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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Subject matter:	Rawlplug injection system R-KER II Fire protection assessment concept for the Rawlplug injection system R-KER II
Client:	Rawlplug SA. ul. Kwidzyńska 6 51-416 Wrocław Poland
Date of order:	25. January 2017
Person in charge:	Dipl.-Wirtsch.-Ing. S. Kramer Dipl.-Ing. S. Bauer
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1 Objective and request

The firm of *Rawlplug SA.* commissioned MFPA Leipzig GmbH on 25. January 2017 to assess the Rawlplug injection system *R-KER II* with respect to its fire protection properties. The installation situation of the anchor used to install the injection system in a reinforced concrete base with a one-sided exposure to fire in accordance with DIN EN 1363-1: 2012-10 [1] was to be considered.

2 Description of the tested construction

The R-KER II system is a bonded anchor consisting of a cartridge containing the injection mortar R-KER II, R-KER II-S (summer version) as well as R-KER II-W (winter version) and a steel part. It uses the bonding effect between steel, composite mortar and concrete to anchor loads in the base.

The system should be used under predominantly static or quasi-static load in reinforced or un-reinforced normal concrete of strength class ≥ C 20/25 and ≤ C 50/60 in accordance with DIN EN 206-1: 2000-12 [2].

No further description of the injection system will be provided here and reference is made to the European Technical Assessment ETA-17/0594.

3 Fire protection assessment concept

In the present fire protection assessment concept, the aforementioned system is assessed with respect to its fire protection properties as anchor applications (cf. Fig. 1) in walls and boards. It is conservative assumed that the anchor is installed vertical to the concrete surface exposed to fire and that the fire load is in accordance with the standard temperature-time curve (ETK) acc. to DIN EN 1363-1: 2012-10 [1]. That means a section of the steel part will be exposed directly to the thermal stress so that there will be a faster influx of heat into the component.

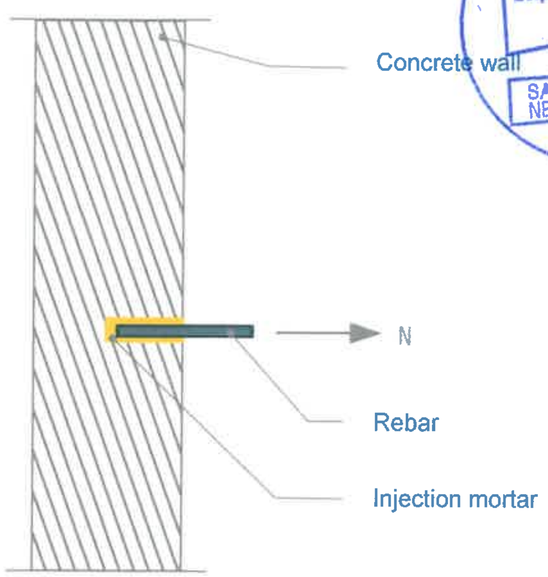
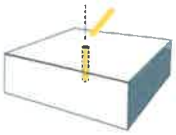
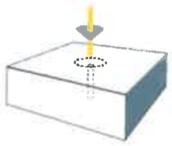


Fig. 1: Anchor use

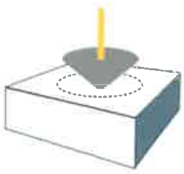
The assessment is carried out in dependence on EAD 330232-00-0601: 2016-10 [3]. A differentiation is generally made between the following types of failure when investigating the load-bearing behaviour of fastenings in the event of a fire in accordance with EAD 330232-00-0601: 2016-10 [3]:



a) Steel failure: failure between the component and metallic anchor (e.g. at the nut) or steel breakage outside the concrete.



b) Pull-out from the concrete: loss of the mechanical load-bearing effect between the anchor and concrete.



c) Concrete cone failure: cone-shaped breakage of the concrete.

All three types of failure, namely steel failure (a), pull-out from the concrete (b), and concrete cone failure (c), will be considered. *The characteristic tension strength results from the smallest value of the three types of failure* (under exposure to fire).

3.1 Determining the steel failure values under fire exposure

At MFPA Leipzig tests were carried out to determine steel failure of the injection system Rawlplug R-KER II. Test setup and results can be taken from the test report PB 3.2/16-369-1 [4]. The test evaluation for steel failure was carried out according to EAD 330232-00-0601: 2016-10 [3]. A graphical analysis of the test results is given in Enclosure 2 for threaded rods and in Enclosure 3 rebars.

To determine the characteristic tension stress the values for M8, M12, M16 and M24 were interpreted based on the test results. The values for M10 and M20 result from the interpolation of the values for M8 and M12 and M16 and M24 respectively based on the steel cross section. For anchors > M24 the tension of the cross section size M24 was used.

Because the rebars used as anchors have other diameters and another steel quality a separate test series and therefore evaluation of the results took place. For rebars the characteristic tension stress for Ø 8, Ø 12 and Ø 16 were interpreted based on the test results. Ø 10 and Ø 14 were interpolated and for anchors > Ø 16 the tension of the cross section for Ø 16 was used.

On this basis, the following characteristic values for stressing under centric tension can be given for the injection system R-KER II. Table 1 shows the values for threaded rods. Table 2 gives the values for rebars as anchor. To design also the characteristic steel stress under normal temperature have to be considered, the smaller stress is decisive.

Table 1 Characteristic tension resistance for electrogalvanised threaded rods in minimum strength class 5.8

Size of threaded rod			M8	M10	M12	M16	M20	M24	M30
Embedment depth	h_{ef}	[mm]	≥ 90	≥ 90	≥ 100	≥ 120	≥ 120	≥ 130	≥ 160
30 min	$N_{Rk,s,fi(30)}$	[kN]	1.07	1.57	2.08	4.92	8.44	13.49	21.44
60 min	$N_{Rk,s,fi(60)}$	[kN]	0.82	1.26	1.76	3.97	6.54	10.04	15.96
90 min	$N_{Rk,s,fi(90)}$	[kN]	0.57	0.94	1.44	3.01	4.64	6.60	10.49
120 min	$N_{Rk,s,fi(120)}$	[kN]	0.45	0.79	1.29	2.53	3.70	4.88	7.75

Table 2 Characteristic tension resistance for rebars as anchors with minimum steel strength 500 N/mm²

Size of rebar			Ø 8	Ø 10	Ø 12	Ø 14	Ø 16	Ø 20	Ø 25	Ø 32
Embedment depth	h_{ef}	[mm]	≥ 90	≥ 90	≥ 100	≥ 110	≥ 120	≥ 140	≥ 170	≥ 190
30 min	$N_{Rk,s,fi(30)}$	[kN]	0.77	1.21	1.54	3.21	5.96	7.82	16.28	27.81
60 min	$N_{Rk,s,fi(60)}$	[kN]	0.51	0.84	1.15	2.36	4.35	5.70	11.87	20.28
90 min	$N_{Rk,s,fi(90)}$	[kN]	0.25	0.47	0.76	1.51	2.73	3.58	7.46	12.75
120 min	$N_{Rk,s,fi(120)}$	[kN]	0.12	0.28	0.56	1.09	1.93	2.52	5.26	8.98

3.2 Determining the pull-out resistance

For lower embedment than the ones given in Table 1 and Table 2, the chance to have pull-out failure rises. So to determine pull-out failure of the injection system Rawlplug R-KER II tests similar to the steel failure tests were carried out at MFPA Leipzig with the minimum embedment depth. Test setup and results can be taken from the test report PB 3.2/16-369-1 [4]. A graphic presentation of the test results is given in Enclosure 4.

To determine the mean bond stress the values for M8, M12, M16 and M24 were interpreted based on the test results. The values for M10 and M20 result from the interpolation of the values for M8 and M12 and M16 and M24 respectively based on the bond area. For anchors > M24 the tension of the cross section size M24 was used.

On this basis, the following characteristic values for stressing under centric tension can be given for the injection system R-KER II (Table 3) with minimum embedment depths.

Table 3 Characteristic bond resistance for electrogalvanised threaded rods in strength class 5.8 with minimum embedment

Size of threaded rod			M8	M10	M12	M16	M20	M24	M30
Embedment depth	$h_{ef\,(min)}$	[mm]	60	60	60	64	80	96	120
30 min	$N_{Rk,p,fi(30)}$	[kN]	0.65	0.77	0.88	1.50	3.16	6.00	9.38
60 min	$N_{Rk,p,fi(60)}$	[kN]	0.50	0.58	0.64	1.00	2.03	3.75	5.86
90 min	$N_{Rk,p,fi(90)}$	[kN]	0.35	0.38	0.40	0.50	1.29	2.75	4.30
120 min	$N_{Rk,p,fi(120)}$	[kN]	0.27	0.29	0.28	-	-	-	-

The loads for the minimum embedment depth were conservatively chosen in dependence on the test results and the EAD 330232-00-0601: 2016-10 [3]. Values for embedment depths between the minimum and the one for steel failure according to Table 1 can be interpolated.

In case of the rebars, only few exploratory test were carried out to evaluate the bond resistance compared to threaded rods of the same size (see [4]). Since the test results are in the same region as the results for threaded rods but not in every case on the safe side, the results determined for threaded rods (see Table 3) may be used for rebars with slightly increased values $h_{ef\,(min)}$ to generate additional safety (see Table 4).

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Table 4 Characteristic bond resistance for rebars as anchors with minimum steel strength 500 N/mm² and minimum embedment

Size of rebar			Ø 8	Ø 10	Ø 12	Ø 14	Ø 16	Ø 20	Ø 25	Ø 32
Embedment depth	$h_{ef\,(min)}$	[mm]	80	80	80	80	80	100	120	140
30 min	$N_{Rk,s,fi(30)}$	[kN]	0.65	0.77	0.88	1.19	1.50	3.16	6.00	9.38
60 min	$N_{Rk,s,fi(60)}$	[kN]	0.50	0.58	0.64	0.82	1.00	2.03	3.75	5.86
90 min	$N_{Rk,s,fi(90)}$	[kN]	0.35	0.38	0.40	0.45	0.50	1.29	2.75	4.30
120 min	$N_{Rk,s,fi(120)}$	[kN]	0.27	0.29	0.28	-	-	-	-	-

3.3 Concrete cone failure

A simplified calculation method can be used to determine the resistance to concrete cone failure in accordance with TR 020: 2004-05 [5]. The following applies for exposure to fire for up to 90 minutes:

$$N^0_{Rk,c,fi(90)} = \frac{h_{ef}}{200} \text{ x } N^0_{Rk,c} \qquad \leq N^0_{Rk,c}$$

The following applies for exposure to fire for 120 minutes:

$$N^0_{Rk,c,fi(120)} = 0{,}8 \text{ x } \frac{h_{ef}}{200} \text{ x } N^0_{Rk,c} \qquad \leq N^0_{Rk,c}$$

Whereby:

$N^0_{Rk,c,fi(90/120)}$ The characteristic resistance of a single anchor not influenced by neighbouring anchors or component edges and exposure to fire for up to 90 minutes (≤ R 90) and up to 120 minutes (≤ R 120) against concrete cone failure in concrete C20/25 to C50/60

h_{ef} Effective anchoring depth in mm

$N^0_{Rk,c}$ Characteristic resistance of a single anchor against concrete cone failure in cracked concrete C20/25 under normal temperature

4 Fire protection assessment concept

To prove that the anchor can resist an exposure under fire, the design value of influence under fire exposure has to be smaller than or equal to the design value of resistance under fire exposure. The design value of resistance under fire exposure is calculated as follows:

$$R_{d,fi(t)} = R_{k,fi(t)} / \gamma_{M,fi}$$

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Whereby:

$R_{d,fi(t)}$ Design value of resistance under fire exposure,

$R_{k,fi(t)}$ Characteristic resistance under fire exposure
= min ($N_{Rk,s,fi(t)}$; $N_{Rk,p,fi(t)}$; $N^0_{Rk,c,fi(t)}$) mit

$N_{Rk,s,fi(t)}$ Characteristic resistance in case of steel failure (see section 3.1)

$N_{Rk,p,fi(t)}$ Characteristic resistance in case of pull-out failure (see section 0) and

$N^0_{Rk,c,fi(t)}$ Characteristic resistance in case of concrete cone failure (see section 3.3) as well as

$\gamma_{M,fi}$ Unless other regulations exist, the partial safety factor for resistance under fire exposure $\gamma_{M,fi}$ = 1,0 can be assumed.

To identify the design value of resistance under fire exposure, the tree possible types of failure mentioned in part 3 – steel failure, pull-out-failure and concrete-cone failure – have to be explored.

- The maximum resistance against steel failure were already identified in part 3.1.
- The calculation of the values for pull-out resistance is given in part 3.2.
- Resistance against concrete cone failure can be calculated according to the simplified design method of part 3.3.

The characteristic tension strength results from the smallest value of the three types of failure under exposure to fire.

5 Scope

The assessment above applies for the Rawlplug injection system R-KER II as anchor use in concrete when installed in accordance with the installation regulations of ETA-17/0594. The rods can be used in the sizes M8 to M30 and for fire-resistance periods of 30 minutes to 120 minutes. The rebars can be used in the sizes 8 mm to 32 mm.

The values quoted apply for threaded rods of electrogalvanised steel from strength classes 5.8 as well as for rebars with a steel strength 500 N/mm². Interim values may be interpolated. An extrapolation is not allowed.

A transfer of the values to steel with a higher strength class or stainless steel is possible.

The pull-out resistances quoted in Table 3 and Table 4 apply for the Rawlplug injection system R-KER II and use in uncracked concrete. The quoted values have to be reduced by the safety factor 0.75 for installation in cracked concrete.

The characteristic tension strength for a single anchor subjected to tension under fire exposure results from the smallest value of the three types of failure (steel failure, pull-out failure and concrete cone failure).

The quoted loads apply for the stress directions central tension, lateral tension and diagonal tension at every angle. For shear load the resistances for concrete pry-out failure and concrete edge failure can be assessed in accordance with CEN/TS 1992-4-1: 2009 Appendix D.

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 edge distance of the anchor is $c \geq 300$ mm and $\geq 2\ h_{ef}$.

This advisory opinion only applies from a technical fire protection point of view. Other requirements, especially concerning statics with normal temperature, should be considered.

Further parameters (geometry, shell spalling, eccentricity, location in the component and other factors) may have to be taken into account separately.

The assessment only applies in combination with reinforced concrete ceilings of strength class ≥ C 20/25 and ≤ C 50/60 according to DIN EN 206-1: 2000-12 [2], that can be classified in at least the fire-resistance class corresponding to that of the anchors. In addition, the notes contained in DIN EN 1992-1-2: 2010-12 [6] (see section 4.5) on the avoidance of concrete spalling also apply. According to this, the moisture content must be less than three (or four according to the National Annex) -% by weight.

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

Leipzig, 29 October 2018

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List of enclosures

Enclosure 1 Installation parameters of R-KER II

Enclosure 2 Graphical analysis of steel failure according to EAD 330232-00-0601: 2016-10 [4] for threaded rods

Enclosure 3 Graphical analysis of steel failure according to EAD 330232-00-0601: 2016-10 [4] for rebars as anchors

Enclosure 4 Graphical analysis of the test results with minimum embedment depth

Belonging documents

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

[2] DIN EN 206-1: 2000-12 *Concrete - Specification, performance, production and conformity*

[3] EAD 330232-00-0601: 2016-10 *Mechanical fasteners for use in concrete*

[4] Test report PB 3.2/16-369-1 *Rawlplug bonded anchor R-KER II - Test according to EAD 330232-00-0601 (October 2016) to determine the characteristic steel strength under tensile load under thermal exposure*, MFPA Leipzig GmbH: 4. August 2017, RAWLPLUG S.A.

[5] TR 020: 2004-05 *Evaluation of Anchorages in Concrete concerning Resistance to Fire*

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

Enclosure 1 Installation parameters of R-KER II

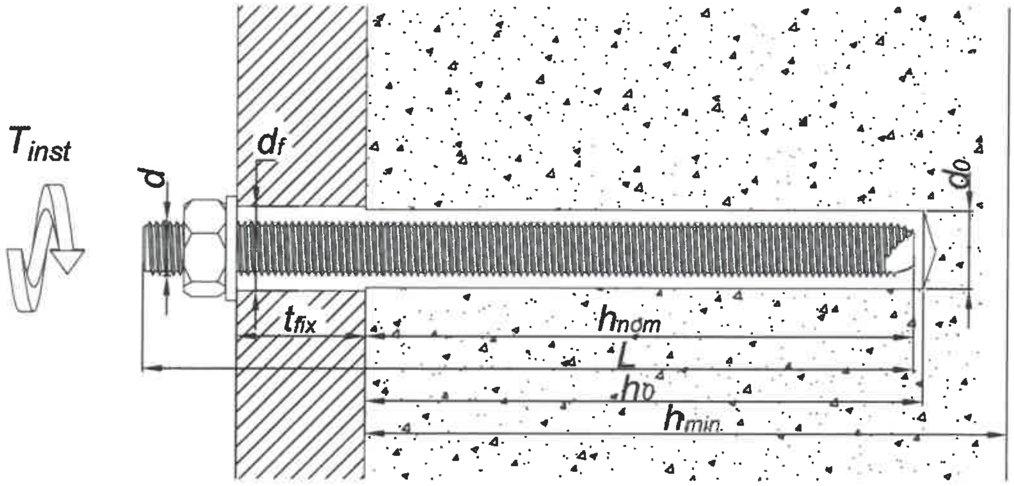

Table A.1 Installation parameters for threaded rods

Size		M8	M10	M12	M16	M20	M24	M30
Diameter of anchor rod	d [mm]	8	10	12	16	20	24	30
Nominal drilling diameter	d_0 [mm]	10	12	14	18	24	28	35
Maximum diameter hole in the fixture	d_f [mm]	9	12	14	18	22	26	32
Depth of the drilling hole	h_0 [mm]	h_{ef} + 5mm						
Minimum thickness of the concrete member	h_{min} [mm]	h_{ef} + 30mm; ≥ 100mm			h_{ef} + 2*d_0			
Torque moment	T_{inst} [Nm]	10	20	40	80	120	160	200
Minimum spacing	s_{min} [mm]	0,5*h_{ef} ≥ 40mm						
Minimum edge distance	c_{min} [mm]	0,5*h_{ef} ≥ 40mm						

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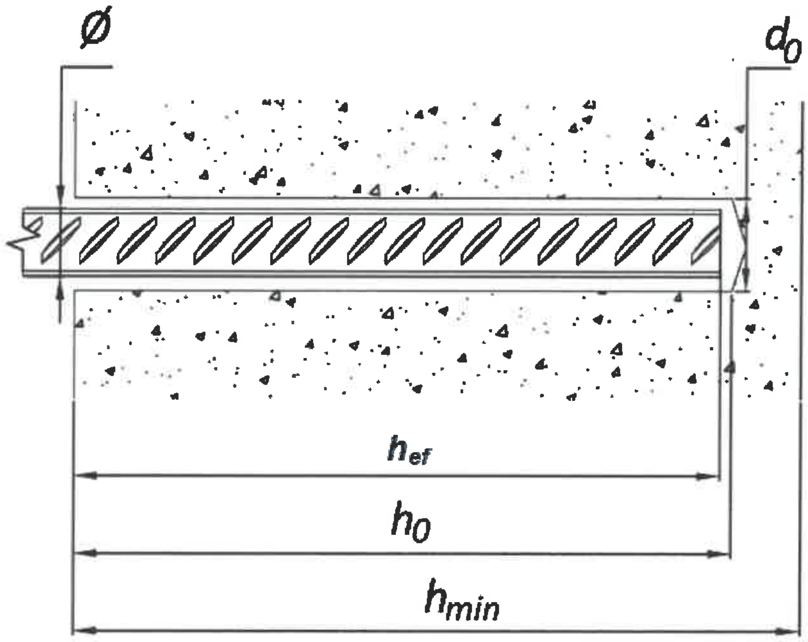

Table A.2 Installation parameters for rebars as anchors

Size		Ø8	Ø10	Ø12	Ø14	Ø16	Ø20	Ø25	Ø32
Nominal diameter of anchor rod	d [mm]	8	10	12	14	16	20	25	32
Minimum diameter of threaded and	d [mm]	5.8	7.8	9.8	11.8	13.8	15.8	22.8	29.8
Drilling diameter	d_0 [mm]	12	14	18	18	22	26	35	40
Maximum diameter hole in the fixture	d_f [mm]	9	12	14	16	18	22	26	32
Depth of the drilling hole	h_0 [mm]	h_{ef} + 5mm							
Minimum thickness of the concrete member	h_{min} [mm]	h_{ef} + 30mm; ≥ 100mm				h_{ef} + 2*d_0			
Torque moment	T_{inst} [Nm]	10	20	40	40	80	120	160	200
Minimum spacing	s_{min} [mm]	0,5*h_{ef} ≥ 40mm							
Minimum edge distance	c_{min} [mm]	0,5*h_{ef} ≥ 40mm							

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Enclosure 2 Graphical analysis of steel failure according to EAD 330232-00-0601: 2016-10 [4] for threaded rods

Diagram A2.1 Graphical analysis of the threaded rod M8x90 mm

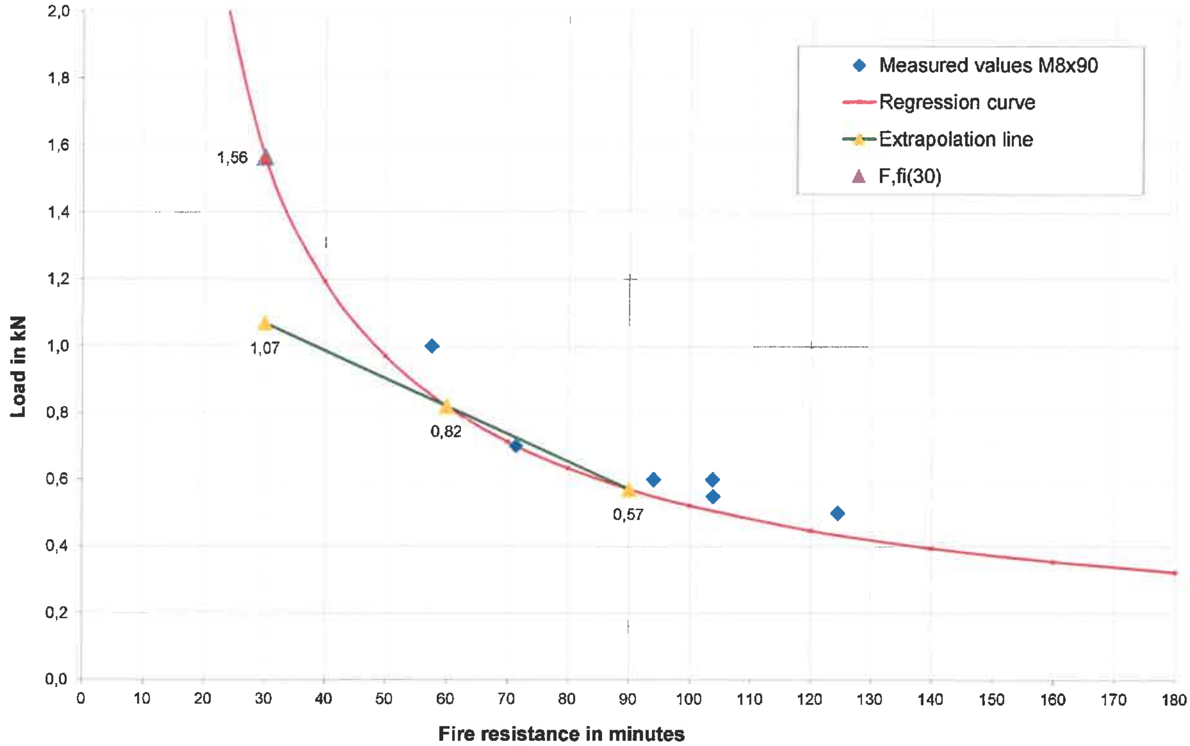


Diagram A2.2 Graphical analysis of the threaded rod M12x100 mm

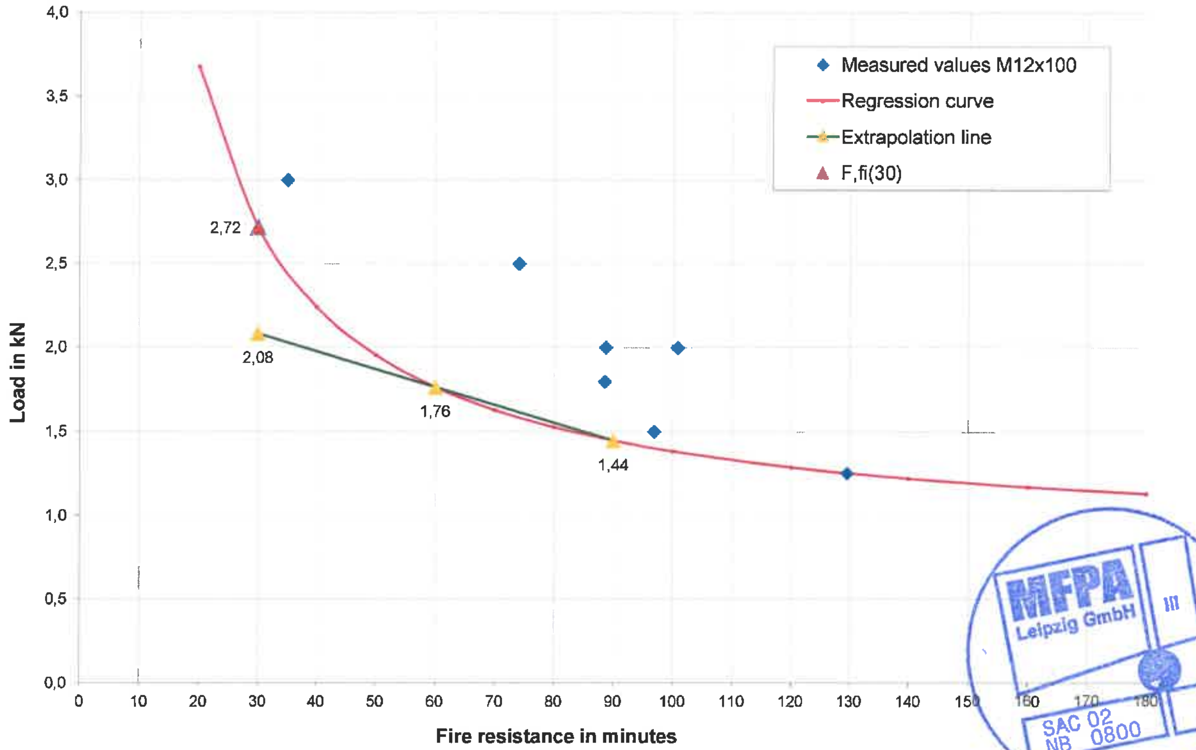


Diagram A2.3 Graphical analysis of the threaded rod M16x120 mm

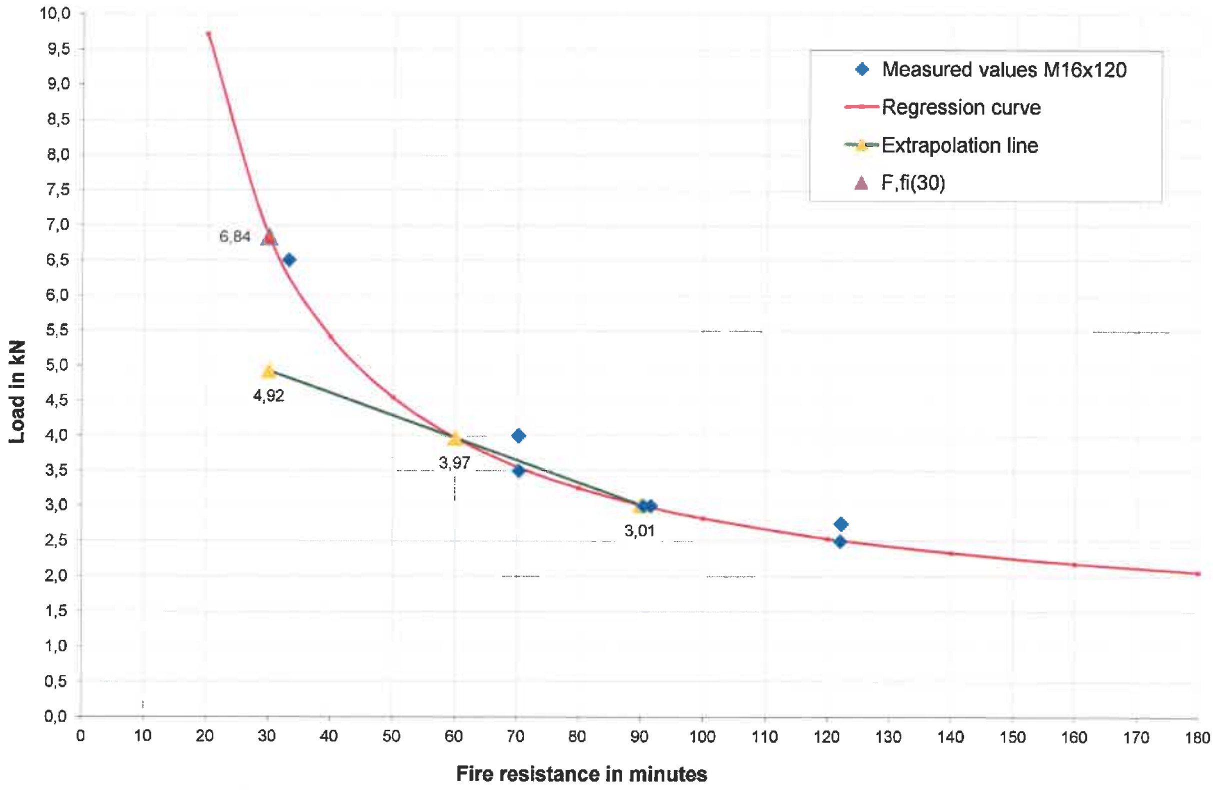
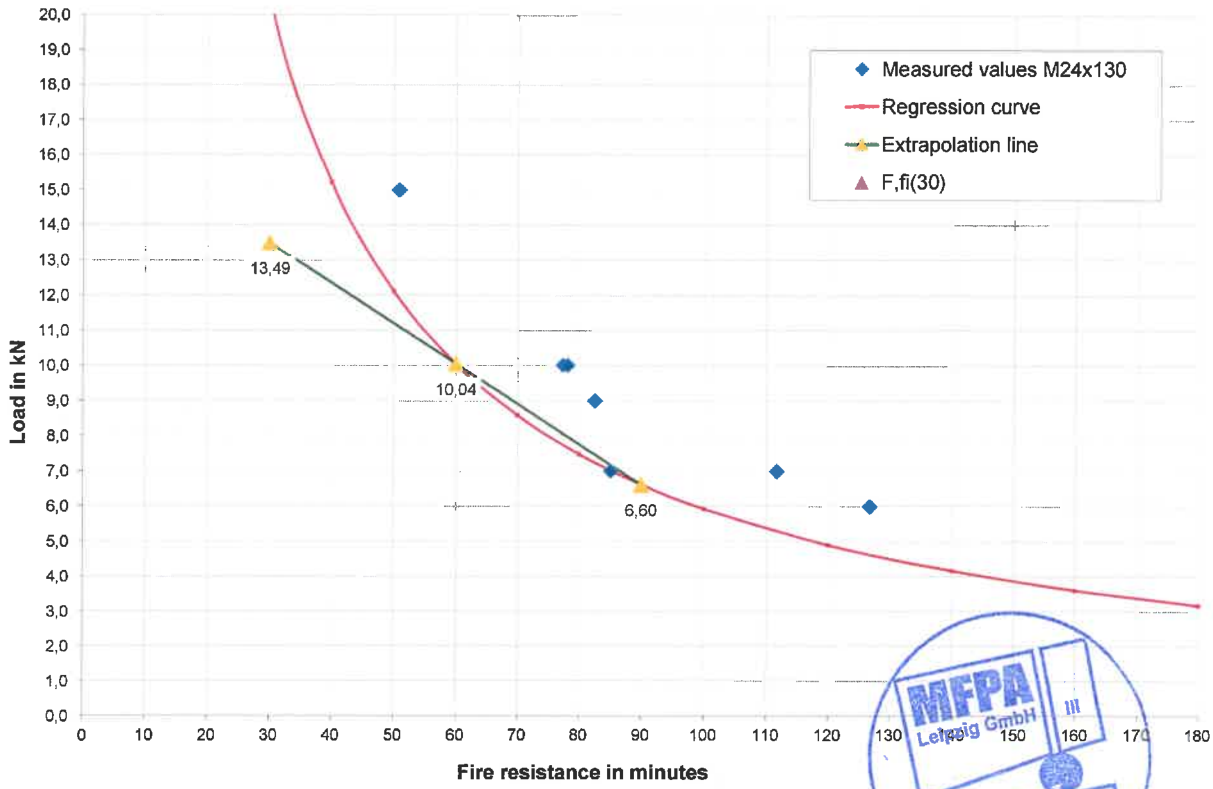


Diagram A2.4 Graphical analysis of the threaded rod M24x130 mm



Enclosure 3 Graphical analysis of steel failure according to EAD 330232-00-0601: 2016-10 [4] for rebars as anchors

Diagram A3.1 Graphical analysis of the rebar Ø 8x90 mm

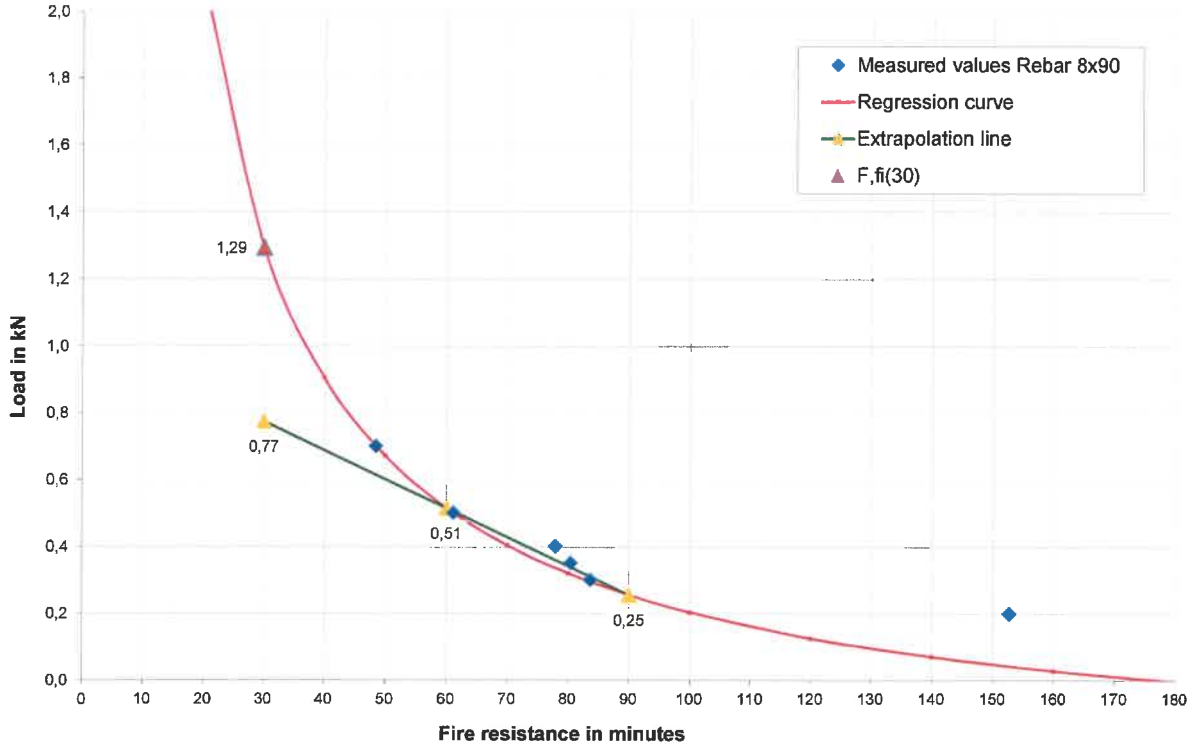


Diagram A3.2 Graphical analysis of the rebar Ø 12x100 mm

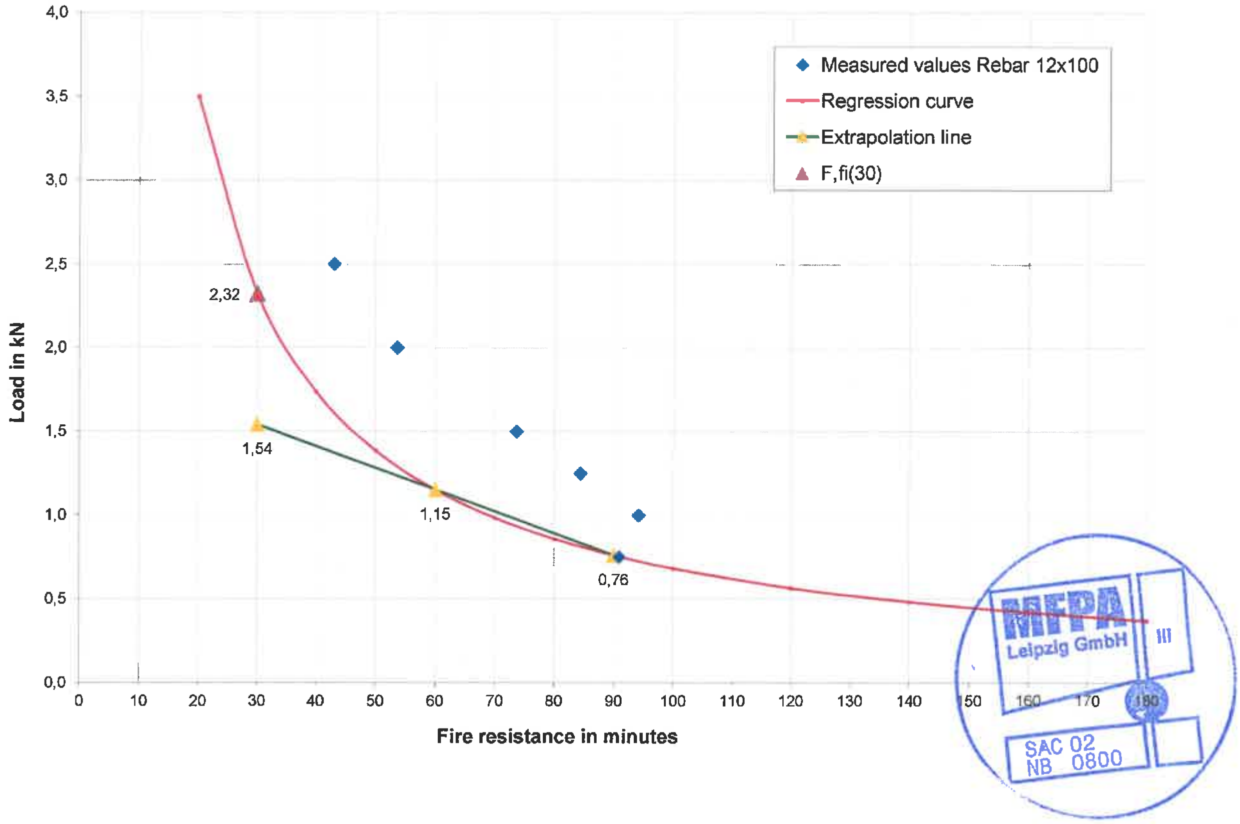
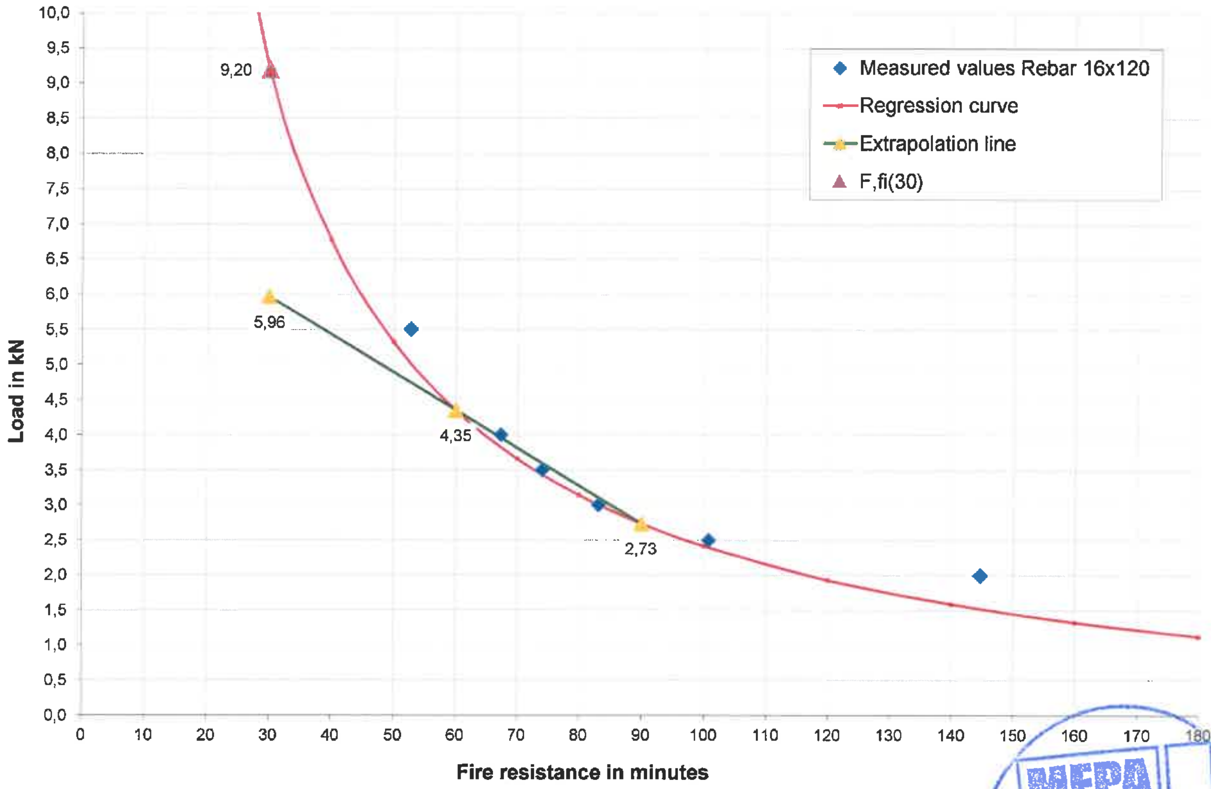


Diagram A3.3 Graphical analysis of the rebar Ø 16x120 mm



Enclosure 4 Graphical analysis of the test results with minimum embedment depth

Diagram A4.1 Graphical analysis of the test results for M8x60 mm

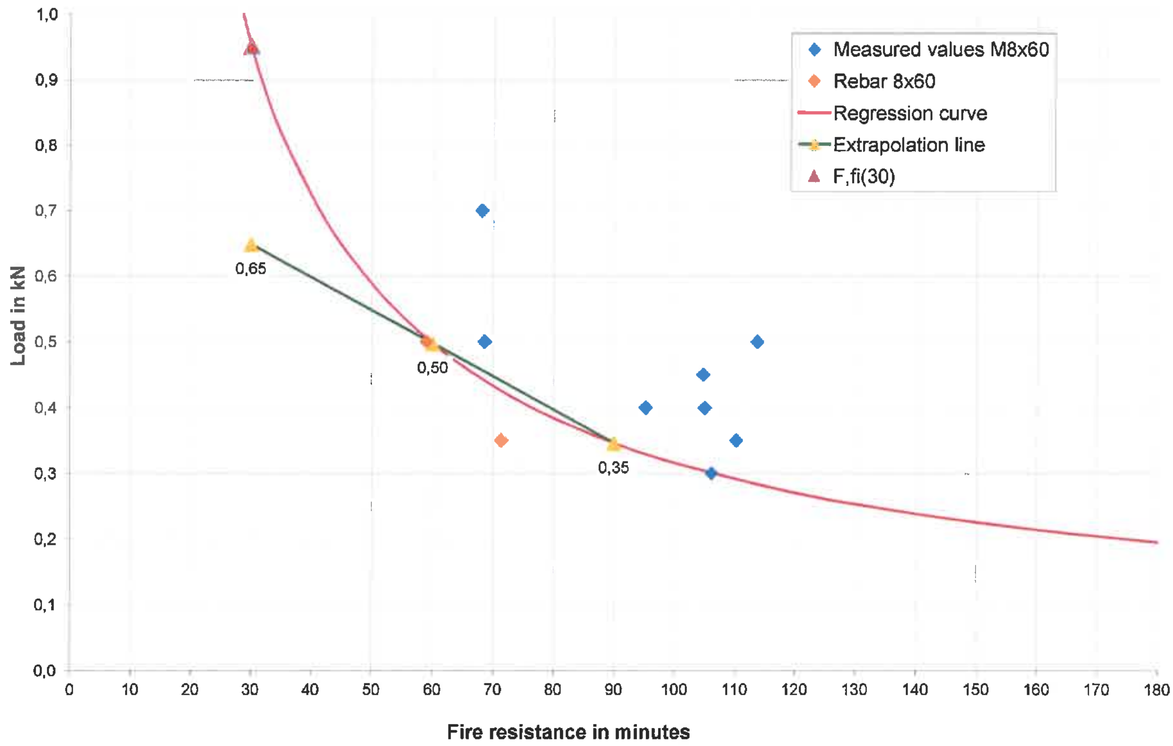


Diagram A4.2 Graphical analysis of the test results for M12x60 mm

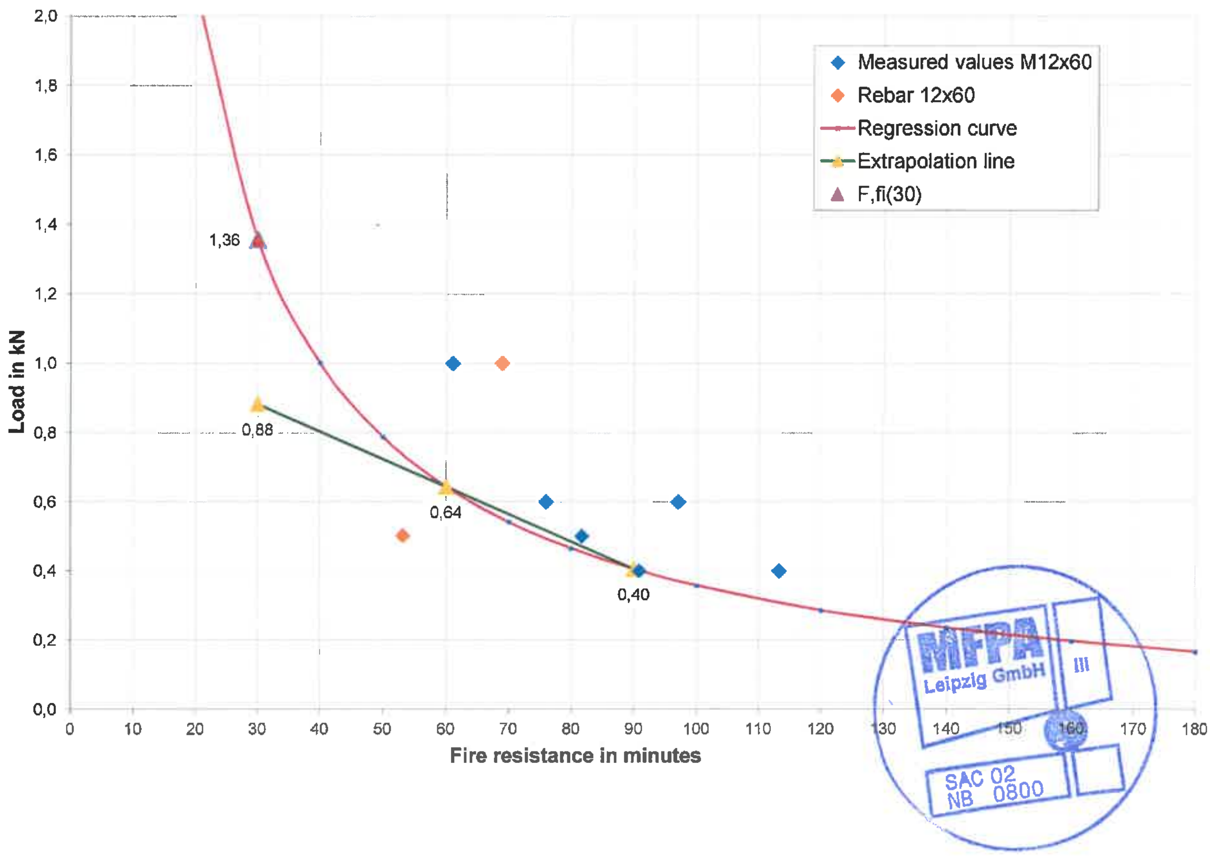


Diagram A4.3 Graphical analysis of the test results for M16x64 mm

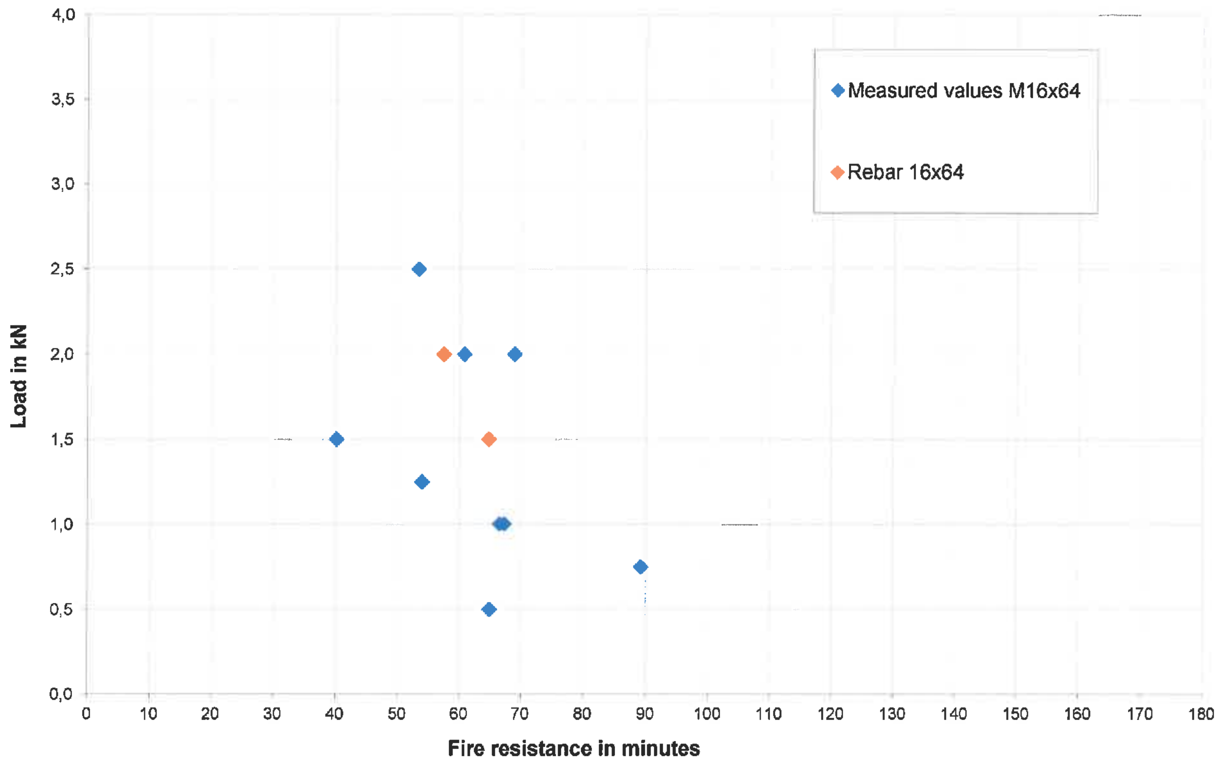


Diagram A4.4 Graphical analysis of the test results for M24x96 mm