16th March 2023

Report No. P19-028

For the determination of the characteristic resistance of the power-actuated fasteners fischer DFN/DFNH with the gas driven tool FGC 100 for multiple use in concrete and masonry for non-structural application

- **Fastening in concrete, masonry and steel under tension load**
- **Fastening in concrete under shear load**

Client

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THIS REPORT CONTAINS 20 PAGES OF TEXT.

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Reference list

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1 Introduction

The company fischerwerke GmbH & Co.KG, located in Waldachtal, Germany, is intended to specify the characteristic resistance, respectively the admissible load of the power-actuated fastener fischer DFN/DFNH on basis of EAD 330083-04-0601 [1].

The power-actuated fastener DFN/DFNH is intended for multiple use for non-structural applications in non-cracked normal weight concrete and in masonry. The system is intended to be used in uncoated concrete of minimum strength class C20/25 and maximum strength class C50/60 as well as in solid masonry units made of clay and calcium silicate.

Tests according to [1] to determine the characteristic bearing capacity with the power-actuated fastener DFN/DFNH were conducted at the test laboratory of the fischer company in absence of the author and are described in [2] and [3].

All investigations were conducted following [1].

2 Test Conditions

2.1 Tested Fasteners

The fischer power-actuated fastener DFN/DFNH consists of a nail of hardened carbon steel with zinc coating.

The geometry and the dimensions of the fischer DFN/DFNH power-actuated fasteners are shown in the following Figure 2.1 and Figure 2.2 as well as in Table 2.1.

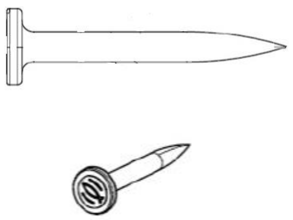
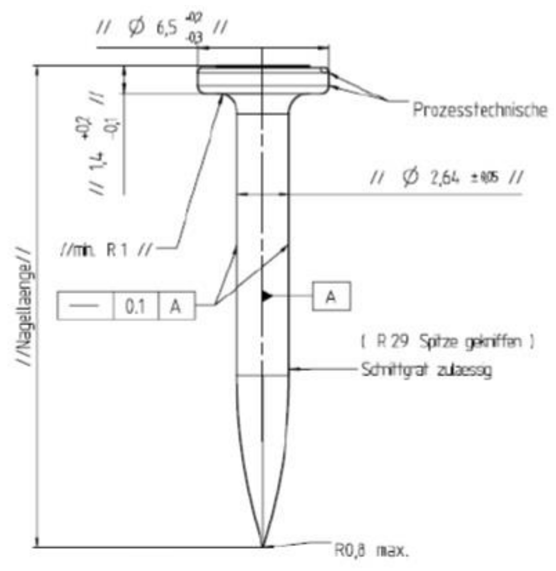
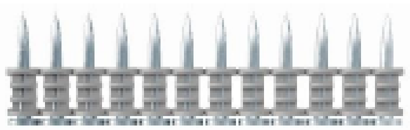
DFN Ø 2,6 mm magazined fastener	**Dimensions**
	
Nail range: **DFN 17 – DFN 40**	
	

Figure 2.1 fischer DFN magazined fastener with Ø 2,6 mm

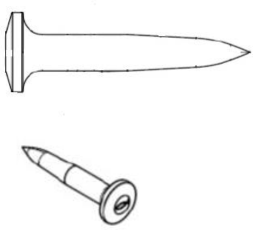
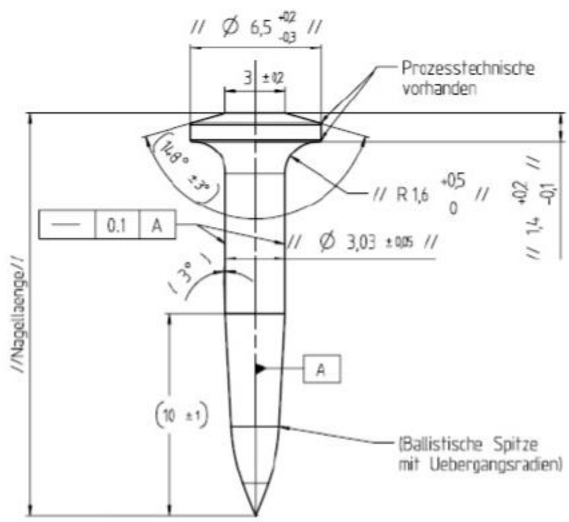
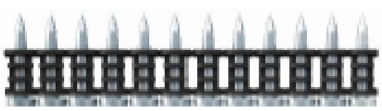
DFNH Ø 3,0 mm magazined fastener	**Dimensions**
	
Nail range: **DFNH 15 – DFNH 32**	
	

Figure 2.2 fischer DFNH magazined fastener with Ø 3,0 mm

Table 2.1 Dimensions of the Fasteners

		DFN 17 to DFN 40	DFNH 15 to DFNH 32
Total length L	[mm]	17 / 20 / 22 / 25 / 30 / 32 / 35 / 40	15 / 17 / 22 / 27 / 32
Shank diameter	[mm]	2.6	3
Head diameter	[mm]	6.5	6.5

The materials of the individual components of the fastener and their properties are assembled in the following Table 2.2.

Table 2.2 Guaranteed Material Properties of Fastener Components

Component	Material	Fastener
Nail	Cold heading wire with hardness specification of 580 - 660 HV Coating: Zinc plating ≥ 5 µm	DFN/DFNH

The fasteners made of carbon steel with zinc coating with minimum thickness of 5 microns can be used in structures subject to dry, internal conditions.

2.2 Installation

Setting requires the following special equipment:

- the fastening tool FGC 100 with gas cartridge FC 165 (Figure 2.3) and
- collated nails DFN/DFNH (Figure 2.1 and Figure 2.2)
- metal tracks with a maximum thickness of t = 2 mm

The setting details for the fastener fischer DFN/DFNH are given in Table 2.3.

Figure 2.3 fischer gas tool

Table 2.3 Installation Parameters

Power-actuated fastener		DFN	DFNH
Non-cracked concrete	[-]	C20/25	C20/25 – C50/60
Minimum thickness of concrete member h_{min}	[mm]	100	100
Solid calcium silicate bricks acc. to DIN 771-2	[-]	KS 16-2,0 with $f_{st,tr} \geq 25$ N/mm²	-
Minimum dimensions l x b x h	[mm³]	998 x 200 x 623	-
Solid clay bricks acc. to DIN 771-1	[-]	Mz 20-2,0 with $f_{st,tr} \geq 25$ N/mm²	-
Minimum dimensions l x b x h	[mm³]	240 x 115 x 113	-
Steel	[-]	-	S 235 with $f_{uk} \geq 500$ N/mm²
Minimum thickness t	[mm]	-	12
Minimum thickness of fixture t_{fix}	[mm]	2	2

2.3 Base Materials

The tests with the fastener fischer DFN/DFNH were conducted in non-cracked concrete acc. to [4], in masonry acc. to [5] and [6] and in steel. Table 2.4 shows a summary of the materials and their properties.

The compressive strengths and the dimensions are shown in Table 2.4.

Table 2.4 Used Materials

Row	Material	Dimensions [mm]	Compressive Strength [N/mm²]	Source
1	C20/25	800 x 800 x 100 800 x 800 x 200	28.89 29.48	[2]/[3]
2	C50/60	800 x 800 x 300 800 x 800 x 200	60.89 62.96	[2]/[3]
3	KS XL-PE 16-2,0	998 x 200 x 498	29.60	[2]
4	Mz 2DF-2,0	240 x 115 x 113	30.39	[2]
5	Steel	300 x 100 x 12	526.90	[2]

3 Test Program

For evaluation of the load-bearing characteristics the following tests were conducted in the different base materials.

The used measurement and setting tools are described in detail in [2] and [3].

Table 3.1 Test Program – Tension Load

Row	Test	Fastener	Base material	n [-]	$h_{ef,m}$ [mm]	source [-]	Remarks
Basic tension tests: Characteristic resistance to tension loading in:							
1a	**A1**	DFN 17	C20/25	15	13,5	[2]	uncracked concrete C20/25
1b	**A1a**	DFN 17	C20/25	15	14,0	[3]	
2a	**A1**	DFN 20	C20/25	15	15,5	[2]	
2b	**A1**	DFN 20	C20/25	15	15,4	[3]	
3a	**A1**	DFN 22	C20/25	15	17,5	[2]	
3b	**A1a**	DFN 22	C20/25	15	18,5	[3]	
4	**A1**	DFN 25	C20/25	15	20,0	[2]	
5a	**A1**	DFN 30	C20/25	15	22,0	[2]	
5b	**A1a**	DFN 30	C20/25	15	23,2	[3]	
6	**A1**	DFN 32	C20/25	15	22,0	[2]	
7a	**A1**	DFNH 17	C20/25	15	13,5	[2]	
7b	**A1a**	DFNH 17	C20/25	15	14,2	[3]	
8a	**A1**	DFNH 22	C20/25	15	18,0	[2]	
8b	**A1a**	DFNH 22	C20/25	15	18,4	[3]	
9	**A1**	DFNH 27	C20/25	15	20,5	[2]	
10	**A2**	DFNH 17	C50/60	15	13,5	[2]	uncracked concrete C50/60
11a	**A2**	DFNH 22	C50/60	15	16,0	[2]	
11b	**A2a**	DFNH 22	C50/60	15	17,9	[3]	
12a	**A2**	DFNH 27	C50/60	15	18,0	[2]	
12b	**A2a**	DFNH 27	C50/60	15	18,5	[3]	
13	**A1**	DFNH 15	S235	15	8,0	[2]	steel
14	**A1**	DFNH 17	S235	15	8,0	[2]	
15	**A1**	DFN 22	KSV	15	17,5	[2]	solid masonry calcium silicate KS
16	**A1**	DFN 25	KSV	15	20,5	[2]	
17	**A1**	DFN 30	KSV	15	24,5	[2]	
18	**A1**	DFN 32	KSV	15	26,5	[2]	
19	**A1**	DFN 35	KSV	15	28,5	[2]	
20	**A1**	DFN 40	KSV	15	28,5	[2]	
21	**A1**	DFN 17	Mz	15	13,0	[2]	solid masonry clay brick Mz
22	**A1**	DFN 20	Mz	15	14,5	[2]	
23	**A1**	DFN 22	Mz	15	16,5	[2]	
24	**A1**	DFN 25	Mz	15	19,5	[2]	
25	**A1**	DFN 32	Mz	15	22,0	[2]	

Table 3.2 Test Program – Shear Load [2]

Row	Test	Fastener	Base material	n [-]	$h_{ef,m}$ [mm]	source [-]	Remarks
Basic shear tests: Characteristic resistance to shear loading in:							
26	**A5**	DFN 22	C20/25	15	16,8	[2]	uncracked concrete C20/25
27	**A5**	DFN 25	C20/25	15	18,1	[2]	
28	**A5**	DFN 30	C20/25	15	18,9	[2]	
29	**A5**	DFNH 22	C20/25	15	16,4	[2]	
30	**A5**	DFNH 27	C20/25	15	18,6	[2]	
31	**A6**	DFNH 22	C50/60	15	16,3	[2]	uncracked concrete C50/60
32	**A6**	DFNH 27	C50/60	15	18,7	[2]	

4 Tests in Concrete, Masonry and Steel

4.1 General

The 5%-quantiles quoted in this subsection were determined on the basis of a logarithmic normal distribution of the maximum loads with a confidence level of 90 %.

The compressive strength and the density of the different base material units were determined in accordance with [4], [5] and [6].

The following symbols are used to describe the results in the next subsections.

n	number of tests
v	coefficient of variation (underlying a normal distribution)
h^t_{ef}	effective embedment depth in base material
$f_{c,test}$	compressive strength according to [4], [5] and [6] of the concrete and masonry specimen (for steel: tensile strength $f_{u,test}$)
f_{ck}	nominal characteristic compressive strength for concrete and masonry units (for steel: characteristic tensile strength f_{uk})
$F^t_{Ru,m}$	mean ultimate load in the test
$F_{Ru,m}$	mean ultimate load normalised to nominal compressive strength or tensile strength
$F_{Rk,0}$	5 %-quantile of the normalised mean ultimate load $F_{Ru,m}$ underlying a normal distribution of the logarithms of the failure loads and a confidence level of 90 %
α_1	reduction factor regarding steady load-displacement behavior
α_v	reduction factor regarding a high coefficient of variation with:

$$\alpha_v = \frac{1}{(1 + 0{,}03 * (v[\%] - 20))} \leq 1{,}0$$

Key to abbreviations for types of failure:

Po	pull-out of the fastener
Pt	pull-through of the nail head
S	steel failure of the fastener
nV	no failure was achieved

4.2 Conversion of the Ultimate Loads

Test results with concrete failure (concrete cone failure, splitting or pull-out) are normalised acc. to [1] using the following formula:

$$F_{Ru} = F^t_{Ru} \times \left(\frac{f_{ck}}{f_{c,test}}\right)^{0,5} \tag{4-1}$$

Test results in masonry units with pull-out failure are normalised using the following formula:

$$F_{Ru} = F^t_{Ru} \times \frac{f_{ck}}{f_{c,test}} \tag{4-2}$$

For steel failure the results are normalised using the following formula:

$$F_{Ru} = F^t_{Ru} \times \frac{f_{uk}}{f_{u,test}} \tag{4-3}$$

4.3 Evaluation Principles

For the assessment of the test results, a normal distribution of logarithms of the failure loads is assumed. Using the following equation for calculating the 5%-quantiles F_{Rk}:

$$F_{Rk} = e^{\ln(F_{Ru,m}) - k \times s} \tag{4-4}$$

For checking the ultimate loads due to outliers the following equation was used:

for maximum values: $$T_n = \frac{(F_{max} - F_{Ru,m})}{s} \tag{4-5}$$

for minimum values: $$T_1 = \frac{(F_{Ru,m} - F_{min})}{s} \tag{4-6}$$

The threshold T_{lim} is gathered from [8] according to the referring confidence level and it has to be lower than the referring values T_1 or T_n respectively for detecting an outlier.

To check whether the results of two test series belong to the same sample the following equation governs:

$$t_{test} = \frac{\sqrt{(n_1 + n_2 - 2)} \times \sqrt{n_1 \times n_2}}{\sqrt{n_1 + n_2}} \times \frac{|F_{Ru,m,1} - F_{Ru,m,2}|}{\sqrt{(n_1 - 1) \times s_1^2 + (n_2 - 1) \times s_2^2}} \tag{4-7}$$

Due to the level of significance the threshold $t_{\alpha,m}$ has to be chosen from a table acc. to [9]. For the evaluation shown in this report the level of significance was chosen to 5 %. The results of two test series belong to the same sample if the following condition fits:

$$t_{test} \leq t_{\propto,m} \tag{4-8}$$

The following abbreviations are used for the above mentioned equations:

F_{Rk}	5%-quantile of the mean failure load underlying a normal distribution of the ultimate loads
$F_{Ru,m}$	mean failure load
F_{max}	maximum failure load
F_{min}	minimum failure load
k	factor for calculating the 5%-quantile acc. to [7]
s	standard deviation of the normal distribution of the ultimate loads
T_n	value for the determination of an outlying maximum
T_1	value for the determination of an outlying minimum
T_{lim}	threshold for the determination of outlying values
t_{test}	value for the determination whether test results were taken from the same sample
$t_{\alpha,m}$	threshold for the determination whether test results were taken from the same sample

4.4 Results of the Tests with the Fastener fischer DFN/DFNH

Table 4.1 Basic Tension Tests in Uncracked Concrete C20/25 and C50/60

Row	Test	Size	Base Material	n [-]	v [%]	h^t_{ef} [mm]	$f_{c,test}$ | $f_{u,test}$ [N/mm²]	f_{ck} | f_{uk} [N/mm²]	failure mode	δ_{Fum} [mm]	$F^t_{Ru,m}$ [kN]	Log. Normal Distribution $F_{Ru,m}$ [kN]	Log. Normal Distribution $F_{Rk,0}$ [kN]	Log. Normal Distribution α_1 [-]	Log. Normal Distribution α_v [-]	remarks
1	A1	DFN 17	C20/25	15	47,15	13,5	28,89	25,0	15xPo	0,15	1,50	1,23	0,35	1,00	0,55	
2	A1a	DFN 17	C20/25	15	38,22	14,0	28,89	25,0	15xPo	0,40	1,69	1,41	0,39	1,00	0,65	
3	A1com	DFN 17	C20/25	30	42,16	13,8	28,89	25,0	30xPo	0,27	1,60	1,32	0,43	1,00	0,60	T1-15: A1 T16-30: A1a
4	A1	DFN 20	C20/25	30	35,24	15,5	28,89 & 29,48	25,0	30xPo	0,29	2,33	1,96	0,68	1,00	0,69	
5	A1	DFN 22	C20/25	30	35,70	17,5	28,89 & 29,48	25,0	30xPo	0,41	3,07	2,54	0,78	1,00	0,68	
6	A1a	DFN 22	C20/25	15	34,76	18,5	28,89	25,0	15xPo	0,54	2,71	2,19	0,39	1,00	0,69	
7	A1com	DFN 22	C20/25	45	35,55	17,8	28,89 & 29,48	25,0	45xPo	0,45	2,95	2,54	0,82	1,00	0,68	T1-30: A1 T31-45: A1a
8	A1	DFN 25	C20/25	15	34,82	20,0	28,89	25,0	15xPo	0,94	3,54	3,07	1,16	1,00	0,69	
9	A1	DFN 30	C20/25	15	45,63	22,0	28,89	25,0	15xPo	4,55	3,63	2,80	0,48	1,00	0,57	
10	A1a	DFN 30	C20/25	15	32,23	23,2	28,89	25,0	11xPo 4xS	3,84	3,29	2,70	1,22	1,00	0,73	
11	A1	DFN 32	C20/25	15	50,76	22,0	28,89	25,0	15xPo	5,37	3,86	2,93	0,47	1,00	0,52	
12	A1	DFN 25 - 32	C20/25	45	43,82	21,3	28,89	25,0	45xPo	3,62	3,68	2,93	0,88	1,00	0,58	T1-15: DFN 25 T16-30: DFN 30 T31-45: DFN 32
13	A1	DFNH 17	C20/25	15	50,72	13,5	28,89	25,0	15xPo	0,18	1,40	1,10	0,22	1,00	0,52	
14	A1a	DFNH 17	C20/25	15	43,41	14,2	28,89	25,0	4xPo 11xS	0,26	1,15	0,89	0,27	1,00	0,59	
15	A1com	DFNH 17	C20/25	30	48,38	13,9	28,89	25,0	19xPo 11xS	0,22	1,27	0,96	0,28	1,00	0,54	T1-15:A1 T16-30: A1a
16	A1	DFNH 22	C20/25	15	31,59	18,0	28,89	25,0	15xPo	1,16	2,56	2,24	0,88	1,00	0,74	
17	A1a	DFNH 22	C20/25	15	38,73	18,4	28,89	25,0	12xPo 3xS	0,66	2,39	1,88	0,60	1,00	0,64	
18	A1com	DFNH 22	C20/25	30	34,68	18,2	28,89	25,0	27xPo 3xS	0,91	2,48	1,98	0,79	1,00	0,69	T1-15: A1 T16-30: A1a
19	A1	DFNH 27	C20/25	15	27,70	20,5	28,89	25,0	15xPo	3,57	3,39	3,04	1,53	1,00	0,81	
20	A2	DFNH 17	C50/60	15	41,73	13,5	60,89	60,0	15xPo	0,52	1,69	1,52	0,49	1,00	0,61	
21	A2	DFNH 22	C50/60	15	39,22	16,0	60,89	60,0	15xPo	1,54	2,68	2,40	0,70	1,00	0,63	
22	A2a	DFNH 22	C50/60	15	45,08	17,9	62,69	60,0	9xPo 6xS	1,27	3,04	2,55	0,62	1,00	0,57	
23	A2com	DFNH 22	C50/60	30	42,13	17,0	60,89 & 62,69	60,0	24xPo 6xS	1,40	2,86	2,46	0,77	1,00	0,60	T1-15: A2 T16-30: A2a
24	A2	DFNH 27	C50/60	15	38,19	18,0	60,89	60,0	15xPo	4,25	2,98	2,69	0,82	1,00	0,65	
25	A2a	DFNH 27	C50/60	15	37,99	18,5	62,69	60,0	6xPo 9xS	5,00	2,73	2,35	0,65	1,00	0,65	
26	A2com	DFNH 27	C50/60	30	37,99	18,3	60,89 & 62,69	60,0	21xPo 9xS	4,62	2,86	2,50	0,84	1,00	0,65	T1-15: A2 T16-30: A2a

Table 4.2 Basic Tension Tests in Masonry Units of Calcium Silicate KS 16 and Clay Mz 20 and Basic Tension Tests in Steel S235

Row	Test	Size	Base Material	n [-]	v [%]	h^t_{ef} [mm]	$f_{c,test}$ | $f_{u,test}$ [N/mm²]	f_{ck} | f_{uk} [N/mm²]	failure mode	δ_{Fum} [mm]	$F^t_{Ru,m}$ [kN]	Log. Normal Distribution $F_{Ru,m}$ [kN]	$F_{Rk,0}$ [kN]	α_1 [-]	α_v [-]	remarks
27	A1	DFN 22	KS	15	42,35	17,5	29,60	25,0	15xPo	0,22	1,22	0,92	0,27	1,00	0,60	
28	A1	DFN 25	KS	15	9,40	20,5	29,60	25,0	15xPo	0,39	2,09	1,75	1,41	1,00	1,00	
29	A1	DFN 30	KS	15	7,69	24,5	29,60	25,0	15xPo	1,37	2,70	2,27	1,90	1,00	1,00	
30	A1	DFN 32	KS	15	8,47	26,5	29,60	25,0	15xPo	1,32	3,28	2,76	2,27	1,00	1,00	
31	A1	DFN 35	KS	15	8,26	28,5	29,60	25,0	15xPo	2,60	3,59	3,02	2,49	1,00	1,00	
32	A1	DFN 40	KS	15	5,34	28,5	29,60	25,0	15xPo	4,10	4,03	3,40	3,00	1,00	1,00	
33	A1	DFN 35 + 40	KS	30	8,89	28,5	29,60	25,0	30xPo	3,35	3,81	3,21	2,65	1,00	1,00	T1-15: DFN 35 T16-30: DFN 40
34	A1	DFN 17	Mz	15	22,01	13,0	30,39	25,0	15xPo	0,36	0,85	0,68	0,39	1,00	0,94	
35	A1	DFN 20	Mz	15	21,91	14,5	30,39	25,0	15xPo	0,56	1,32	1,06	0,59	1,00	0,95	
36	A1	DFN 22	Mz	15	12,93	16,5	30,39	25,0	15xPo	0,62	1,69	1,38	1,01	1,00	1,00	
37	A1	DFN 25	Mz	15	25,47	19,5	30,39	25,0	15xPo	1,29	2,00	1,58	0,78	1,00	0,86	
38	A1	DFN 32	Mz	15	29,84	22,0	30,39	25,0	15xPo	4,34	2,16	1,69	0,75	1,00	0,77	
39	A1	DFN 25 + 32	Mz	30	27,73	20,8	30,39	25,0	30xPo	2,81	2,08	1,64	0,84	1,00	0,81	T1-15: DFN 25 T16-30: DFN 32
	A1	DFN 35	Mz	15	29,99	22,0	30,39	25,0	15xPo	7,79	2,03	1,58	0,64	1,00	0,77	
	A1	DFN 40	Mz	5	34,66	36,0	30,39	25,0	5xPo	10,04	2,09	1,62	0,42	1,00	0,69	
40	A1	DFNH 15	S235	15	12,70	8,0	526,90	500,0	7xPo 8xS	2,70	2,54	2,39	1,78	1,00	1,00	
41	A1	DFNH 17	S235	15	11,47	8,0	526,90	500,0	11xPo 4xS	3,94	3,06	2,88	2,20	1,00	1,00	
42	A1	DFNH 15 + 17	S235	30	15,14	8,0	526,90	360,0	18xPo 12xS	3,32	2,80	1,89	1,37	1,00	1,00	T1-15: DFNH 15 T16-30: DFNH 17

Table 4.3 Basic Shear Tests in Concrete C20/25 and C50/60

Row	Test	Size	Base Material	n [-]	v [%]	h^t_{ef} [mm]	$f_{c,test}$ | $f_{u,test}$ [N/mm²]	f_{ck} | f_{uk} [N/mm²]	failure mode	δ_{Fum} [mm]	$F^t_{Ru,m}$ [kN]	Log. Normal Distribution $F_{Ru,m}$ [kN]	Log. Normal Distribution $F_{Rk,0}$ [kN]	Log. Normal Distribution α_1 [-]	Log. Normal Distribution α_v [-]	remarks
43	A5	DFN 22	C20/25	15	19,43	16,8	29,48	25,0	15xPo	2,44	4,02	3,64	2,32	1,00	1,00	
44	A5	DFN 25	C20/25	15	29,98	18,1	29,48	25,0	15xS	3,52	3,07	2,95	1,48	1,00	0,77	
45	A5	DFN 30	C20/25	15	23,45	18,9	29,48	25,0	11xPo 15xPt 4xS	6,78	4,62	3,81	2,15	1,00	0,91	
46	A5	DFNH 22	C20/25	15	17,29	16,4	29,48	25,0	15xPo	1,79	5,00	4,54	3,05	1,00	1,00	
47	A5	DFNH 27	C20/25	15	41,94	18,5	29,48	25,0	9xPo 6xS	3,81	3,07	2,43	1,04	1,00	0,60	
48	A6	DFNH 22	C50/60	15	24,56	16,2	62,96	60,0	13xPo 2xS	2,94	4,35	4,03	2,31	1,00	0,88	
49	A6	DFNH 27	C50/60	15	14,45	18,7	62,96	60,0	6xPo 9xS	4,11	3,59	3,40	2,50	1,00	1,00	

Table 4.4 Statistical Analysis of Significance

Row	Test Series 1			Test Series 2			Level α [%]	n_1 [-]	n_2 [-]	Normalised Values s_1 [kN]	s_2 [kN]	$F_{Ru,m,1}$ [kN]	$F_{Ru,m,2}$ [kN]	t_{test} [-]	$t(\alpha,m)$ [-]	$t_{test}/t(\alpha,m)$ [-]	Failure Modes Test 1	Test 2
1	A1	DFN 17	C20/25	A1	DFN 20	C20/25	5	15	30	0,66	0,76	1,40	2,15	3,05	1,68	>1	15xPo	30xPo
2	A1	DFN 20	C20/25	A1	DFN 22	C20/25	5	30	30	0,76	1,01	2,15	2,84	2,75	1,67	>1	30xPo	30xPo
3	A1	DFN 22	C20/25	A1	DFN 25	C20/25	5	30	15	1,01	1,15	2,84	3,29	1,26	1,68	0,75	30xPo	15xPo
4	A1	DFN 25	C20/25	A1	DFN 30	C20/25	5	15	15	1,15	1,54	3,29	3,37	0,15	1,70	0,09	15xPo	15xPo
5	A1	DFN 25	C20/25	A1	DFN 32	C20/25	5	15	15	1,15	1,82	3,29	3,59	0,49	1,70	0,29	15xPo	15xPo
6	A1	DFN 30	C20/25	A1	DFN 32	C20/25	5	15	15	1,54	1,82	3,37	3,59	0,32	1,70	0,19	15xPo	15xPo
7	A1	DFN 17	C20/25	A1a	DFN 17	C20/25	5	15	15	0,66	0,60	1,40	1,57	0,71	1,70	0,42	15xPo	15xPo
8	A1	DFN 22	C20/25	A1a	DFN 22	C20/25	5	30	15	1,01	0,88	2,84	2,52	0,95	1,68	0,57	30xPo	15xPo
9	A1com	DFN 22	C20/25	A1	DFN 25 - 32	C20/25	5	45	45	1,01	1,33	2,73	3,42	2,55	1,67	>1	45xPo	45xPo
10	A1	DFNH 17	C20/25	A1a	DFNH 17	C20/25	5	15	15	0,66	0,43	1,30	0,99	1,38	1,70	0,81	15xPo	4xPo 11xS
11	A1	DFNH 22	C20/25	A1a	DFNH 22	C20/25	5	15	15	0,75	0,80	2,38	2,07	0,98	1,70	0,58	15xPo	12xPo 3xS
12	A2	DFNH 17	C50/60	A2	DFNH 22	C50/60	5	15	15	0,70	1,04	1,68	2,66	3,00	1,70	>1	15xPo	15xPo
13	A2	DFNH 22	C50/60	A2	DFNH 27	C50/60	5	15	15	1,04	1,13	2,66	2,96	0,75	1,70	0,44	15xPo	15xPo
14	A2	DFNH 22	C50/60	A2a	DFNH 22	C50/60	5	15	15	1,04	1,31	2,66	2,91	0,56	1,70	0,33	15xPo	9xPo 6xS
15	A2	DFNH 27	C50/60	A2a	DFNH 27	C50/60	5	15	15	1,13	0,99	2,96	2,61	0,88	1,70	0,52	15xPo	6xPo 9xS
16	A1	DFN 22	KS	A1	DFN 25	KS	5	15	15	0,44	0,17	1,03	1,76	5,14	1,70	>1	15xPo	15xPo
17	A1	DFN 25	KS	A1	DFN 30	KS	5	15	15	0,17	0,18	1,76	2,28	7,03	1,70	>1	15xPo	15xPo
18	A1	DFN 30	KS	A1	DFN 32	KS	5	15	15	0,18	0,23	2,28	2,77	5,47	1,70	>1	15xPo	15xPo
19	A1	DFN 32	KS	A1	DFN 35	KS	5	15	15	0,23	0,25	2,77	3,03	2,51	1,70	>1	15xPo	15xPo
20	A1	DFN 35	KS	A1	DFN 40	KS	5	15	15	0,25	0,18	3,03	3,40	3,92	1,70	>1	15xPo	15xPo
21	A1	DFN 17	Mz	A1	DFN 20	Mz	5	15	15	0,15	0,24	0,70	1,09	4,40	1,70	>1	15xPo	15xPo
22	A1	DFN 20	Mz	A1	DFN 22	Mz	5	15	15	0,24	0,18	1,09	1,39	3,24	1,70	>1	15xPo	15xPo
23	A1	DFN 22	Mz	A1	DFN 25	Mz	5	15	15	0,18	0,42	1,39	1,65	1,78	1,70	>1	15xPo	15xPo
24	A1	DFN 25	Mz	A1	DFN 32	Mz	5	15	15	0,42	0,53	1,65	1,78	0,63	1,70	0,37	15xPo	15xPo
25	A1	DFNH 15	S235	A1	DFNH 17	S235	5	15	15	0,31	0,33	2,41	2,90	4,02	1,70	>1	7xPo 8xS	11xPo 4xS
26	A5	DFN 22	C20/25	A5	DFN 25	C20/25	5	15	15	0,72	0,92	3,70	3,07	2,03	1,70	>1	15xPo	15xS
27	A5	DFN 25	C20/25	A5	DFN 30	C20/25	5	15	15	0,92	0,92	3,07	3,91	2,30	1,70	>1	15xS	11xPo 15xPt 4xS
28	A5	DFNH 22	C20/25	A5	DFNH 27	C20/25	5	15	15	0,80	1,09	4,60	2,60	4,99	1,70	>1	15xPo	9xPo 6xS
29	A6	DFNH 22	C50/60	A6	DFNH 27	C50/60	5	15	15	1,02	0,50	4,14	3,43	2,35	1,70	>1	13xPo 2xS	6xPo 9xS

4.5 Summary of the Basic Tension and Shear Tests

Summaries of all results of the basic tension and shear tests are shown in Table 4.1 to Table 4.3 for the fastener fischer DFN/DFNH.

4.5.1 Tension in Uncracked Concrete

For all test series a mixed failure of nail pull-out and steel / nail failure occurs. The load-displacement curves nearly show a continuous increase. Therefore, the corresponding reduction factor results to $\alpha_1 = 1.00$.

The coefficient of variation for all the tension test series is v > 20 % and therefore the requirements on the scatter of the ultimate load are not fulfilled and the corresponding reduction factors α_v according to Table 4.1, row 1-26 have to be regarded.

The statistical analysis in Table 4.4 of the test series in lower strength concrete C20/25 with the nail DFN “A1/DFN25” to “A1/DFN32” (see row 4 to 6), “A1/DFN17” and “A1a/DFN17” (row 7) as well as “A1/DFN22” and “A1a/DFN22” (row 8) shows that the results were taken from the same sample and are evaluated together in Table 4.1 (row 3, 7 and 12).

For the nail DFNH the statistical analysis in Table 4.4 of the test series in lower strength concrete “A1/DFNH17” and “A1a/DFNH17” (row 10) as well as “A1/DFN22” and “A1a/DFN22” (row 11) shows that the results were taken from the same sample and are evaluated together in Table 4.1 (row 15 and 18).

In higher strength cracked concrete C50/60 the test series in Table 4.4 “A2/DFNH22” and “A2a/DFNH22” (row 14) as well as “A2/DFNH27” and “A2a/DFNH27” (row 15) shows that the results were taken from the same sample and are evaluated together in Table 4.1 (row 23 and 26).

4.5.2 Tension in Masonry Units of Calcium Silicate and Clay

For all test series nail pull-out failure occurs. The load-displacement curves show a continuous increase. Therefore, the corresponding reduction factor results to $\alpha_1 = 1.00$.

The coefficient of variation for the test series in calcium silicate masonry units “A1/DFN25” to “A1/DFN40” in Table 4.2 is v < 20 % and therefore the requirements on the scatter of the ultimate load are fulfilled and the reduction factor $\alpha_v = 1.00$ has to be regarded. For the test series “A1/DFN22” is v > 20 % and therefore the requirements on the scatter of the ultimate load are not fulfilled and the corresponding reduction factor $\alpha_v = 0.60$ has to be taken into account.

The statistical analysis in Table 4.4 of the test series in masonry units made of calcium silicate “A1/DFN35” and “A1/DFN40” (row 20) shows that the results were taken from the same sample and are evaluated together in Table 4.2 (row 33).

For masonry units made of clay the coefficient of variation for the test series “A1/DFN22” in Table 4.2 is v < 20 % and therefore the requirements on the scatter of the ultimate load are fulfilled and the reduction factor $\alpha_v = 1.00$ has to be regarded. For all other test series in masonry made of clay is v > 20 % and therefore the requirements on the scatter of the ultimate load are not fulfilled and the corresponding reduction factor α_v according to Table 4.2, row 34-35 and row 37-39 have to be taken into account.

The statistical analysis in Table 4.4 of the test series in masonry units made of clay “A1/DFN25” and “A1/DFN32” (row 24) shows that the results were taken from the same sample and are evaluated together in Table 4.2 (row 39).

4.5.3 Tension in Steel

For all test series a mixed failure of nail pull-out and nail steel failure occurs. The load-displacement curves show a continuous increase. Therefore, the corresponding reduction factor results to α_1 = 1.00.

The coefficient of variation for all test series in steel in Table 4.2 is v < 20 % and therefore the requirements on the scatter of the ultimate load are fulfilled and the reduction factor α_v = 1.00 has to be regarded.

The statistical analysis in Table 4.4 of the test series “A1/DFNH15” and “A1/DFNH17” (row 25) shows that the results were taken from the same sample and are evaluated together in Table 4.2 (row 42).

4.5.4 Shear in Uncracked Concrete

For the test series “A5/DFN25” and “A5/DFNH22” only pull-out failure and all other test series a mixed failure of nail pull-out and steel failure occurs. The load-displacement curves show a continuous increase. Therefore, the corresponding reduction factor results to α_1 = 1.00.

The coefficient of variation for the test series in lower strength concrete C20/25 “A5/DFN22” and “A5/DFNH22” and the test series in higher strength concrete C50/60 “A6/DFNH27” in Table 4.3 is v < 20 % and therefore the requirements on the scatter of the ultimate load are fulfilled and the reduction factor α_v = 1.00 has to be regarded. For the other test series in concrete the coefficient of variation is v > 20 % and therefore the requirements on the scatter of the ultimate load are not fulfilled and the corresponding reduction factor α_v according to Table 4.3, row 44-45 and row 47-48 have to be taken into account..

5 Evaluation of the Test Results

5.1 Partial Safety Factors

According to [1] the material factors given in EN 1992-4 [10] and TR 054 [11] apply for the relevant failure mode and failed part of the fastening. For the calculation of the design resistance of a single fastener fischer DFN/DFNH the partial safety factor for fastener resistance γ_{Ms} or γ_{Mc} can be taken.

5.1.1 Steel Failure

For tensile loading: $\gamma_{Ms} = \frac{1,2}{f_{yk}/f_{uk}} \geq 1,4$ (5-1)

For shear loading: $\gamma_{Ms} = 1,5\ with\ f_{uk} > 800N/mm^2$ (5-2)

5.1.2 Failure of the Nail in each Anchor Base Material

Concrete: $\gamma_{Mc} = 1,8$ (5-3)

Masonry units made of clay: $\gamma_{Mc} = 2,5$ (5-4)

Masonry units made of calcium silicate: $\gamma_{Mc} = 2,0$ (5-5)

According to [11] the partial safety factor for masonry made of autoclaved aerated concrete is $\gamma_{Mc} = 2,0$. The bearing capacity of fasteners in calcium silicate masonry resembles that in higher strength autoclaved aerated concrete. Therefore this partial safety factor has been taken for the evaluation.

5.2 Recommendation for the Intended Use

For the calculation of the admissible load of a single fastener Hilti X-P B3 the partial safety factor for fastener resistance γ_M = 1,5 and for acting load γ_F = 1,4 can be taken.

$$F_I \leq \frac{F_{Rk}}{\gamma_M \cdot \gamma_F} \quad (5\text{-}6)$$

$$with\ F_{Rk} = F_{Rk,0} \cdot \alpha_1 \cdot \alpha_v$$

A summary of the assembled admissible loads for the fischer fasteners DFN and DFNH is given in the following Table 5.1.

Table 5.1 Admissible Loads for the Fastener fischer DFN/DFNH

Row	Test	Size	Base Material	$F_{Rk,0}$ [kN]	α_1 [-]	α_v [-]	γ_M [-]	γ_F [-]	**F_l [kN]**
1	A1com	DFN 17	C20/25	0,43	1,00	0,60	1,80	1,40	**0,10**
2	A1	DFN 20	C20/25	0,68	1,00	0,69	1,80	1,40	**0,18**
3	A1com	DFN 22	C20/25	0,82	1,00	0,68	1,80	1,40	**0,22**
4	A1	DFN 25 - 32	C20/25	0,88	1,00	0,58	1,80	1,40	**0,20**
5	A1com	DFNH 17	C20/25	0,28	1,00	0,54	1,80	1,40	**0,06**
6	A1com	DFNH 22	C20/25	0,79	1,00	0,69	1,80	1,40	**0,22**
7	A1	DFNH 27	C20/25	1,53	1,00	0,81	1,80	1,40	**0,49**
8	A2	DFNH 17	C50/60	0,49	1,00	0,61	1,80	1,40	**0,12**
9	A2com	DFNH 22	C50/60	0,77	1,00	0,60	1,80	1,40	**0,18**
10	A2com	DFNH 27	C50/60	0,84	1,00	0,65	1,80	1,40	**0,22**
11	A1	DFN 22	KS	0,27	1,00	0,60	2,00	1,40	**0,06**
12	A1	DFN 25	KS	1,41	1,00	1,00	2,00	1,40	**0,50**
13	A1	DFN 30	KS	1,90	1,00	1,00	2,00	1,40	**0,68**
14	A1	DFN 32	KS	2,27	1,00	1,00	2,00	1,40	**0,81**
15	A1	DFN 35 + 40	KS	2,65	1,00	1,00	2,00	1,40	**0,95**
16	A1	DFN 17	Mz	0,39	1,00	0,94	2,50	1,40	**0,11**
17	A1	DFN 20	Mz	0,59	1,00	0,95	2,50	1,40	**0,16**
18	A1	DFN 22	Mz	1,01	1,00	1,00	2,50	1,40	**0,29**
19	A1	DFN 25 + 32	Mz	0,84	1,00	0,81	2,50	1,40	**0,19**
20	A1	DFNH 15 + 17	S235	1,37	1,00	1,00	1,50	1,40	**0,65**
21	A5	DFN 22	C20/25	2,32	1,00	1,00	1,50	1,40	**1,10**
22	A5	DFN 25	C20/25	1,48	1,00	0,77	1,50	1,40	**0,54**
23	A5	DFN 30	C20/25	2,15	1,00	0,91	1,50	1,40	**0,93**
24	A5	DFNH 22	C20/25	3,05	1,00	1,00	1,50	1,40	**1,45**
25	A5	DFNH 27	C20/25	1,04	1,00	0,60	1,50	1,40	**0,30**
26	A6	DFNH 22	C50/60	2,31	1,00	0,88	1,50	1,40	**0,97**
27	A6	DFNH 27	C50/60	2,50	1,00	1,00	1,50	1,40	**1,19**

Dortmund, 16th March 2023

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