# MFPA Leipzig GmbH

Testing, Inspection and Certification Authority for
Construction Products and Construction Types

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

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## Advisory Opinion No. GS 3.2/15-431-4

29 April 2016
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*Short version of GS 3.2/15-431-3 of 29 April 2016*

| | |
|---|---|
| Subject matter: | Hilti injection system HIT-RE 100 as a system for post-installed rebar connections<br><br>Fire protection assessment concept for the Hilti injection system HIT-RE 100 in conjunction with reinforcing steel for concrete BSt 500 S corresponding to EAD 330087-00-0601 (Draft 17. April 2015) |
| Client: | Hilti Entwicklungsgesellschaft mbH<br><br>Hiltistraße 6<br>86916 Kaufering |
| Date of order: | 01 December 2015 |
| Person in charge: | Dipl.-Wirtsch.-Ing. S. Kramer<br>Dipl.-Ing. S. Hauswaldt |

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This document consists of 7 text pages and 2 enclosures.




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## 1 Objective and request

On 01 December 2015, Hilti Entwicklungsgesellschaft mbH commissioned MFPA Leipzig GmbH to prepare an advisory opinion on the fire behaviour of the Hilti injection system HIT-RE 100, i.e. the Hilti injection mortar HIT-RE 100 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 Hilti rebar connection reinforcing bars with a diameter $d_s$ from 8 to 40 mm and the injection mortar HIT-RE 100 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.

The European Technical Assessment [2] contains a detailed description of the Hilti injection system HIT-RE 100. Variable anchoring depths are permissible for construction. No further description of the injection system will be provided here and reference is made to [2].

## 3 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. 1) 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. 2), 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.

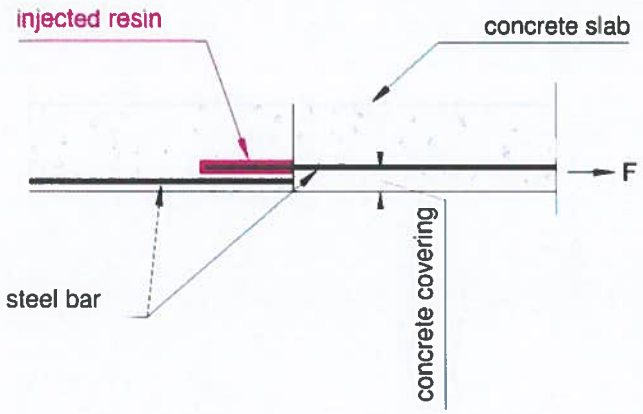


*Fig. 1 Overlap joint*

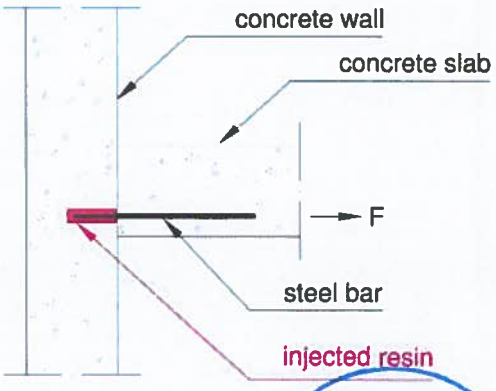


*Fig. 2 End anchorage*

In accordance with [6] 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. 3 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 EN 1363-1.

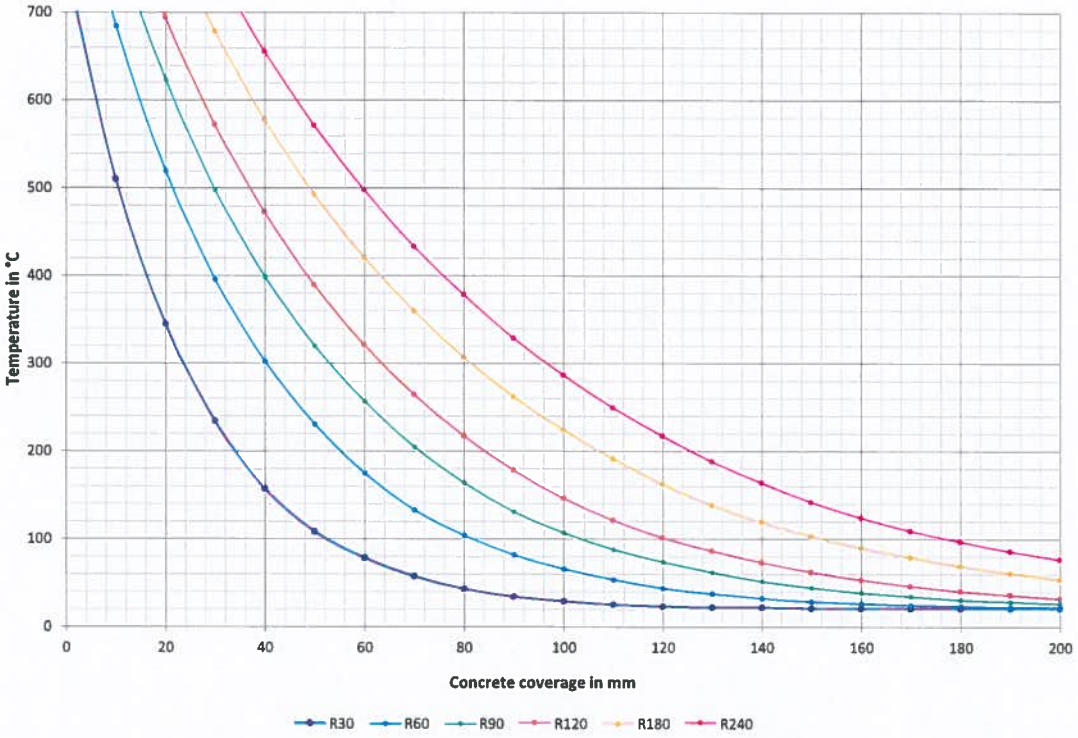


*Fig. 3* *Temperatures in reinforced concrete structural components after 30, 60, 90, 120, 180 and 240 minutes exposure to fire on one side in accordance with EN 1363-1, data from [6]*

A 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 in GS 3.2/15-431-3 [3] where it is defined as follows:

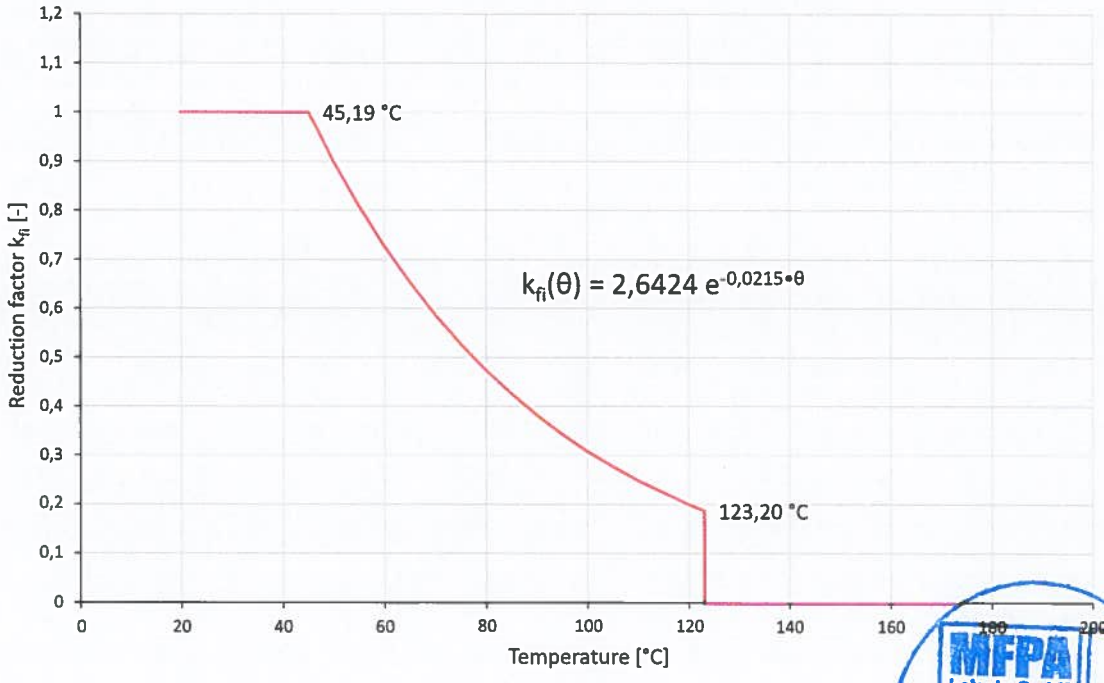


*Fig. 4* *Temperature reduction factor $k_{fi}(\theta)$*

### 3.1 Application case: overlap joint

Based on the temperature curves quoted in Fig. 3 the reduction factor for the temperature stresses shown in Fig. 4 the characteristic bond resistance to any pulling out of the reinforcing rods at a 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.

### 3.2 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 EC 2 [3] 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.

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*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 |
| 18 | 652 | 196 | 84.8 |
| 20 | 725 | 217 | 104.7 |
| 22 | 797 | 239 | 126.7 |
| 24 | 870 | 261 | 105.8 |
| 25 | 906 | 272 | 163.6 |
| 26 | 942 | 283 | 177.0 |
| 28 | 1014 | 304 | 205.3 |
| 30 | 1087 | 326 | 235.6 |
| 32 | 1159 | 348 | 268.1 |
| 34 | 1232 | 370 | 302.6 |
| 36 | 1304 | 391 | 339.3 |
| 40 | 1449 | 435 | 418.9 |

Fig. 2 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. 3 and the reduction factor for the temperature stress (Fig. 4) by the equation

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

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.

## 4 Scope

The assessment concept applies for reinforcing steel for concrete grades with apparent limits of elasticity of 500 MPa, for rods with a nominal diameter of ø 8 to ø 40 mm and for fire-resistance periods of 30 minutes to 240 minutes, taking into account the partial safety factors quoted in section 3 and with a thermal load in accordance with the standard temperature-time curve in accordance with EN 1363-1.

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 EN 1992-1-1, 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.

## 5 Special notes

The assessment above applies for the Hilti injection system HIT-RE 100 in concrete when installed in accordance with the installation regulations of ETA-15/0883 [2].

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 ≥ 300 mm and ≥ 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 EN 1992-1-2 (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.

The results of the tests exclusively refer to the described test objects but not to the main unit. This document does not replace a certificate of conformity or suitability according to national and European building codes.

Leipzig, 29 April 2016

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|---|---|---|
| *Head of Business Division* | *Head of Work Group* | *Testing Engineer* |

**Sources**

[1] EAD 330087-00-0601 *Systems for post-installed rebar connections with mortar*: DRAFT 03/2015 (EOTA file No: 14-33-0087-06.01) of the European Organisation for Technical Approvals (EOTA),

[2] European Technical Assessment ETA-15/0883 issued by Deutsches Institut für Bautechnik on 21. April 2016,

[3] Advisory opinion GS 3.2/15-431-3 of MFPA Leipzig GmbH of 29 April 2016,

[4] EN 1992-1-1:2011-01: Eurocode 2: Design and construction of reinforced concrete structures - Part 1-1: General design rules and rules for civil engineering,

[5] EN 1992-1-2:2010-12: Eurocode 2: Design and construction of reinforced concrete structures - Part 1-2: General - Structural fire design,

[6] EN 13381-3:2015-06 – Test methods for determining the contribution to the fire resistance of structural members - Part 3: Applied protection to concrete members.

**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

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Enclosure 1 Maximum bond strength when connecting two reinforced concrete slabs

| Bond strength (N/mm²) | | | | | | |
|---|---|---|---|---|---|---|
| Concrete coverage mm | R30 | R60 | R90 | R120 | R180 | R240 |
| 50 | 0.9 | | | | | |
| 60 | 1.7 | | | | | |
| 70 | 2.7 | | | | | |
| 80 | 3.5 | 1.0 | | | | |
| 90 | 3.5 | 1.6 | | | | |
| 100 | 3.5 | 2.3 | 1.0 | | | |
| 110 | 3.5 | 3.0 | 1.4 | 0.7 | | |
| 120 | 3.5 | 3.5 | 1.9 | 1.0 | | |
| 130 | 3.5 | 3.5 | 2.5 | 1.4 | | |
| 140 | 3.5 | 3.5 | 3.1 | 1.9 | 0.7 | |
| 150 | 3.5 | 3.5 | 3.5 | 2.4 | 1.0 | |
| 160 | 3.5 | 3.5 | 3.5 | 2.9 | 1.3 | |
| 170 | 3.5 | 3.5 | 3.5 | 3.4 | 1.7 | 0.9 |
| 180 | 3.5 | 3.5 | 3.5 | 3.5 | 2.1 | 1.1 |
| 190 | 3.5 | 3.5 | 3.5 | 3.5 | 2.5 | 1.4 |
| 200 | 3.5 | 3.5 | 3.5 | 3.5 | 2.9 | 1.7 |
| 210 | 3.5 | 3.5 | 3.5 | 3.5 | 3.3 | 2.1 |
| 220 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 2.5 |
| 230 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 2.8 |
| 240 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.1 |
| 250 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 |
| 260 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 |

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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 | 3.4 | 1.0 | 0.2 | 0.0 | 0.0 | 0.0 |
| | 110 | 4.3 | 1.7 | 0.5 | 0.0 | 0.0 | 0.0 |
| | 120 | 5.1 | 2.5 | 0.9 | 0.2 | 0.0 | 0.0 |
| | 130 | 6.0 | 3.4 | 1.5 | 0.5 | 0.0 | 0.0 |
| | 140 | 6.9 | 4.2 | 2.2 | 0.9 | 0.0 | 0.0 |
| | 150 | 7.7 | 5.1 | 3.0 | 1.5 | 0.2 | 0.0 |
| | 160 | 8.6 | 6.0 | 3.9 | 2.1 | 0.5 | 0.0 |
| | 170 | 9.5 | 6.8 | 4.7 | 2.9 | 0.9 | 0.2 |
| | 180 | 10.3 | 7.7 | 5.6 | 3.8 | 1.4 | 0.4 |
| | 190 | 11.2 | 8.6 | 6.5 | 4.7 | 1.9 | 0.8 |
| | 200 | 12.1 | 9.4 | 7.3 | 5.5 | 2.6 | 1.2 |
| | 210 | 12.9 | 10.3 | 8.2 | 6.4 | 3.4 | 1.6 |
| | 220 | 13.8 | 11.2 | 9.1 | 7.3 | 4.3 | 2.2 |
| | 230 | 14.7 | 12.0 | 9.9 | 8.1 | 5.1 | 2.9 |
| | 240 | 15.5 | 12.9 | 10.8 | 9.0 | 6.0 | 3.6 |
| | 250 | 16.4 | 13.8 | 11.7 | 9.9 | 6.9 | 4.4 |
| | 260 | 16.8 | 14.6 | 12.5 | 10.7 | 7.7 | 5.3 |
| | 270 | 16.8 | 15.5 | 13.4 | 11.6 | 8.6 | 6.2 |
| | 280 | 16.8 | 16.4 | 14.3 | 12.5 | 9.5 | 7.0 |
| | 290 | 16.8 | 16.8 | 15.1 | 13.3 | 10.3 | 7.9 |
| | 300 | 16.8 | 16.8 | 16.0 | 14.2 | 11.2 | 8.8 |
| | 310 | 16.8 | 16.8 | 16.8 | 15.1 | 12.1 | 9.6 |
| | 320 | 16.8 | 16.8 | 16.8 | 15.9 | 12.9 | 10.5 |
| | 330 | 16.8 | 16.8 | 16.8 | 16.8 | 13.8 | 11.4 |
| | 340 | 16.8 | 16.8 | 16.8 | 16.8 | 14.7 | 12.2 |
| | 350 | 16.8 | 16.8 | 16.8 | 16.8 | 15.5 | 13.1 |
| | 360 | 16.8 | 16.8 | 16.8 | 16.8 | 16.4 | 14.0 |
| | 370 | 16.8 | 16.8 | 16.8 | 16.8 | 16.8 | 14.8 |
| | 380 | 16.8 | 16.8 | 16.8 | 16.8 | 16.8 | 15.7 |
| | 390 | 16.8 | 16.8 | 16.8 | 16.8 | 16.8 | 16.6 |
| | 400 | 16.8 | 16.8 | 16.8 | 16.8 | 16.8 | 16.8 |

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*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 | 110 | 5.3 | 2.1 | 0.6 | 0.0 | 0.0 | 0.0 |
| | 120 | 6.4 | 3.1 | 1.1 | 0.3 | 0.0 | 0.0 |
| | 130 | 7.5 | 4.2 | 1.8 | 0.6 | 0.0 | 0.0 |
| | 140 | 8.6 | 5.3 | 2.7 | 1.2 | 0.0 | 0.0 |
| | 150 | 9.7 | 6.4 | 3.7 | 1.8 | 0.3 | 0.0 |
| | 160 | 10.8 | 7.4 | 4.8 | 2.7 | 0.6 | 0.0 |
| | 170 | 11.8 | 8.5 | 5.9 | 3.7 | 1.1 | 0.2 |
| | 180 | 12.9 | 9.6 | 7.0 | 4.7 | 1.7 | 0.5 |
| | 190 | 14.0 | 10.7 | 8.1 | 5.8 | 2.4 | 0.9 |
| | 200 | 15.1 | 11.8 | 9.2 | 6.9 | 3.3 | 1.4 |
| | 210 | 16.2 | 12.9 | 10.3 | 8.0 | 4.3 | 2.0 |
| | 220 | 17.3 | 14.0 | 11.3 | 9.1 | 5.3 | 2.7 |
| | 230 | 18.3 | 15.0 | 12.4 | 10.2 | 6.4 | 3.6 |
| | 240 | 19.4 | 16.1 | 13.5 | 11.2 | 7.5 | 4.5 |
| | 250 | 20.5 | 17.2 | 14.6 | 12.3 | 8.6 | 5.5 |
| | 260 | 21.6 | 18.3 | 15.7 | 13.4 | 9.7 | 6.6 |
| | 270 | 22.7 | 19.4 | 16.8 | 14.5 | 10.8 | 7.7 |
| | 280 | 23.8 | 20.5 | 17.8 | 15.6 | 11.8 | 8.8 |
| | 290 | 24.8 | 21.5 | 18.9 | 16.7 | 12.9 | 9.9 |
| | 300 | 25.9 | 22.6 | 20.0 | 17.7 | 14.0 | 10.9 |
| | 310 | 26.2 | 23.7 | 21.1 | 18.8 | 15.1 | 12.0 |
| | 320 | 26.2 | 24.8 | 22.2 | 19.9 | 16.2 | 13.1 |
| | 330 | 26.2 | 25.9 | 23.3 | 21.0 | 17.3 | 14.2 |
| | 340 | 26.2 | 26.2 | 24.3 | 22.1 | 18.3 | 15.3 |
| | 350 | 26.2 | 26.2 | 25.4 | 23.2 | 19.4 | 16.4 |
| | 360 | 26.2 | 26.2 | 26.2 | 24.2 | 20.5 | 17.5 |
| | 370 | 26.2 | 26.2 | 26.2 | 25.3 | 21.6 | 18.5 |
| | 380 | 26.2 | 26.2 | 26.2 | 26.2 | 22.7 | 19.6 |
| | 390 | 26.2 | 26.2 | 26.2 | 26.2 | 23.8 | 20.7 |
| | 400 | 26.2 | 26.2 | 26.2 | 26.2 | 24.9 | 21.8 |
| | 450 | 26.2 | 26.2 | 26.2 | 26.2 | 26.2 | 26.2 |

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*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 | 9.0 | 5.0 | 2.2 | 0.8 | 0.0 | 0.0 |
| | 140 | 10.3 | 6.3 | 3.2 | 1.4 | 0.0 | 0.0 |
| | 150 | 11.6 | 7.6 | 4.5 | 2.2 | 0.3 | 0.0 |
| | 160 | 12.9 | 8.9 | 5.8 | 3.2 | 0.8 | 0.0 |
| | 170 | 14.2 | 10.2 | 7.1 | 4.4 | 1.3 | 0.3 |
| | 180 | 15.5 | 11.5 | 8.4 | 5.7 | 2.1 | 0.7 |
| | 190 | 16.8 | 12.8 | 9.7 | 7.0 | 2.9 | 1.1 |
| | 200 | 18.1 | 14.1 | 11.0 | 8.3 | 3.9 | 1.7 |
| | 210 | 19.4 | 15.4 | 12.3 | 9.6 | 5.1 | 2.4 |
| | 220 | 20.7 | 16.7 | 13.6 | 10.9 | 6.4 | 3.3 |
| | 230 | 22.0 | 18.0 | 14.9 | 12.2 | 7.7 | 4.3 |
| | 240 | 23.3 | 19.3 | 16.2 | 13.5 | 9.0 | 5.4 |
| | 250 | 24.6 | 20.6 | 17.5 | 14.8 | 10.3 | 6.6 |
| | 260 | 25.9 | 21.9 | 18.8 | 16.1 | 11.6 | 7.9 |
| | 270 | 27.2 | 23.2 | 20.1 | 17.4 | 12.9 | 9.2 |
| | 280 | 28.5 | 24.5 | 21.4 | 18.7 | 14.2 | 10.5 |
| | 290 | 29.8 | 25.8 | 22.7 | 20.0 | 15.5 | 11.8 |
| | 300 | 31.1 | 27.1 | 24.0 | 21.3 | 16.8 | 13.1 |
| | 310 | 32.4 | 28.4 | 25.3 | 22.6 | 18.1 | 14.4 |
| | 320 | 33.7 | 29.7 | 26.6 | 23.9 | 19.4 | 15.7 |
| | 330 | 35.0 | 31.0 | 27.9 | 25.2 | 20.7 | 17.0 |
| | 340 | 36.3 | 32.3 | 29.2 | 26.5 | 22.0 | 18.3 |
| | 350 | 37.6 | 33.7 | 30.5 | 27.8 | 23.3 | 19.6 |
| | 360 | 37.7 | 35.0 | 31.8 | 29.1 | 24.6 | 20.9 |
| | 370 | 37.7 | 36.3 | 33.1 | 30.4 | 25.9 | 22.2 |
| | 380 | 37.7 | 37.6 | 34.4 | 31.7 | 27.2 | 23.5 |
| | 390 | 37.7 | 37.7 | 35.7 | 33.0 | 28.5 | 24.8 |
| | 400 | 37.7 | 37.7 | 37.0 | 34.3 | 29.8 | 26.1 |
| | 450 | 37.7 | 37.7 | 37.7 | 37.7 | 36.3 | 32.6 |
| | 500 | 37.7 | 37.7 | 37.7 | 37.7 | 37.7 | 37.7 |

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*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 | 160 | 15.1 | 10.4 | 6.8 | 3.7 | 0.9 | 0.0 |
| | 170 | 16.6 | 11.9 | 8.3 | 5.1 | 1.6 | 0.3 |
| | 180 | 18.1 | 13.5 | 9.8 | 6.6 | 2.4 | 0.8 |
| | 190 | 19.6 | 15.0 | 11.3 | 8.2 | 3.4 | 1.3 |
| | 200 | 21.1 | 16.5 | 12.8 | 9.7 | 4.6 | 2.0 |
| | 210 | 22.6 | 18.0 | 14.4 | 11.2 | 6.0 | 2.9 |
| | 220 | 24.2 | 19.5 | 15.9 | 12.7 | 7.5 | 3.8 |
| | 230 | 25.7 | 21.1 | 17.4 | 14.2 | 9.0 | 5.0 |
| | 240 | 27.2 | 22.6 | 18.9 | 15.7 | 10.5 | 6.3 |
| | 250 | 28.7 | 24.1 | 20.4 | 17.3 | 12.0 | 7.7 |
| | 260 | 30.2 | 25.6 | 21.9 | 18.8 | 13.5 | 9.3 |
| | 270 | 31.7 | 27.1 | 23.5 | 20.3 | 15.1 | 10.8 |
| | 280 | 33.3 | 28.6 | 25.0 | 21.8 | 16.6 | 12.3 |
| | 290 | 34.8 | 30.2 | 26.5 | 23.3 | 18.1 | 13.8 |
| | 300 | 36.3 | 31.7 | 28.0 | 24.8 | 19.6 | 15.3 |
| | 310 | 37.8 | 33.2 | 29.5 | 26.4 | 21.1 | 16.8 |
| | 320 | 39.3 | 34.7 | 31.0 | 27.9 | 22.7 | 18.4 |
| | 330 | 40.8 | 36.2 | 32.6 | 29.4 | 24.2 | 19.9 |
| | 340 | 42.4 | 37.7 | 34.1 | 30.9 | 25.7 | 21.4 |
| | 350 | 43.9 | 39.3 | 35.6 | 32.4 | 27.2 | 22.9 |
| | 360 | 45.4 | 40.8 | 37.1 | 33.9 | 28.7 | 24.4 |
| | 370 | 46.9 | 42.3 | 38.6 | 35.5 | 30.2 | 25.9 |
| | 380 | 48.4 | 43.8 | 40.1 | 37.0 | 31.8 | 27.5 |
| | 390 | 50.0 | 45.3 | 41.7 | 38.5 | 33.3 | 29.0 |
| | 400 | 51.3 | 46.8 | 43.2 | 40.0 | 34.8 | 30.5 |
| | 450 | 51.3 | 51.3 | 50.8 | 47.6 | 42.4 | 38.1 |
| | 500 | 51.3 | 51.3 | 51.3 | 51.3 | 50.0 | 45.7 |
| | 550 | 51.3 | 51.3 | 51.3 | 51.3 | 51.3 | 51.3 |

grey background = steel failure decisive

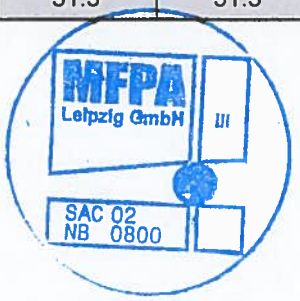

*Table A2.5 Characteristic resistance with an end anchorage for Ø 16 mm*

| Characteristic resistance against pulling out (kN) | | | | | | | |
|---|---|---|---|---|---|---|---|
| Ø [mm] | Lenght lv [mm] | R30 | R60 | R90 | R120 | R180 | R240 |
| 16 | 180 | 20.7 | 15.4 | 11.2 | 7.6 | 2.7 | 0.9 |
| | 190 | 22.4 | 17.1 | 12.9 | 9.3 | 3.9 | 1.5 |
| | 200 | 24.1 | 18.9 | 14.7 | 11.1 | 5.3 | 2.3 |
| | 210 | 25.9 | 20.6 | 16.4 | 12.8 | 6.8 | 3.3 |
| | 220 | 27.6 | 22.3 | 18.1 | 14.5 | 8.5 | 4.4 |
| | 230 | 29.3 | 24.1 | 19.9 | 16.3 | 10.3 | 5.7 |
| | 240 | 31.1 | 25.8 | 21.6 | 18.0 | 12.0 | 7.2 |
| | 250 | 32.8 | 27.5 | 23.3 | 19.7 | 13.8 | 8.8 |
| | 260 | 34.5 | 29.3 | 25.1 | 21.5 | 15.5 | 10.6 |
| | 270 | 36.3 | 31.0 | 26.8 | 23.2 | 17.2 | 12.3 |
| | 280 | 38.0 | 32.7 | 28.5 | 24.9 | 19.0 | 14.0 |
| | 290 | 39.7 | 34.5 | 30.3 | 26.7 | 20.7 | 15.8 |
| | 300 | 41.5 | 36.2 | 32.0 | 28.4 | 22.4 | 17.5 |
| | 310 | 43.2 | 37.9 | 33.7 | 30.1 | 24.2 | 19.3 |
| | 320 | 44.9 | 39.7 | 35.5 | 31.9 | 25.9 | 21.0 |
| | 330 | 46.7 | 41.4 | 37.2 | 33.6 | 27.6 | 22.7 |
| | 340 | 48.4 | 43.1 | 38.9 | 35.3 | 29.4 | 24.5 |
| | 350 | 50.2 | 44.9 | 40.7 | 37.1 | 31.1 | 26.2 |
| | 360 | 51.9 | 46.6 | 42.4 | 38.8 | 32.8 | 27.9 |
| | 370 | 53.6 | 48.3 | 44.1 | 40.5 | 34.6 | 29.7 |
| | 380 | 55.4 | 50.1 | 45.9 | 42.3 | 36.3 | 31.4 |
| | 390 | 57.1 | 51.8 | 47.6 | 44.0 | 38.0 | 33.1 |
| | 400 | 58.8 | 53.5 | 49.4 | 45.7 | 39.8 | 34.9 |
| | 450 | 67.0 | 62.2 | 58.0 | 54.4 | 48.4 | 43.5 |
| | 500 | 67.0 | 67.0 | 66.7 | 63.1 | 57.1 | 52.2 |
| | 550 | 67.0 | 67.0 | 67.0 | 67.0 | 65.8 | 60.9 |
| | 600 | 67.0 | 67.0 | 67.0 | 67.0 | 67.0 | 67.0 |

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*Table A2.6* *Characteristic resistance with an end anchorage for Ø 18 mm*

| Characteristic resistance against pulling out (kN) | | | | | | | |
|---|---|---|---|---|---|---|---|
| Ø [mm] | Lenght lv [mm] | R30 | R60 | R90 | R120 | R180 | R240 |
| 18 | 200 | 27.2 | 21.2 | 16.5 | 12.4 | 5.9 | 2.6 |
| | 210 | 29.1 | 23.2 | 18.5 | 14.4 | 7.7 | 3.7 |
| | 220 | 31.1 | 25.1 | 20.4 | 16.3 | 9.6 | 4.9 |
| | 230 | 33.0 | 27.1 | 22.4 | 18.3 | 11.6 | 6.4 |
| | 240 | 35.0 | 29.0 | 24.3 | 20.2 | 13.5 | 8.1 |
| | 250 | 36.9 | 31.0 | 26.3 | 22.2 | 15.5 | 10.0 |
| | 260 | 38.9 | 32.9 | 28.2 | 24.1 | 17.4 | 11.9 |
| | 270 | 40.8 | 34.9 | 30.2 | 26.1 | 19.4 | 13.9 |
| | 280 | 42.8 | 36.8 | 32.1 | 28.0 | 21.3 | 15.8 |
| | 290 | 44.7 | 38.8 | 34.1 | 30.0 | 23.3 | 17.8 |
| | 300 | 46.7 | 40.7 | 36.0 | 31.9 | 25.2 | 19.7 |
| | 310 | 48.6 | 42.7 | 38.0 | 33.9 | 27.2 | 21.7 |
| | 320 | 50.6 | 44.6 | 39.9 | 35.8 | 29.1 | 23.6 |
| | 330 | 52.5 | 46.6 | 41.9 | 37.8 | 31.1 | 25.6 |
| | 340 | 54.5 | 48.5 | 43.8 | 39.7 | 33.0 | 27.5 |
| | 350 | 56.4 | 50.5 | 45.8 | 41.7 | 35.0 | 29.5 |
| | 360 | 58.4 | 52.4 | 47.7 | 43.6 | 36.9 | 31.4 |
| | 370 | 60.3 | 54.4 | 49.7 | 45.6 | 38.9 | 33.4 |
| | 380 | 62.3 | 56.3 | 51.6 | 47.6 | 40.8 | 35.3 |
| | 390 | 64.2 | 58.3 | 53.6 | 49.5 | 42.8 | 37.3 |
| | 400 | 66.2 | 60.2 | 55.5 | 51.5 | 44.7 | 39.2 |
| | 450 | 75.9 | 70.0 | 65.3 | 61.2 | 54.5 | 49.0 |
| | 500 | 84.8 | 79.7 | 75.0 | 71.0 | 64.2 | 58.7 |
| | 550 | 84.8 | 84.8 | 84.8 | 80.7 | 74.0 | 68.5 |
| | 600 | 84.8 | 84.8 | 84.8 | 84.8 | 83.8 | 78.2 |
| | 650 | 84.8 | 84.8 | 84.8 | 84.8 | 84.8 | 84.8 |

grey background = steel failure decisive

*Table A2.7 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 | 220 | 34.5 | 27.9 | 22.7 | 18.2 | 10.7 | 5.5 |
| | 230 | 36.7 | 30.1 | 24.8 | 20.3 | 12.9 | 7.1 |
| | 240 | 38.8 | 32.2 | 27.0 | 22.5 | 15.0 | 9.0 |
| | 250 | 41.0 | 34.4 | 29.2 | 24.7 | 17.2 | 11.1 |
| | 260 | 43.2 | 36.6 | 31.3 | 26.8 | 19.4 | 13.2 |
| | 270 | 45.3 | 38.7 | 33.5 | 29.0 | 21.5 | 15.4 |
| | 280 | 47.5 | 40.9 | 35.7 | 31.2 | 23.7 | 17.6 |
| | 290 | 49.7 | 43.1 | 37.8 | 33.3 | 25.9 | 19.7 |
| | 300 | 51.9 | 45.2 | 40.0 | 35.5 | 28.0 | 21.9 |
| | 310 | 54.0 | 47.4 | 42.2 | 37.7 | 30.2 | 24.1 |
| | 320 | 56.2 | 49.6 | 44.3 | 39.8 | 32.4 | 26.2 |
| | 330 | 58.4 | 51.7 | 46.5 | 42.0 | 34.5 | 28.4 |
| | 340 | 60.5 | 53.9 | 48.7 | 44.2 | 36.7 | 30.6 |
| | 350 | 62.7 | 56.1 | 50.8 | 46.3 | 38.9 | 32.7 |
| | 360 | 64.9 | 58.3 | 53.0 | 48.5 | 41.0 | 34.9 |
| | 370 | 67.0 | 60.4 | 55.2 | 50.7 | 43.2 | 37.1 |
| | 380 | 69.2 | 62.6 | 57.4 | 52.8 | 45.4 | 39.2 |
| | 390 | 71.4 | 64.8 | 59.5 | 55.0 | 47.5 | 41.4 |
| | 400 | 73.5 | 66.9 | 61.7 | 57.2 | 49.7 | 43.6 |
| | 450 | 84.4 | 77.8 | 72.5 | 68.0 | 60.5 | 54.4 |
| | 500 | 95.2 | 88.6 | 83.4 | 78.8 | 71.4 | 65.2 |
| | 550 | 104.7 | 99.4 | 94.2 | 89.7 | 82.2 | 76.1 |
| | 600 | 104.7 | 104.7 | 104.7 | 100.5 | 93.1 | 86.9 |
| | 650 | 104.7 | 104.7 | 104.7 | 104.7 | 103.9 | 97.8 |
| | 700 | 104.7 | 104.7 | 104.7 | 104.7 | 104.7 | 104.7 |

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*Table A2.8* *Characteristic resistance with an end anchorage for Ø 22 mm*

| Characteristic resistance against pulling out (kN) | | | | | | | |
|---|---|---|---|---|---|---|---|
| Ø [mm] | Lenght lv [mm] | R30 | R60 | R90 | R120 | R180 | R240 |
| 22 | 240 | 42.7 | 35.5 | 29.7 | 24.7 | 16.5 | 9.9 |
| | 250 | 45.1 | 37.8 | 32.1 | 27.1 | 18.9 | 12.2 |
| | 260 | 47.5 | 40.2 | 34.5 | 29.5 | 21.3 | 14.5 |
| | 270 | 49.9 | 42.6 | 36.9 | 31.9 | 23.7 | 16.9 |
| | 280 | 52.3 | 45.0 | 39.2 | 34.3 | 26.1 | 19.3 |
| | 290 | 54.7 | 47.4 | 41.6 | 36.7 | 28.4 | 21.7 |
| | 300 | 57.0 | 49.8 | 44.0 | 39.0 | 30.8 | 24.1 |
| | 310 | 59.4 | 52.2 | 46.4 | 41.4 | 33.2 | 26.5 |
| | 320 | 61.8 | 54.5 | 48.8 | 43.8 | 35.6 | 28.9 |
| | 330 | 64.2 | 56.9 | 51.2 | 46.2 | 38.0 | 31.2 |
| | 340 | 66.6 | 59.3 | 53.5 | 48.6 | 40.4 | 33.6 |
| | 350 | 69.0 | 61.7 | 55.9 | 51.0 | 42.8 | 36.0 |
| | 360 | 71.3 | 64.1 | 58.3 | 53.3 | 45.1 | 38.4 |
| | 370 | 73.7 | 66.5 | 60.7 | 55.7 | 47.5 | 40.8 |
| | 380 | 76.1 | 68.8 | 63.1 | 58.1 | 49.9 | 43.2 |
| | 390 | 78.5 | 71.2 | 65.5 | 60.5 | 52.3 | 45.5 |
| | 400 | 80.9 | 73.6 | 67.9 | 62.9 | 54.7 | 47.9 |
| | 450 | 92.8 | 85.5 | 79.8 | 74.8 | 66.6 | 59.9 |
| | 500 | 104.7 | 97.5 | 91.7 | 86.7 | 78.5 | 71.8 |
| | 550 | 116.6 | 109.4 | 103.6 | 98.7 | 90.4 | 83.7 |
| | 600 | 126.7 | 121.3 | 115.5 | 110.6 | 102.4 | 95.6 |
| | 650 | 126.7 | 126.7 | 126.7 | 122.5 | 114.3 | 107.5 |
| | 700 | 126.7 | 126.7 | 126.7 | 126.7 | 126.2 | 119.5 |
| | 750 | 126.7 | 126.7 | 126.7 | 126.7 | 126.7 | 126.7 |

grey background = steel failure decisive

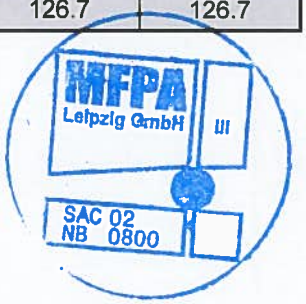

*Table A2.9* *Characteristic resistance with an end anchorage for Ø 24 mm*

| Characteristic resistance against pulling out (kN) | | | | | | | |
|---|---|---|---|---|---|---|---|
| Ø [mm] | Lenght lv [mm] | R30 | R60 | R90 | R120 | R180 | R240 |
| 24 | 270 | 54.4 | 46.5 | 40.2 | 34.8 | 25.8 | 18.5 |
| | 280 | 57.0 | 49.1 | 42.8 | 37.4 | 28.4 | 21.1 |
| | 290 | 59.6 | 51.7 | 45.4 | 40.0 | 31.0 | 23.7 |
| | 300 | 62.2 | 54.3 | 48.0 | 42.6 | 33.6 | 26.3 |
| | 310 | 64.8 | 56.9 | 50.6 | 45.2 | 36.2 | 28.9 |
| | 320 | 67.4 | 59.5 | 53.2 | 47.8 | 38.8 | 31.5 |
| | 330 | 70.0 | 62.1 | 55.8 | 50.4 | 41.4 | 34.1 |
| | 340 | 72.6 | 64.7 | 58.4 | 53.0 | 44.0 | 36.7 |
| | 350 | 75.2 | 67.3 | 61.0 | 55.6 | 46.6 | 39.3 |
| | 360 | 77.8 | 69.9 | 63.6 | 58.2 | 49.2 | 41.9 |
| | 370 | 80.4 | 72.5 | 66.2 | 60.8 | 51.8 | 44.5 |
| | 380 | 83.0 | 75.1 | 68.8 | 63.4 | 54.4 | 47.1 |
| | 390 | 85.6 | 77.7 | 71.4 | 66.0 | 57.0 | 49.7 |
| | 400 | 88.2 | 80.3 | 74.0 | 68.6 | 59.6 | 52.3 |
| | 450 | 101.2 | 93.3 | 87.0 | 81.6 | 72.7 | 65.3 |
| | 500 | 114.2 | 106.3 | 100.0 | 94.6 | 85.7 | 78.3 |
| | 550 | 127.3 | 119.3 | 113.0 | 107.6 | 98.7 | 91.3 |
| | 600 | 140.3 | 132.3 | 126.0 | 120.6 | 111.7 | 104.3 |
| | 650 | 150.8 | 145.3 | 139.1 | 133.6 | 124.7 | 117.3 |
| | 700 | 150.8 | 150.8 | 150.8 | 146.6 | 137.7 | 130.3 |
| | 750 | 150.8 | 150.8 | 150.8 | 150.8 | 150.7 | 143.3 |
| | 800 | 150.8 | 150.8 | 150.8 | 150.8 | 150.8 | 150.8 |

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*Table A2.10 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 | 280 | 59.4 | 51.1 | 44.6 | 38.9 | 29.6 | 22.0 |
| | 290 | 62.1 | 53.8 | 47.3 | 41.7 | 32.3 | 24.7 |
| | 300 | 64.8 | 56.6 | 50.0 | 44.4 | 35.0 | 27.4 |
| | 310 | 67.5 | 59.3 | 52.7 | 47.1 | 37.7 | 30.1 |
| | 320 | 70.2 | 62.0 | 55.4 | 49.8 | 40.5 | 32.8 |
| | 330 | 72.9 | 64.7 | 58.1 | 52.5 | 43.2 | 35.5 |
| | 340 | 75.7 | 67.4 | 60.9 | 55.2 | 45.9 | 38.2 |
| | 350 | 78.4 | 70.1 | 63.6 | 57.9 | 48.6 | 40.9 |
| | 360 | 81.1 | 72.8 | 66.3 | 60.6 | 51.3 | 43.6 |
| | 370 | 83.8 | 75.5 | 69.0 | 63.3 | 54.0 | 46.3 |
| | 380 | 86.5 | 78.2 | 71.7 | 66.0 | 56.7 | 49.0 |
| | 390 | 89.2 | 80.9 | 74.4 | 68.8 | 59.4 | 51.8 |
| | 400 | 91.9 | 83.7 | 77.1 | 71.5 | 62.1 | 54.5 |
| | 450 | 105.5 | 97.2 | 90.7 | 85.0 | 75.7 | 68.0 |
| | 500 | 119.0 | 110.7 | 104.2 | 98.6 | 89.2 | 81.6 |
| | 550 | 132.6 | 124.3 | 117.8 | 112.1 | 102.8 | 95.1 |
| | 600 | 146.1 | 137.8 | 131.3 | 125.7 | 116.3 | 108.7 |
| | 650 | 159.6 | 151.4 | 144.9 | 139.2 | 129.9 | 122.2 |
| | 700 | 163.6 | 163.6 | 158.4 | 152.8 | 143.4 | 135.8 |
| | 750 | 163.6 | 163.6 | 163.6 | 163.6 | 157.0 | 149.3 |
| | 800 | 163.6 | 163.6 | 163.6 | 163.6 | 163.6 | 162.9 |
| | 850 | 163.6 | 163.6 | 163.6 | 163.6 | 163.6 | 163.6 |

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*Table A2.11 Characteristic resistance with an end anchorage for Ø 26 mm*

| Characteristic resistance against pulling out (kN) | | | | | | | |
|---|---|---|---|---|---|---|---|
| Ø [mm] | Lenght lv [mm] | R30 | R60 | R90 | R120 | R180 | R240 |
| 26 | 290 | 64.6 | 56.0 | 49.2 | 43.3 | 33.6 | 25.6 |
| | 300 | 67.4 | 58.8 | 52.0 | 46.1 | 36.4 | 28.5 |
| | 310 | 70.2 | 61.6 | 54.8 | 49.0 | 39.3 | 31.3 |
| | 320 | 73.0 | 64.5 | 57.6 | 51.8 | 42.1 | 34.1 |
| | 330 | 75.9 | 67.3 | 60.5 | 54.6 | 44.9 | 36.9 |
| | 340 | 78.7 | 70.1 | 63.3 | 57.4 | 47.7 | 39.7 |
| | 350 | 81.5 | 72.9 | 66.1 | 60.2 | 50.5 | 42.6 |
| | 360 | 84.3 | 75.7 | 68.9 | 63.0 | 53.3 | 45.4 |
| | 370 | 87.1 | 78.5 | 71.7 | 65.9 | 56.2 | 48.2 |
| | 380 | 89.9 | 81.4 | 74.6 | 68.7 | 59.0 | 51.0 |
| | 390 | 92.8 | 84.2 | 77.4 | 71.5 | 61.8 | 53.8 |
| | 400 | 95.6 | 87.0 | 80.2 | 74.3 | 64.6 | 56.6 |
| | 450 | 109.7 | 101.1 | 94.3 | 88.4 | 78.7 | 70.7 |
| | 500 | 123.8 | 115.2 | 108.4 | 102.5 | 92.8 | 84.8 |
| | 550 | 137.9 | 129.3 | 122.5 | 116.6 | 106.9 | 98.9 |
| | 600 | 151.9 | 143.4 | 136.6 | 130.7 | 121.0 | 113.0 |
| | 650 | 166.0 | 157.4 | 150.6 | 144.8 | 135.1 | 127.1 |
| | 700 | 177.0 | 171.5 | 164.7 | 158.9 | 149.2 | 141.2 |
| | 750 | 177.0 | 177.0 | 177.0 | 173.0 | 163.2 | 155.3 |
| | 800 | 177.0 | 177.0 | 177.0 | 177.0 | 177.0 | 169.4 |
| | 850 | 177.0 | 177.0 | 177.0 | 177.0 | 177.0 | 177.0 |

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*Table A2.12 Characteristic resistance with an end anchorage for Ø 27 mm*

| Characteristic resistance against pulling out (kN) | | | | | | | |
|---|---|---|---|---|---|---|---|
| Ø [mm] | Lenght lv [mm] | R30 | R60 | R90 | R120 | R180 | R240 |
| 27 | 300 | 70.0 | 61.1 | 54.0 | 47.9 | 37.8 | 29.6 |
| | 310 | 72.9 | 64.0 | 56.9 | 50.8 | 40.8 | 32.5 |
| | 320 | 75.9 | 66.9 | 59.9 | 53.8 | 43.7 | 35.4 |
| | 330 | 78.8 | 69.9 | 62.8 | 56.7 | 46.6 | 38.3 |
| | 340 | 81.7 | 72.8 | 65.7 | 59.6 | 49.5 | 41.3 |
| | 350 | 84.6 | 75.7 | 68.6 | 62.5 | 52.5 | 44.2 |
| | 360 | 87.6 | 78.6 | 71.6 | 65.5 | 55.4 | 47.1 |
| | 370 | 90.5 | 81.6 | 74.5 | 68.4 | 58.3 | 50.0 |
| | 380 | 93.4 | 84.5 | 77.4 | 71.3 | 61.2 | 53.0 |
| | 390 | 96.3 | 87.4 | 80.4 | 74.3 | 64.2 | 55.9 |
| | 400 | 99.3 | 90.3 | 83.3 | 77.2 | 67.1 | 58.8 |
| | 450 | 113.9 | 105.0 | 97.9 | 91.8 | 81.7 | 73.5 |
| | 500 | 128.5 | 119.6 | 112.5 | 106.4 | 96.4 | 88.1 |
| | 550 | 143.2 | 134.2 | 127.2 | 121.1 | 111.0 | 102.7 |
| | 600 | 157.8 | 148.9 | 141.8 | 135.7 | 125.6 | 117.4 |
| | 650 | 172.4 | 163.5 | 156.4 | 150.3 | 140.3 | 132.0 |
| | 700 | 187.1 | 178.1 | 171.1 | 165.0 | 154.9 | 146.6 |
| | 750 | 190.9 | 190.9 | 185.7 | 179.6 | 169.5 | 161.2 |
| | 800 | 190.9 | 190.9 | 190.9 | 190.9 | 184.2 | 175.9 |
| | 850 | 190.9 | 190.9 | 190.9 | 190.9 | 190.9 | 190.5 |
| | 900 | 190.9 | 190.9 | 190.9 | 190.9 | 190.9 | 190.9 |

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*Table A2.13 Characteristic resistance with an end anchorage for Ø 28 mm*

| Characteristic resistance against pulling out (kN) | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Ø [mm]** | **Lenght lv [mm]** | **R30** | **R60** | **R90** | **R120** | **R180** | **R240** |
| 28 | 310 | 75.6 | 66.4 | 59.0 | 52.7 | 42.3 | 33.7 |
| | 320 | 78.7 | 69.4 | 62.1 | 55.8 | 45.3 | 36.7 |
| | 330 | 81.7 | 72.4 | 65.1 | 58.8 | 48.3 | 39.8 |
| | 340 | 84.7 | 75.5 | 68.2 | 61.8 | 51.4 | 42.8 |
| | 350 | 87.8 | 78.5 | 71.2 | 64.9 | 54.4 | 45.8 |
| | 360 | 90.8 | 81.6 | 74.2 | 67.9 | 57.4 | 48.9 |
| | 370 | 93.8 | 84.6 | 77.3 | 70.9 | 60.5 | 51.9 |
| | 380 | 96.9 | 87.6 | 80.3 | 74.0 | 63.5 | 54.9 |
| | 390 | 99.9 | 90.7 | 83.3 | 77.0 | 66.6 | 58.0 |
| | 400 | 102.9 | 93.7 | 86.4 | 80.0 | 69.6 | 61.0 |
| | 450 | 118.1 | 108.9 | 101.5 | 95.2 | 84.8 | 76.2 |
| | 500 | 133.3 | 124.0 | 116.7 | 110.4 | 99.9 | 91.3 |
| | 550 | 148.5 | 139.2 | 131.9 | 125.6 | 115.1 | 106.5 |
| | 600 | 163.6 | 154.4 | 147.1 | 140.7 | 130.3 | 121.7 |
| | 650 | 178.8 | 169.6 | 162.2 | 155.9 | 145.5 | 136.9 |
| | 700 | 194.0 | 184.7 | 177.4 | 171.1 | 160.6 | 152.0 |
| | 750 | 205.3 | 199.9 | 192.6 | 186.3 | 175.8 | 167.2 |
| | 800 | 205.3 | 205.3 | 205.3 | 201.4 | 191.0 | 182.4 |
| | 850 | 205.3 | 205.3 | 205.3 | 205.3 | 205.3 | 197.6 |
| | 900 | 205.3 | 205.3 | 205.3 | 205.3 | 205.3 | 205.3 |

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*Table A2.14 Characteristic resistance with an end anchorage for Ø 30 mm*

| Characteristic resistance against pulling out (kN) | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Ø [mm]** | **Lenght lv [mm]** | **R30** | **R60** | **R90** | **R120** | **R180** | **R240** |
| **30** | 330 | 87.5 | 77.6 | 69.8 | 63.0 | 51.8 | 42.6 |
| | 340 | 90.8 | 80.9 | 73.0 | 66.2 | 55.0 | 45.9 |
| | 350 | 94.0 | 84.1 | 76.3 | 69.5 | 58.3 | 49.1 |
| | 360 | 97.3 | 87.4 | 79.5 | 72.7 | 61.6 | 52.4 |
| | 370 | 100.5 | 90.6 | 82.8 | 76.0 | 64.8 | 55.6 |
| | 380 | 103.8 | 93.9 | 86.0 | 79.3 | 68.1 | 58.9 |
| | 390 | 107.0 | 97.1 | 89.3 | 82.5 | 71.3 | 62.1 |
| | 400 | 110.3 | 100.4 | 92.5 | 85.8 | 74.6 | 65.4 |
| | 450 | 126.5 | 116.6 | 108.8 | 102.0 | 90.8 | 81.6 |
| | 500 | 142.8 | 132.9 | 125.0 | 118.3 | 107.1 | 97.9 |
| | 550 | 159.1 | 149.2 | 141.3 | 134.5 | 123.3 | 114.1 |
| | 600 | 175.3 | 165.4 | 157.6 | 150.8 | 139.6 | 130.4 |
| | 650 | 191.6 | 181.7 | 173.8 | 167.0 | 155.8 | 146.6 |
| | 700 | 207.8 | 197.9 | 190.1 | 183.3 | 172.1 | 162.9 |
| | 750 | 224.1 | 214.2 | 206.3 | 199.6 | 188.4 | 179.2 |
| | 800 | 235.6 | 230.4 | 222.6 | 215.8 | 204.6 | 195.4 |
| | 850 | 235.6 | 235.6 | 235.6 | 232.1 | 220.9 | 211.7 |
| | 900 | 235.6 | 235.6 | 235.6 | 235.6 | 235.6 | 227.9 |
| | 950 | 235.6 | 235.6 | 235.6 | 235.6 | 235.6 | 235.6 |

grey background = steel failure decisive

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*Table A2.15 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 | 350 | 100.3 | 89.7 | 81.4 | 74.1 | 62.2 | 52.4 |
| | 360 | 103.8 | 93.2 | 84.8 | 77.6 | 65.7 | 55.8 |
| | 370 | 107.2 | 96.7 | 88.3 | 81.1 | 69.1 | 59.3 |
| | 380 | 110.7 | 100.1 | 91.8 | 84.5 | 72.6 | 62.8 |
| | 390 | 114.2 | 103.6 | 95.2 | 88.0 | 76.1 | 66.2 |
| | 400 | 117.6 | 107.1 | 98.7 | 91.5 | 79.5 | 69.7 |
| | 450 | 135.0 | 124.4 | 116.0 | 108.8 | 96.9 | 87.1 |
| | 500 | 152.3 | 141.8 | 133.4 | 126.2 | 114.2 | 104.4 |
| | 550 | 169.7 | 159.1 | 150.7 | 143.5 | 131.6 | 121.7 |
| | 600 | 187.0 | 176.4 | 168.1 | 160.8 | 148.9 | 139.1 |
| | 650 | 204.4 | 193.8 | 185.4 | 178.2 | 166.2 | 156.4 |
| | 700 | 221.7 | 211.1 | 202.7 | 195.5 | 183.6 | 173.8 |
| | 750 | 239.0 | 228.5 | 220.1 | 212.9 | 200.9 | 191.1 |
| | 800 | 256.4 | 245.8 | 237.4 | 230.2 | 218.3 | 208.4 |
| | 850 | 268.1 | 263.2 | 254.8 | 247.5 | 235.6 | 225.8 |
| | 900 | 268.1 | 268.1 | 268.1 | 264.9 | 252.9 | 243.1 |
| | 950 | 268.1 | 268.1 | 268.1 | 268.1 | 268.1 | 260.5 |

grey background = steel failure decisive

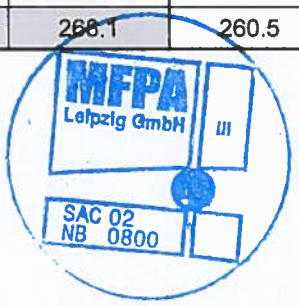

*Table A2.16 Characteristic resistance with an end anchorage for Ø 34 mm*

| Characteristic resistance against pulling out (kN) | | | | | | | |
|---|---|---|---|---|---|---|---|
| Ø [mm] | Lenght lv [mm] | R30 | R60 | R90 | R120 | R180 | R240 |
| 34 | 370 | 113.9 | 102.7 | 93.8 | 86.1 | 73.4 | 63.0 |
| | 380 | 117.6 | 106.4 | 97.5 | 89.8 | 77.1 | 66.7 |
| | 390 | 121.3 | 110.1 | 101.2 | 93.5 | 80.8 | 70.4 |
| | 400 | 125.0 | 113.8 | 104.9 | 97.2 | 84.5 | 74.1 |
| | 450 | 143.4 | 132.2 | 123.3 | 115.6 | 102.9 | 92.5 |
| | 500 | 161.8 | 150.6 | 141.7 | 134.0 | 121.3 | 110.9 |
| | 550 | 180.3 | 169.0 | 160.1 | 152.5 | 139.8 | 129.4 |
| | 600 | 198.7 | 187.5 | 178.6 | 170.9 | 158.2 | 147.8 |
| | 650 | 217.1 | 205.9 | 197.0 | 189.3 | 176.6 | 166.2 |
| | 700 | 235.5 | 224.3 | 215.4 | 207.7 | 195.1 | 184.6 |
| | 750 | 254.0 | 242.7 | 233.8 | 226.2 | 213.5 | 203.1 |
| | 800 | 272.4 | 261.2 | 252.3 | 244.6 | 231.9 | 221.5 |
| | 850 | 290.8 | 279.6 | 270.7 | 263.0 | 250.3 | 239.9 |
| | 900 | 302.6 | 298.0 | 289.1 | 281.4 | 268.8 | 258.3 |
| | 950 | 302.6 | 302.6 | 302.6 | 299.9 | 287.2 | 276.8 |

grey background = steel failure decisive

*Table A2.17 Characteristic resistance with an end anchorage for Ø 36 mm*

| Characteristic resistance against pulling out (kN) | | | | | | | |
|---|---|---|---|---|---|---|---|
| Ø [mm] | Lenght lv [mm] | R30 | R60 | R90 | R120 | R180 | R240 |
| 36 | 400 | 132.3 | 120.5 | 111.0 | 102.9 | 89.5 | 78.4 |
| | 450 | 151.9 | 140.0 | 130.5 | 122.4 | 109.0 | 97.9 |
| | 500 | 171.4 | 159.5 | 150.1 | 141.9 | 128.5 | 117.4 |
| | 550 | 190.9 | 179.0 | 169.6 | 161.4 | 148.0 | 137.0 |
| | 600 | 210.4 | 198.5 | 189.1 | 180.9 | 167.5 | 156.5 |
| | 650 | 229.9 | 218.0 | 208.6 | 200.5 | 187.0 | 176.0 |
| | 700 | 249.4 | 237.5 | 228.1 | 220.0 | 206.5 | 195.5 |
| | 750 | 268.9 | 257.0 | 247.6 | 239.5 | 226.0 | 215.0 |
| | 800 | 288.4 | 276.5 | 267.1 | 259.0 | 245.5 | 234.5 |
| | 850 | 307.9 | 296.0 | 286.6 | 278.5 | 265.1 | 254.0 |
| | 900 | 327.4 | 315.6 | 306.1 | 298.0 | 284.6 | 273.5 |
| | 950 | 339.3 | 335.1 | 325.6 | 317.5 | 304.1 | 293.0 |

grey background = steel failure decisive

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*Table A2.18 Characteristic resistance with an end anchorage for Ø 40 mm*

| Characteristic resistance against pulling out (kN) | | | | | | | |
|---|---|---|---|---|---|---|---|
| Ø [mm] | Lenght lv [mm] | R30 | R60 | R90 | R120 | R180 | R240 |
| 40 | 450 | 168.7 | 155.5 | 145.1 | 136.0 | 121.1 | 108.8 |
| | 500 | 190.4 | 177.2 | 166.7 | 157.7 | 142.8 | 130.5 |
| | 550 | 212.1 | 198.9 | 188.4 | 179.4 | 164.4 | 152.2 |
| | 600 | 233.8 | 220.6 | 210.1 | 201.0 | 186.1 | 173.9 |
| | 650 | 255.4 | 242.2 | 231.8 | 222.7 | 207.8 | 195.5 |
| | 700 | 277.1 | 263.9 | 253.4 | 244.4 | 229.5 | 217.2 |
| | 750 | 298.8 | 285.6 | 275.1 | 266.1 | 251.1 | 238.9 |
| | 800 | 320.5 | 307.3 | 296.8 | 287.8 | 272.8 | 260.6 |
| | 850 | 342.1 | 328.9 | 318.5 | 309.4 | 294.5 | 282.2 |
| | 900 | 363.8 | 350.6 | 340.1 | 331.1 | 316.2 | 303.9 |
| | 950 | 385.5 | 372.3 | 361.8 | 352.8 | 337.9 | 325.6 |

grey background = steel failure decisive