MFPA Leipzig GmbH according to EAD 330087-00-0601 Draft: 2016-05 [3]. The testing procedure and results are presented in the test report PB 3.2/16-369-2 [4].

The concrete cylinders had a diameter of 150 mm and a height of 250 mm. The size of the rebar was named d. Embedment depth was 10 d and the diameter of the drilling hole was equal to d + 5 mm. The thermocouples were placed at the end of the rebar (TC2) and 10 mm underneath the concrete surface (TC1). For more details about the test setup and the testing procedure, please see PB 3.2/16-369-2 [4].

The test results are given in PB 3.2/16-369-2 [4]. In Fig. 2 the results are presented graphically.

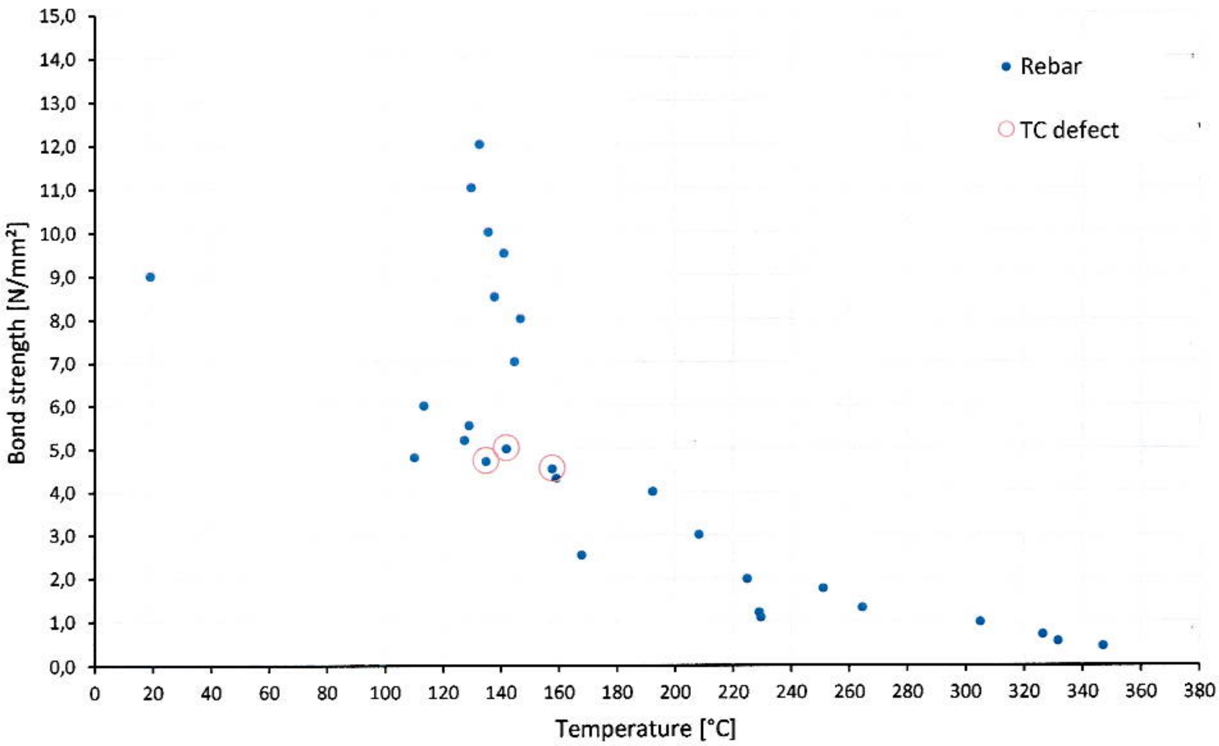

Fig. 2 Test results according to PB 3.2/16-369-2 [4]

As you can see there were three tests, were one of the thermocouples failed to measure the temperature during the test. These three test results are not taken into account because failure temperature could only be guessed. Also the one test with 9 N/mm² which failed without heating up is ignored while determining the function. The reason for this early failure was most likely that the resin was not mixed completely.

The mean bond resistance f_{bm} has to be specified with an exponential function of the type

$$f_{bm(\theta)} = a \cdot e^{-b \cdot \theta} \, [N/mm^2]$$

using the least square fitting method. Higher values than 10 N/mm² must be cut short. The fitting curve must also be cut off at maximum temperature, which is calculated as mean temperature of the 3 highest valid results. The resulting fitting curve is given in Fig. 3.

MFPA Leipzig GmbH
SAC 02
NB 0800

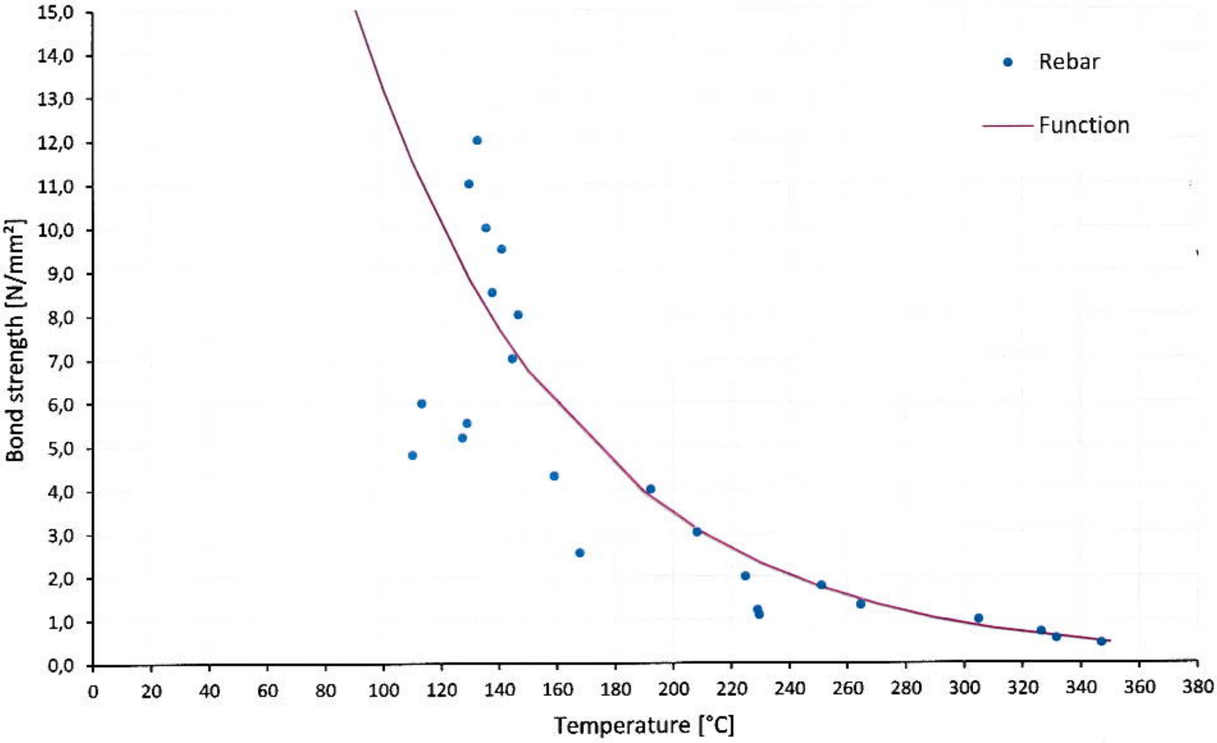

Fig. 3 Fitting curve for f_{bm}

The coefficient of variation cv should be calculated as the relative deviation from the fitting curve according to the following equation:

$$cv = \sqrt{\frac{1}{n_{test}-1}\sum_{i=1}^{n_{test}}\left(\frac{f_{b,t,i}}{f_{bm}(\theta_i)}-1\right)^2} \leq 45\,\%$$

With this curve the coefficient of variation cv is equal to 27.05 %.

The temperature reduction factor is determined according to the following equations:

$$k_{fi}(\theta) = \frac{f_{bm}(\theta)}{f_{bm,rqd,d}} \leq 1{,}0 \qquad \text{for} \qquad 20°C \leq \theta \leq \theta_{max}$$

$$k_{fi}(\theta) = 0 \qquad \text{for} \qquad \theta > \theta_{max}$$

No extrapolation on test temperatures is allowed. For temperatures higher than the maximum measured temperature, the reduction factor is equal to zero. In Fig. 4 the reduction factor and its limitation is plotted.

MFPA Leipzig GmbH III SAC 02 NB 0800

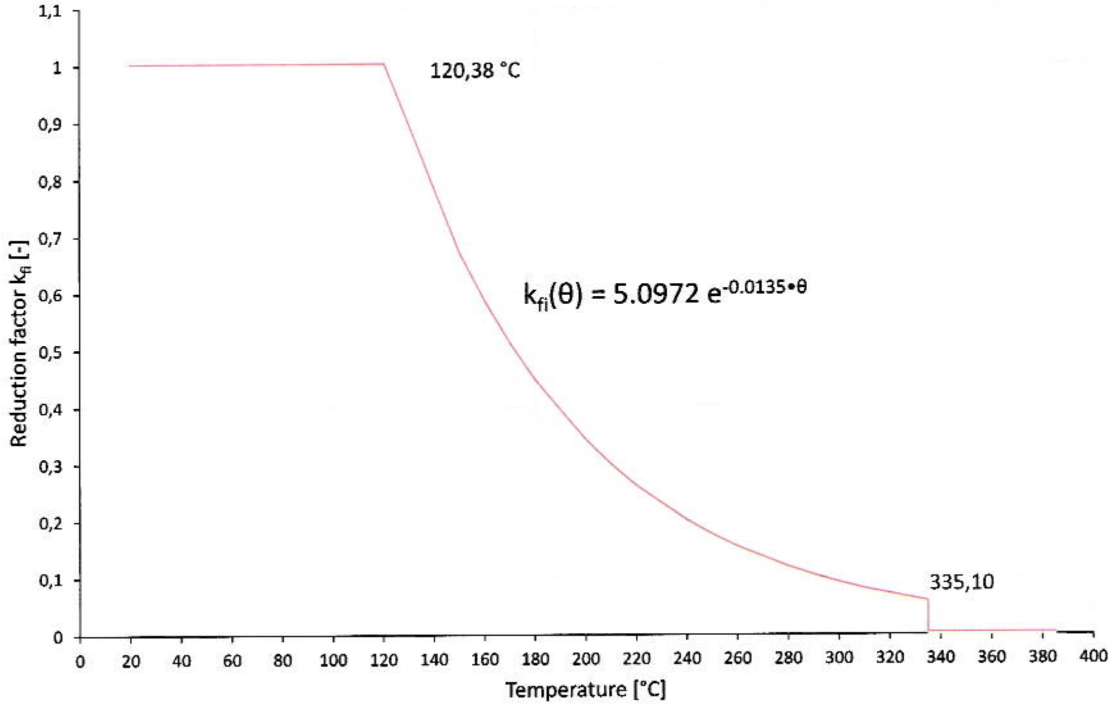

Fig. 4 Temperature reduction factor $k_{fi}(\theta)$

4 Fire protection assessment concept

This fire protection assessment concept for rebar connections considers the two application cases "overlap joint" and "end anchorage".

The overlap joint (see Fig. 5) represents the connection of two reinforced concrete slabs. Only the lower surface of the slabs is exposed to fire. The rebars lie horizontally at a temperature level. Accordingly, the temperature distribution in the steel is homogeneous over the entire anchoring depth and only depends on the concrete coverage.

An end anchorage (see Fig. 6), represents the connection of a ceiling panel to a wall. The rebar is hereby installed vertical to the side of the wall that is exposed to fire. The temperatures along the anchoring depth thus fall with an increasing anchoring depth. Consequently, different bond strength exist over the anchoring depth.

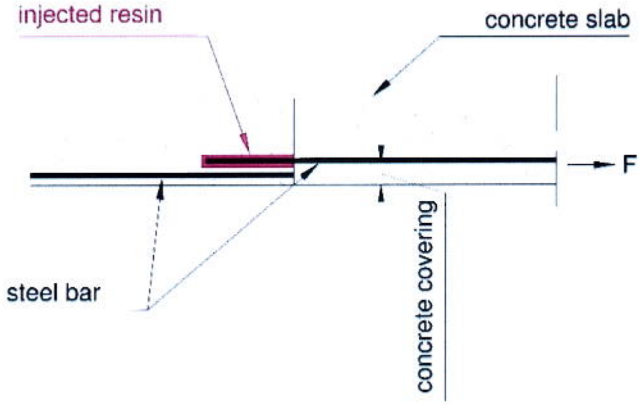

Fig. 5 Overlap joint

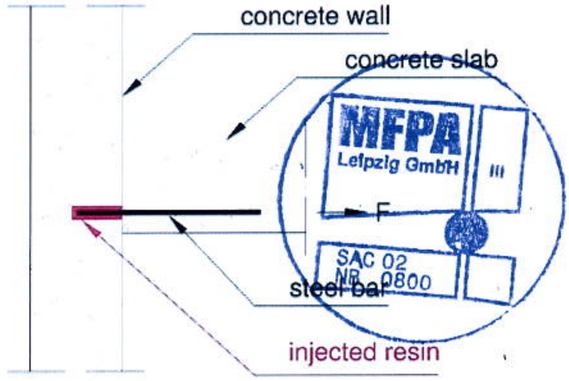

Fig. 6 End anchorage

4.1 Application case: overlap joint

Based on the temperature curves quoted in Fig. 1 the reduction factor for the temperature stresses shown in Fig. 4 the characteristic bond resistance to any pulling out of the reinforcing rods at an overlap joint can be calculated with the following equation.

$$f_{bd,fire}(\theta) = f_{bd,20°C} \cdot \frac{\gamma_{M,20°C}}{\gamma_{M,fire}} \cdot k(\theta)$$

Whereby

$f_{bd,fire}(\theta)$	is the characteristic bond strength under fire exposure,
$f_{bd,20°C}$	is the characteristic bond strength for C20/25 at 20°C, = 2.3 N/mm².
$\gamma_{M,20°C}$	is the coefficient of safety at an ambient temperature, = 1.5
$\gamma_{M,fire}$	is the coefficient of safety under the temperature stress, = 1.0
$k(\theta)$	is the reduction factor under fire exposure.

Enclosure 1 shows the characteristic bond resistances for various anchoring depths.

4.2 Application case: end anchorage

The characteristic resistances to any pulling out are quoted in Enclosure 2 for the application case "end anchorage", starting with the minimum anchoring depth $l_{fire,min}$. These values are limited by the steel failure values at the ambient temperature.

The minimum anchoring depth was determined in accordance with DIN EN 1992-1-2: 2010-12 [5] as

$$l_{fire,min} = l_{b,min} = max\{0{,}3 \cdot l_{b,rqd}\ ;\ 10 \cdot d\ ;\ 100\ mm\}$$

In this case, $l_{b,rqd}$ is the necessary length of the reinforcing steel with

$$l_{b,rqd} = \frac{d}{4} \cdot \frac{\sigma_{s,d}}{f_{bd}} = \frac{d}{4} \cdot \frac{\sigma_{s,yield}}{\gamma_{M,20°C} \cdot f_{bd,20°C}}$$ whereby

$\sigma_{s,yield}$	= 500 N/mm² and is the apparent limit of elasticity of steel, and
d	is the diameter of the reinforcing steel

Accordingly, the steel failure value at ambient temperature is calculated from

$$N_{rebar,yield} = \frac{\sigma_{s,yield}}{\gamma_{M,20°C}} \cdot \pi \cdot \left(\frac{d}{2}\right)^2$$

Table 1 shows the minimum anchoring depths resulting from this as well as the maximum steel stresses.

Table 1 Minimum anchoring depths and maximum steel failure values

Ø [mm]	$l_{b,rqd}$ [mm]	$l_{b,min}$ [mm]	$N_{rebar,yield}$ [kN]
8	290	100	16.8
10	362	109	26.2
12	435	130	37.7
14	507	152	51.3
16	580	174	67.0
20	725	217	104.7
25	906	272	163.6
32	1159	348	268.1

Fig. 6 explains how the end anchor is used. The anchorage zone of the reinforcement is located vertical to the surface of the element exposed to fire and lies in different temperature areas.

The characteristic resistance of the anchor against being pulled out of concrete can be determined with the aid of the temperature curves from Fig. 1 and the reduction factor for the temperature stress (Fig. 4) by the equation

$$N_{rd,fire} = \pi \cdot \mathrm{d} \cdot f_{bd,20°C} \cdot \frac{\gamma_{M,20°C}}{\gamma_{M,fire}} \cdot \int_0^{lv} k(\theta(x)) \cdot dx$$

whereby:

$N_{rd,fire}$ is the characteristic resistance against pulling out at a certain time

l_v is the anchoring depth of the compound anchor.

Since the temperature of the shear plane in the concrete varies with the depth of the hole, the characteristic values for the resistance in the fire case for the failure type "pulling out of the concrete" are determined through the integration of the critical, temperature-dependent bond strength (multiplied by the circumference) as a function of the anchoring depth.

The calculation is carried out assuming that the temperature at the anchor corresponds to the temperature in the concrete. To be on the safe side, the heating of the wall is assumed to be an extensive flame impingement. The cooling and protective effect of the connected solid structural part is not taken into account.

Enclosure 2 shows the results of the calculations. However, these only relate to the application case end anchorage. The proof of the connected slab has to be verified separately with the aid of Enclosure 1.

The values for the end anchorage also apply for connected beams. However, the results of the calculation of the overlap joints may only be transferred to a beam with a one-sided exposure to fire since the temperature yield in the beam can be much higher with a multi-sided exposure to fire. The strength of beams in the event of fire thus has to be determined separately.

MFPA Leipzig GmbH
SAC 02
NB 0800

5 Scope

The assessment concept applies for reinforcing steel for concrete grades with apparent effective yield strength of 500 MPa, for rods with a nominal diameter of ø 8 to ø 32 mm and for fire-resistance periods of 30 minutes to 240 minutes, taking into account the partial safety factors quoted in section 4 and with a thermal load in accordance with the standard temperature-time curve in accordance with DIN EN 1363-1: 2012-10 [2].

The values quoted relate to the concrete strength class C20/25 and are applicable for concretes with strength classes up to C50/60.

The results for the end anchorage can also be used for overlap joints on the safe side. The values for the overlap joints are not applicable for beam joints.

The concrete coverage is only regarded as a thermal protection in this assessment. The necessary concrete coverage must be calculated in accordance with DIN EN 1992-1-1: 2011-01 [6], Section 4.

The characteristic values for the overlap joint are compiled in Enclosure 1 as a function of the concrete coverage. The characteristic values for the failure with an end anchorage are shown in Enclosure 2. The end anchorage values are limited by the steel failure values (grey background).

Interim values may be interpolated. An extrapolation is not allowed. The quoted loads apply for the stress directions central tension, lateral tension and diagonal tension at every angle.

6 Special notes

The assessment above applies for the Rawlplug injection system R-KER-II-S in concrete when installed in accordance with the installation regulations of ETA-17/0874.

The assessment applies in general to a one-sided fire loading of the structural elements. In the event of a fire loading on several sides, the verification procedure can only be applied if the gap to the outer edge of the plug is $c \geq 300$ mm and $\geq 2\ h_{ef}$.

The assessment only applies in combination with reinforced concrete ceilings of strength class ≥ C 20/25 and ≤ C 50/60 according to EN 206-1: 2000-12, that can be classified in at least the fire-resistance class corresponding to that of the plugs. In addition, the notes contained in DIN EN 1992-1-2: 2010-12 [5] (see section 4.5) on the avoidance of concrete spallation also apply. According to this, the moisture content must be less than three (or four according to the National Annex) -% by weight.

This document does not replace a certificate of conformity or suitability according to national and European building codes.

Leipzig, 11 August 2017

MFPA Leipzig GmbH III SAC 02 NB 0800

Dipl.-Ing. S. Hauswaldt
Head of Business Division

Dipl.-Ing. M. Juknat
Head of Laboratory

Dipl.-Ing. S. Bauer
Testing Engineer

List of enclosures

Enclosure 1 Maximum bond strength when connecting two reinforced concrete slabs

Enclosure 2 Maximum permissible loads when using the reinforcing bars as anchors

Belonging documents

[1] DIN EN 13381-3: 2015-06

[2] DIN EN 1363-1: 2012-10 *Fire resistance tests - Part 1: General Requirements*

[3] EAD 330087-00-0601 Draft: 2016-05 *Systems for post-installed rebar connections with mortar*

[4] Test report PB 3.2/16-369-2 *Rawlplug bonded anchor R-KER II - Tests according to EAD 330087-00-0601 to determine the characteristic bond strength*, MFPA Leipzig GmbH: 4. August 2017, RAWLPLUG S.A.

[5] DIN EN 1992-1-2: 2010-12 *Eurocode 2: Design of concrete structures - Part 1-2: General rules - Structural fire design*

[6] DIN EN 1992-1-1: 2011-01 *Eurocode 2: Design of concrete structures - Part 1-1: General rules and rules for buildings*

MFPA Leipzig GmbH
SAC 02
NB 0800

Enclosure 1 Maximum bond strength when connecting two reinforced concrete slabs

Bond strength (N/mm²)						
Concrete coverage mm	**R30**	**R60**	**R90**	**R120**	**R180**	**R240**
30	0.8	-	-	-	-	-
40	2.1	0.3	-	-	-	-
50	3.5	0.8	0.2	-	-	-
60	3.5	1.7	0.6	0.2	-	-
70	3.5	3.0	1.1	0.5	-	-
80	3.5	3.5	2.0	0.9	0.3	-
90	3.5	3.5	3.1	1.6	0.5	0.2
100	3.5	3.5	3.5	2.4	0.9	0.4
110	3.5	3.5	3.5	3.4	1.3	0.6
120	3.5	3.5	3.5	3.5	2.0	0.9
130	3.5	3.5	3.5	3.5	2.8	1.4
140	3.5	3.5	3.5	3.5	3.5	1.9
150	3.5	3.5	3.5	3.5	3.5	2.6
160	3.5	3.5	3.5	3.5	3.5	3.3
170	3.5	3.5	3.5	3.5	3.5	3.5

MFPA Leipzig GmbH III
SAC 02
NB 0800

Enclosure 2 Maximum permissible loads when using the reinforcing bars as anchors

Table A2.1 Characteristic resistance with an end anchorage for Ø 8 mm

Characteristic resistance against pulling out (kN)							
Ø [mm]	Lenght lv [mm]	R30	R60	R90	R120	R180	R240
8	100	5.5	3.6	2.1	1.1	0.3	0.1
	110	6.4	4.4	3.0	1.8	0.6	0.2
	120	7.2	5.3	3.9	2.6	1.0	0.4
	130	8.1	6.2	4.8	3.5	1.6	0.7
	140	9.0	7.0	5.6	4.4	2.4	1.1
	150	9.8	7.9	6.5	5.2	3.2	1.6
	160	10.7	8.8	7.4	6.1	4.1	2.4
	170	11.6	9.6	8.2	7.0	5.0	3.2
	180	12.4	10.5	9.1	7.9	5.8	4.1
	190	13.3	11.4	10.0	8.7	6.7	5.0
	200	14.2	12.3	10.8	9.6	7.6	5.8
	210	15.0	13.1	11.7	10.5	8.4	6.7
	220	15.9	14.0	12.6	11.3	9.3	7.6
	230	16.8	14.9	13.4	12.2	10.2	8.4
	240	16.8	15.7	14.3	13.1	11.0	9.3
	250	16.8	16.6	15.2	13.9	11.9	10.2
	260	16.8	16.8	16.0	14.8	12.8	11.0
	270	16.8	16.8	16.8	15.7	13.6	11.9
	280	16.8	16.8	16.8	16.5	14.5	12.8
	290	16.8	16.8	16.8	16.8	15.4	13.6
	300	16.8	16.8	16.8	16.8	16.2	14.5
	310	16.8	16.8	16.8	16.8	16.8	15.4
	320	16.8	16.8	16.8	16.8	16.8	16.2
	330	16.8	16.8	16.8	16.8	16.8	16.8

grey background = steel failure decisive

MFPA Leipzig GmbH
SAC 02
NB 0800

Table A2.2 Characteristic resistance with an end anchorage for Ø 10 mm

Characteristic resistance against pulling out (kN)							
Ø [mm]	**Lenght lv [mm]**	**R30**	**R60**	**R90**	**R120**	**R180**	**R240**
10	100	6.9	4.5	2.7	1.3	0.4	0.1
	110	7.9	5.6	3.8	2.2	0.7	0.2
	120	9.0	6.6	4.9	3.3	1.2	0.5
	130	10.1	7.7	5.9	4.4	2.0	0.8
	140	11.2	8.8	7.0	5.5	3.0	1.3
	150	12.3	9.9	8.1	6.6	4.0	2.0
	160	13.4	11.0	9.2	7.6	5.1	2.9
	170	14.4	12.1	10.3	8.7	6.2	4.0
	180	15.5	13.1	11.4	9.8	7.3	5.1
	190	16.6	14.2	12.4	10.9	8.4	6.2
	200	17.7	15.3	13.5	12.0	9.5	7.3
	210	18.8	16.4	14.6	13.1	10.5	8.4
	220	19.9	17.5	15.7	14.1	11.6	9.5
	230	21.0	18.6	16.8	15.2	12.7	10.5
	240	22.0	19.6	17.9	16.3	13.8	11.6
	250	23.1	20.7	18.9	17.4	14.9	12.7
	260	24.2	21.8	20.0	18.5	16.0	13.8
	270	25.3	22.9	21.1	19.6	17.1	14.9
	280	26.2	24.0	22.2	20.7	18.1	16.0
	290	26.2	25.1	23.3	21.7	19.2	17.0
	300	26.2	26.2	24.4	22.8	20.3	18.1
	310	26.2	26.2	25.4	23.9	21.4	19.2
	320	26.2	26.2	26.2	25.0	22.5	20.3
	330	26.2	26.2	26.2	26.1	23.6	21.4
	340	26.2	26.2	26.2	26.2	24.6	22.5
	350	26.2	26.2	26.2	26.2	25.7	23.5
	360	26.2	26.2	26.2	26.2	26.2	24.6
	370	26.2	26.2	26.2	26.2	26.2	25.7
	380	26.2	26.2	26.2	26.2	26.2	26.2

grey background = steel failure decisive

MFPA Leipzig GmbH
SAC 02
NB 0800

Table A2.3 Characteristic resistance with an end anchorage for Ø 12 mm

Characteristic resistance against pulling out (kN)							
Ø [mm]	**Lenght lv [mm]**	**R30**	**R60**	**R90**	**R120**	**R180**	**R240**
12	130	12.1	9.3	7.1	5.3	2.4	1.0
	140	13.4	10.6	8.4	6.6	3.6	1.6
	150	14.7	11.9	9.7	7.9	4.9	2.4
	160	16.0	13.2	11.0	9.2	6.2	3.5
	170	17.3	14.5	12.3	10.5	7.5	4.8
	180	18.6	15.8	13.6	11.8	8.8	6.1
	190	19.9	17.1	14.9	13.1	10.1	7.4
	200	21.2	18.4	16.2	14.4	11.4	8.7
	210	22.5	19.7	17.5	15.7	12.7	10.0
	220	23.8	21.0	18.8	17.0	14.0	11.3
	230	25.1	22.3	20.1	18.3	15.3	12.6
	240	26.4	23.6	21.4	19.6	16.6	13.9
	250	27.7	24.9	22.7	20.9	17.9	15.2
	260	29.0	26.2	24.0	22.2	19.2	16.5
	270	30.3	27.5	25.3	23.5	20.5	17.8
	280	31.6	28.8	26.6	24.8	21.8	19.1
	290	32.9	30.1	27.9	26.1	23.1	20.4
	300	34.2	31.4	29.2	27.4	24.4	21.7
	310	35.5	32.7	30.5	28.7	25.7	23.0
	320	36.8	34.0	31.8	30.0	27.0	24.3
	330	37.7	35.3	33.1	31.3	28.3	25.6
	340	37.7	36.6	34.4	32.6	29.6	27.0
	350	37.7	37.7	35.7	33.9	30.9	28.3
	360	37.7	37.7	37.0	35.2	32.2	29.6
	370	37.7	37.7	37.7	36.5	33.5	30.9
	380	37.7	37.7	37.7	37.7	34.8	32.2
	390	37.7	37.7	37.7	37.7	36.1	33.5
	400	37.7	37.7	37.7	37.7	37.4	34.8
	450	37.7	37.7	37.7	37.7	37.7	37.7

grey background = steel failure decisive

MFPA Leipzig GmbH III SAC 02 NB 0800

Table A2.4 Characteristic resistance with an end anchorage for Ø 14 mm

Characteristic resistance against pulling out (kN)							
Ø [mm]	**Lenght lv [mm]**	**R30**	**R60**	**R90**	**R120**	**R180**	**R240**
14	150	17.2	13.9	11.3	9.2	5.7	2.8
	160	18.7	15.4	12.9	10.7	7.2	4.1
	170	20.2	16.9	14.4	12.2	8.7	5.6
	180	21.7	18.4	15.9	13.7	10.2	7.2
	190	23.3	19.9	17.4	15.3	11.7	8.7
	200	24.8	21.4	18.9	16.8	13.3	10.2
	210	26.3	23.0	20.5	18.3	14.8	11.7
	220	27.8	24.5	22.0	19.8	16.3	13.2
	230	29.3	26.0	23.5	21.3	17.8	14.8
	240	30.8	27.5	25.0	22.8	19.3	16.3
	250	32.4	29.0	26.5	24.4	20.8	17.8
	260	33.9	30.5	28.0	25.9	22.4	19.3
	270	35.4	32.1	29.6	27.4	23.9	20.8
	280	36.9	33.6	31.1	28.9	25.4	22.3
	290	38.4	35.1	32.6	30.4	26.9	23.9
	300	40.0	36.6	34.1	31.9	28.4	25.4
	310	41.5	38.1	35.6	33.5	29.9	26.9
	320	43.0	39.6	37.1	35.0	31.5	28.4
	330	44.5	41.2	38.7	36.5	33.0	29.9
	340	46.0	42.7	40.2	38.0	34.5	31.4
	350	47.5	44.2	41.7	39.5	36.0	33.0
	360	49.1	45.7	43.2	41.1	37.5	34.5
	370	50.6	47.2	44.7	42.6	39.0	36.0
	380	51.3	48.8	46.2	44.1	40.6	37.5
	390	51.3	50.3	47.8	45.6	42.1	39.0
	400	51.3	51.3	49.3	47.1	43.6	40.5
	450	51.3	51.3	51.3	51.3	51.2	48.1
	500	51.3	51.3	51.3	51.3	51.3	51.3

grey background = steel failure decisive

MFPA Leipzig GmbH III
SAC 02
NB 0800

Table A2.5 Characteristic resistance with an end anchorage for Ø 16 mm

Characteristic resistance against pulling out (kN)							
Ø [mm]	**Lenght lv [mm]**	**R30**	**R60**	**R90**	**R120**	**R180**	**R240**
	170	23.1	19.3	16.4	14.0	9.9	6.5
	180	24.9	21.0	18.2	15.7	11.7	8.2
	190	26.6	22.8	19.9	17.4	13.4	9.9
	200	28.3	24.5	21.6	19.2	15.1	11.7
	210	30.1	26.2	23.4	20.9	16.9	13.4
	220	31.8	28.0	25.1	22.6	18.6	15.1
	230	33.5	29.7	26.8	24.4	20.3	16.9
	240	35.3	31.4	28.6	26.1	22.1	18.6
	250	37.0	33.2	30.3	27.8	23.8	20.3
	260	38.7	34.9	32.0	29.6	25.5	22.1
	270	40.5	36.6	33.8	31.3	27.3	23.8
	280	42.2	38.4	35.5	33.0	29.0	25.5
	290	43.9	40.1	37.2	34.8	30.8	27.3
16	300	45.7	41.8	39.0	36.5	32.5	29.0
	310	47.4	43.6	40.7	38.2	34.2	30.7
	320	49.1	45.3	42.4	40.0	36.0	32.5
	330	50.9	47.0	44.2	41.7	37.7	34.2
	340	52.6	48.8	45.9	43.4	39.4	35.9
	350	54.3	50.5	47.7	45.2	41.2	37.7
	360	56.1	52.2	49.4	46.9	42.9	39.4
	370	57.8	54.0	51.1	48.7	44.6	41.1
	380	59.5	55.7	52.9	50.4	46.4	42.9
	390	61.3	57.5	54.6	52.1	48.1	44.6
	400	63.0	59.2	56.3	53.9	49.8	46.3
	450	67.0	67.0	65.0	62.5	58.5	55.0
	500	67.0	67.0	67.0	67.0	67.0	63.7
	550	67.0	67.0	67.0	67.0	67.0	67.0

grey background = steel failure decisive

MFPA Leipzig GmbH
SAC 02
NB 0800

Table A2.6 Characteristic resistance with an end anchorage for Ø 20 mm

Characteristic resistance against pulling out (kN)							
Ø [mm]	**Lenght lv [mm]**	**R30**	**R60**	**R90**	**R120**	**R180**	**R240**
20	210	37.6	32.8	29.2	26.1	21.1	16.7
	220	39.7	35.0	31.4	28.3	23.3	18.9
	230	41.9	37.1	33.6	30.5	25.4	21.1
	240	44.1	39.3	35.7	32.6	27.6	23.2
	250	46.2	41.5	37.9	34.8	29.8	25.4
	260	48.4	43.6	40.1	37.0	31.9	27.6
	270	50.6	45.8	42.2	39.1	34.1	29.7
	280	52.7	48.0	44.4	41.3	36.3	31.9
	290	54.9	50.1	46.6	43.5	38.4	34.1
	300	57.1	52.3	48.7	45.6	40.6	36.2
	310	59.2	54.5	50.9	47.8	42.8	38.4
	320	61.4	56.6	53.1	50.0	44.9	40.6
	330	63.6	58.8	55.2	52.1	47.1	42.7
	340	65.7	61.0	57.4	54.3	49.3	44.9
	350	67.9	63.1	59.6	56.5	51.4	47.1
	360	70.1	65.3	61.7	58.6	53.6	49.3
	370	72.2	67.5	63.9	60.8	55.8	51.4
	380	74.4	69.6	66.1	63.0	57.9	53.6
	390	76.6	71.8	68.2	65.1	60.1	55.8
	400	78.8	74.0	70.4	67.3	62.3	57.9
	450	89.6	84.8	81.2	78.2	73.1	68.8
	500	100.4	95.7	92.1	89.0	84.0	79.6
	550	104.7	104.7	102.9	99.8	94.8	90.4
	600	104.7	104.7	104.7	104.7	104.7	101.3
	650	104.7	104.7	104.7	104.7	104.7	104.7

grey background = steel failure decisive

MFPA Leipzig GmbH III
SAC 02
NB 0800

Table A2.7 Characteristic resistance with an end anchorage for Ø 25 mm

Characteristic resistance against pulling out (kN)							
Ø [mm]	**Lenght lv [mm]**	**R30**	**R60**	**R90**	**R120**	**R180**	**R240**
25	270	63.2	57.3	52.8	48.9	42.6	37.2
	280	65.9	60.0	55.5	51.6	45.3	39.9
	290	68.6	62.7	58.2	54.3	48.0	42.6
	300	71.3	65.4	60.9	57.0	50.8	45.3
	310	74.1	68.1	63.6	59.8	53.5	48.0
	320	76.8	70.8	66.3	62.5	56.2	50.7
	330	79.5	73.5	69.0	65.2	58.9	53.4
	340	82.2	76.2	71.7	67.9	61.6	56.1
	350	84.9	78.9	74.5	70.6	64.3	58.9
	360	87.6	81.6	77.2	73.3	67.0	61.6
	370	90.3	84.3	79.9	76.0	69.7	64.3
	380	93.0	87.1	82.6	78.7	72.4	67.0
	390	95.7	89.8	85.3	81.4	75.1	69.7
	400	98.4	92.5	88.0	84.1	77.9	72.4
	450	112.0	106.0	101.6	97.7	91.4	86.0
	500	125.5	119.6	115.1	111.2	105.0	99.5
	550	139.1	133.1	128.6	124.8	118.5	113.0
	600	152.6	146.7	142.2	138.3	132.0	126.6
	650	163.6	160.2	155.7	151.9	145.6	140.1
	700	163.6	163.6	163.6	163.6	159.1	153.7
	750	163.6	163.6	163.6	163.6	163.6	163.6

grey background = steel failure decisive

MFPA Leipzig GmbH
SAC 02
NB 0800

Table A2.8 Characteristic resistance with an end anchorage for Ø 32 mm

Characteristic resistance against pulling out (kN)							
Ø [mm]	**Lenght lv [mm]**	**R30**	**R60**	**R90**	**R120**	**R180**	**R240**
32	340	105.2	97.6	91.8	86.9	78.8	71.9
	350	108.7	101.0	95.3	90.4	82.3	75.3
	360	112.1	104.5	98.8	93.8	85.8	78.8
	370	115.6	108.0	102.2	97.3	89.3	82.3
	380	119.1	111.4	105.7	100.8	92.7	85.7
	390	122.5	114.9	109.2	104.2	96.2	89.2
	400	126.0	118.4	112.6	107.7	99.7	92.7
	450	143.3	135.7	130.0	125.0	117.0	110.0
	500	160.7	153.1	147.3	142.4	134.3	127.4
	550	178.0	170.4	164.7	159.7	151.7	144.7
	600	195.4	187.7	182.0	177.1	169.0	162.0
	650	212.7	205.1	199.4	194.4	186.4	179.4
	700	230.1	222.4	216.7	211.8	203.7	196.7
	750	247.4	239.8	234.0	229.1	221.0	214.1
	800	264.7	257.1	251.4	246.4	238.4	231.4
	850	268.1	268.1	268.1	263.8	255.7	248.8
	900	268.1	268.1	268.1	268.1	268.1	266.1
	950	268.1	268.1	268.1	268.1	268.1	268.1

grey background = steel failure decisive

MFPA Leipzig GmbH
SAC 02
NB 0800