MFPA Leipzig GmbH

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

Center for Innovation and Calculation
Dr.-Ing. Susanne Reichel

Work Group - FEM

Dr.-Ing. Susanne Reichel
Telefon +49 (0) 341-6582-106
s.reichel@mfpa-leipzig.de

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Object: Assessment of the load-bearing behaviour of fischer nail anchors FNA II R and FNA II HCR under tension load and one-sided fire loading according to the ZTV-ING-curve

Client: **fischerwerke GmbH & Co. KG**
Klaus-Fischer-Straße 1
D-72178 Waldachtal

Prepared by: Dr.-Ing. Susanne Reichel

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

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

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I Objective and request

MFPA Leipzig GmbH was ordered by fischerwerke GmbH & Co. KG to assess the load-bearing behaviour of fischer nail anchors FNA II R and FNA II HCR under tension load and one-sided fire loading according to the ZTV-ING-curve according to [N1].

1 Description of the construction

The fischer nail anchor FNA II is an anchor made of galvanised steel (FNA II), stainless steel (FNA II R) or high corrosion resistant steel (FNA II HCR) consisting of an cone bolt (threaded bolt or nail head) and an expansion sleeve which is placed in a drilled, cylindrical hole and anchored by load-controlled expansion. With [P1] an European Technical Assessment is available for fischer nail anchors FNA II.
The nail anchors are available in the different designs specified in Figure 1 and are used for multiple fastening of non-structural applications in reinforced and unreinforced normal-weight concrete (cracked and non-cracked) of strength class of at least C12/15 and at most C50/60 according to [N2].

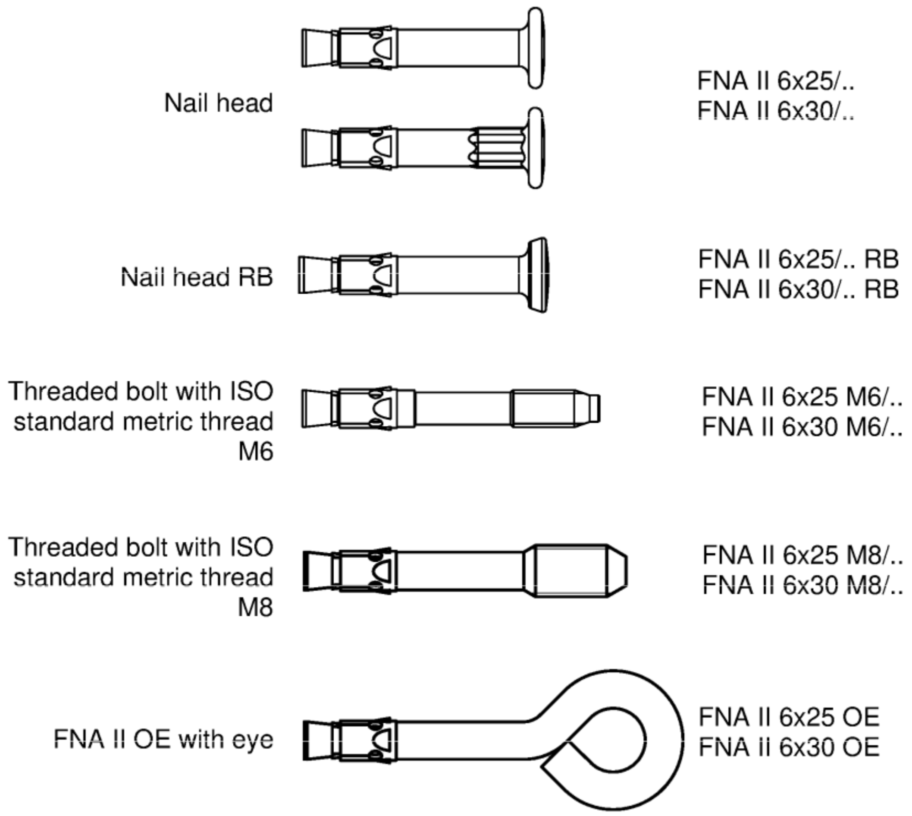

Figure 1: fischer nail anchor FNA II: Design options, see [P1]

The required diameter of the drilled hole as well as the required drilled hole depth and the minimum component thickness are given for each anchor type in [P1]. The geometry of the nail anchors in the installed condition is shown in Figure 2. For the installation of the nail anchors, the manufacturers installation instruction according to [P1] is required.

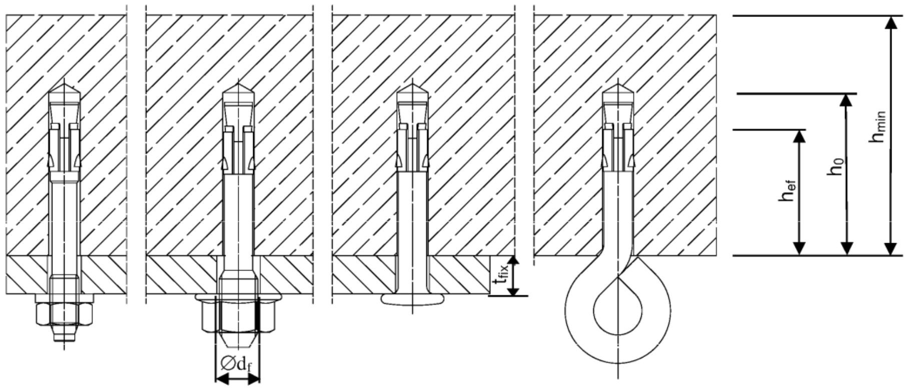

Figure 2: fischer nail anchor FNA II: Geometry in installed condition, see [P1]

Material information for the FNA II, FNA II R and FNA II HCR anchors is shown in Figure 3.

Table A2.1: Materials FNA II

Part	Designation	Material		
		FNA II	FNA II R	FNA II HCR
	Steel grade	Steel	Stainless steel R	High corrosion resistant steel HCR
		Zinc plated ≥ 5 µm, ISO 4042:2018	Acc. to EN 10088:2014 Corrosion resistance class CRC III acc. to EN 1993-1-4:2015	Acc. to EN 10088:2014 Corrosion resistance class CRC V acc. to EN 1993-1-4:2015
1	Expansion sleeve	Cold strip, EN 10139:2016 or stainless steel EN 10088:2014	Stainless steel EN 10088:2014	Stainless steel EN 10088:2014
2	Cone bolt	Cold form steel or free cutting steel		High corrosion resistant steel EN 10088:2014

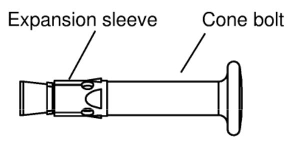

Figure 3: fischer nail anchor FNA II: Material information, see [P1]

For a detailed product description and further information on the field of application, please see [P1].
This advisory opinion covers nail anchors FNA II 6x30 with nail head and FNA II 6x30 M6 with threaded bolt (embedment depth $h_{ef} \geq 30mm$) in the versions FNA II R and FNA II HCR.

II References

1 Utilised guidelines, rules and standards

The analyses are based on the following guidelines, rules and standards:

[N1] Zusätzliche Technische Vertragsbedingungen und Richtlinien für Ingenieurbauten, ZTV-ING: Teil 5, Tunnelbau – Bundesanstalt für Straßenwesen, Stand: 2018/01

[N2] DIN EN 206:2017-01: Concrete - Specification, performance, production and conformity; German version EN 206:2013+A1:2016

[N3] EAD 330747-00-0601: Fasteners for use in concrete for redundant non-structural systems; 05/2018

[N4] EAD 330232-00-0601: Mechanical fasteners for use in concrete; 10/2016

[N5] DIN EN 1992-4:2019-04: Eurocode 2 - Design of concrete structures - Part 4: Design of fastenings for use in concrete; German version EN 1992-4:2018

[N6] DIN EN 1993-1-2:2010-12: Eurocode 3: Design of steel structures - Part 1-2: General rules - Structural fire design; German version EN 1993-1-2:2005 + AC:2009

[N7] TR 020: Evaluation of Anchorages in Concrete concerning Resistance to Fire; 05/2004

[N8] DIN EN 1992-1-2:2010-12: Eurocode 2: Design of concrete structures - Part 1-2: General rules - Structural fire design; German version EN 1992-1-2:2004 + AC:2008

2 Reference documents

The analyses are based on the following additional documents:

2.1 ETAs and Verifications of applicability

[P1] ETA-06/0175: fischer nail anchor FNA II, Load controlled expansion anchor for multiple use for non-structural applications in concrete – Deutsches Institut für Bautechnik, 02.03.2021

2.2 Assessment and test reports

[G1] Prüfbericht Nr. PB III/B-07-114: fischer Nagelanker FNA II A4, Prüfung und Bewertung des Brandverhaltens unter einer Beanspruchung nach der Temperatur-Zeitkurve der ZTV-ING: 2003-1 von in die Zugzone von Stahlbetondeckenabschnitten gesetzten und auf zentrischen Zug beanspruchten Dübeln. – MFPA Leipzig GmbH; 11.04.2007

[G2] Bescheid über die zweite Verlängerung der Geltungsdauer des Prüfberichts PB III/B-07-114 vom11.04.2007 – MFPA Leipzig GmbH; 06.09.2017

2.3 Miscellaneous

[S1] Manufacturer's declaration from fischerwerke GmbH & Co. KG to MFPA Leipzig GmbH for the product FNA II R (formerly A4) and FNA II HCR (formerly C); 10.08.2021

III Assessment of the performance

1 Basics

The currently valid European Technical Assessment [P1] is based on the European Assessment Document EAD 330747-00-0601 [N3]. In [N3], Chapter 2.2.12, reference is made to EAD 330232-00-0601 [N4], Chapters 2.2.13 to 2.2.15 with respect to the determination of fire resistance. According to this, in connection with centric tensile loading, the fire resistance shall be determined experimentally for the failure modes "steel failure" and "pull-out failure".
A simplified approach for determining the fire resistance of mechanical anchors is described in DIN EN 1992-4 [N5], Annex D. According to this, verifications are to be carried out for the failure types "steel failure", "pull-out failure" and "concrete cone failure".
The verification methods described in [N4, N5] are designed for fire exposure using the standard temperature-time curve. From an expert's point of view, however, the same qualitative failure mechanisms can be expected for fire exposure with the ZTV-ING-curve. Therefore, the verifications anchored in [N5], Annex D, are carried out in the following.

2 Design concept

The characteristic load-bearing capacity of a nail anchor in case of fire under tension load has to be determined as the minimum value of the load-bearing capacities for the failure modes pull-out failure, steel failure and concrete cone failure

$$N_{Rk,fi} = min\left[N_{Rk,p,fi}, \quad N_{Rk,s,fi}, \quad N_{Rk,c,fi}\right]. \tag{1}$$

3 Steel failure

In [G1] fire tests on reinforced concrete specimens of strength class C20/25 are described, which are aimed at investigating the fire resistance of fischer nail anchors FNA II R for steel failure under fire load according to ZTV-ING:2003-1. The temperature-time curve of fire exposure according to ZTV-ING:2003-1 corresponds to the current edition of the guideline (see [N1]). In [S1, G2], the applicability of the test results shown in [G1] is confirmed for the present considerations.
Tests were carried out for the fischer nail anchor FNA II R 6x30 with nail head and FNA II R 6x30 M6 with threaded bolt. The observed failure during the tests was always steel failure (Offshearing of the nut) with the threaded bolt version. The nail head version always failed by pull-out.

The corresponding results are decisive for the load-bearing capacity under tensile stress.
The tensile load-bearing capacity is characterised by the largest load tested in the series of tests, for which no failure occurred during the entire fire exposure period. On the safe side, and based on the results documented in [G1], the following applies to both tested variants

$$N_{Rk,s,fi} = 0.1kN. \tag{2}$$

4 Pull-out failure

Since failure due to pull-out has been observed during the fire tests documented in [G1] applies

$$N_{Rk,p,fi} = N_{Rk,s,fi} = 0.1kN. \tag{3}$$

5 Concrete cone failure

Concrete cone failure in conjunction with tension loaded nail anchors occurs, when the tensile strength of the concrete is locally exceeded.
From an expert's point of view, the characteristic load-bearing capacities $N^0_{Rk,c,fi}$ for concrete cone failure under fire loading according to the ZTV-ING-curve may be estimated using the determination equation for fire loading according to the standard time-temperature curve specified in [N5], Annex D.4.2.2 for a fire exposure of 120min

$$N^0_{Rk,c,fi} = N^0_{Rk,c,fi(120)} = 0.8 \cdot \frac{h_{ef}}{200} \cdot N^0_{Rk,c} \leq N^0_{Rk,c} \tag{4}$$

with $N^0_{Rk,c}$: characteristic resistance to concrete cone failure of a single nail anchor in cracked concrete C20/25 under ambient climate.
The performance characteristics under environmental conditions specified in [P1], Table C1.1 are valid for all failure modes and load directions. In contrast to the procedure described in [N5], Chapter 7.2.1.4 and Annex D.4.2.2, influences of adjacent fasteners and component edges are already considered. With $N_{Rk} = 0.85kN$ for the smallest spacing and edge distance and concrete C12/15, one obtains on the safe side

$$N_{Rk,c,fi} = 0.8 \cdot \frac{30}{200} \cdot 0.85kN = 0.102kN. \tag{5}$$

6 Transferability of the results to other steel materials

In [G1], the decisive failure mechanism was found to be the pull-out of the nail anchors from the concrete specimen. This occurs when the applied tensile stresses exceed the force that can be transferred from the anchor

to the substrate. In connection with fire resistance, it can be assumed that the transferable force has a temperature dependence and is thus influenced by the heat input into the joint.
In case of the same anchor geometry, the heat input into the joint is influenced by the thermal properties of the material used. These are specified for stainless steels with material numbers 1.4301, 1.4401, 1.4571, 1.4003 and 1.4462 in [N6], Annex C. From an expert's point of view and on the basis of corresponding test experience, it may be assumed that other stainless and high corrosion resistant types of steel also exhibit comparable thermal properties.
The characteristic load-bearing capacity determined for fischer nail anchors FNA II R are therefore transferable to fischer nail anchors FNA II HCR from an expert's point of view.

7 Summary

The characteristic load-bearing capacity of a fischer nail anchor

- FNA II R 6x30 with nail head,
- FNA II R 6x30 M6 with threaded bolt,
- FNA II HCR 6x30 with nail head,
- FNA II HCR 6x30 M6 with threaded bolt

in case of centric tensile loading and fire loading by the ZTV-ING-curve according to [N1] is

$$N_{Rk,fi} = 0{,}1 kN. \tag{6}$$

IV Special notes/Limits of application

This advisory opinion applies for fischer nail anchors

- FNA II R 6x30 with nail head,
- FNA II R 6x30 M6 with threaded bolt,
- FNA II HCR 6x30 with nail head,
- FNA II HCR 6x30 M6 with threaded bolt

($h_{ef} \geq 30mm$) of the company fischerwerke GmbH & Co. KG, which are installed in compliance with the installation regulations described in [P1]. The mechanical stress must not exceed the load-bearing capacity specified in [P1] for ambient conditions.

The load-bearing capacities for steel failure and pull-out failure specified in the framework of the document at hand were determined for one-sided fire loading according to the ZTV-ING-curve according to [N1]. Following [N7], the values may also be applied for multi-sided fire loading, provided that $c \geq 300mm$ and $c \geq 2 \cdot h_{ef}$ apply to the edge distance of the anchor.

The load bearing capacities for steel failure and pull-out failure specified in the framework of the document at hand were determined for centric tensile loading in the longitudinal direction of the anchor. Following [N4], on the safe side a transfer to steel failure due to tensile loads perpendicular and diagonal to the anchor axis is possible. Types of failure affecting the substrate for tensile loads perpendicular and diagonal to the anchor axis, such as concrete edge failure, must be verified separately (cf. [N5]).

The assessment at hand is valid for constructions of reinforced or unreinforced normal-weight concrete of the strength class $\geq$ C20/25 and $\leq$ C50/60 according to [N2], which exhibit at least the same fire resistance as the utilised nail anchors. The design of the concrete construction has to be carried out according to [N8] and considering [N1].

The load bearing capacities specified in the framework of the document at hand are determined assuming that no concrete spalling occurs and are only valid under this condition. Evidence on the prevention of concrete spalling is given in [N8], Chapter 4.5.

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

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Dr.-Ing. S. Reichel
Head of Business Division

MFPA Leipzig GmbH VI
SAC 02
NB 0800