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Technical Report

Assessment of the essential characteristic

for fischer FAZ II anchors

in concrete strength class C12/15 and C80/95

Client: fischerwerke GmbH & Co. KG
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1 INTRODUCTION

The FAZ II anchor bolt is made of galvanised (gvz) and stainless steel (A4/C) to be used in cracked and non-cracked concrete of the strength classes C20/25 to C50/60. The working principle is a torque-controlled expanding anchor.

According to EN 1992-4 the range of application is valid for fasteners installed in members made of compacted normal weight concrete without fibers with strength classes between C12/15 and C90/105 all in accordance with EN 206. However, in the design of fastenings the concrete strength, f_{ck}, used for calculation shall not exceed 60 N/mm², even if the structure uses a higher strength class. The range of concrete strength classes in which particular fasteners may be used is given in the relevant European Technical Product Specification and may be more restrictive than stated above. For the expansion anchors FAZ II the restriction given in the ETA is C20/25 to C50/60.

The company fischerwerke GmbH Co. KG wants to enlarge the admissible service conditions regarding the concrete strength to low strength concrete C12/15 and high strength concrete C80/95. For the expansion anchors FAZ II the restriction in the ETA applied for is C12/15 to C80/95.

The geometry and material specification of the anchor can be taken from the assessment [G8] because the existing approved anchor taken from the stock is used for the tests in C12/15 and C80/95.

To extend the range of application to the concrete strength classes C12/15 and C80/95 internal tests under supervision were performed. The behaviour of the anchors in C12/15 and C80/95 is compared in this evaluation report to show that the behaviour is equivalent to the behaviour in C20/25 to C50/60.

The tests program was developed to determine the performance in C12/15 (test series A1 and A3) and in C80/95 (test series F1). To investigate the functional behaviour, additional suitability tests were performed in C12/15 (F3 test series) and in C80/95 (F4 test series). The test program is given in section 4.

2 LITERATURE

2.1 Test Reports

[R1] Prüfbericht-Nr.: S35-2016, FAZ II Funktion und Leistung in Beton C12/15 und C80/95, Entwicklung Stahl Tumlingen, fischerwerke GmbH & Co. KG, 12.09.2016

[R2] Evaluation report for fischer group of companies Anchor bolt FAZ II M20, M24 ETAG 001 Part 2 "Torque Controlled Anchors", University of Natural Resources and Applied Life Sciences, Vienna Department of Structural Engineering and Natural Hazards Institute of Structural Engineering Accredited Testing Laboratory, März 2006.

[R3] Evaluation Report for the assessment of fischer Ankerbolzen FAZ II A4/C, Kraftkontrolliert spreizender Dübel aus galvanisch verzinktem und nichtrostendem Stahl in den Größen M8, M10, M12, M16, M20 und M24 zur Verankerung im Beton, Deutsches Institut für Bautechnik, 30 June 2008

[R4] Beurteilungsbericht für Unternehmensgruppe fischer Ankerbolzen FAZ II M8 – M16 zur Verankerung im gerissenen und ungerissenen Beton, University of Natural Resources and Applied Life Sciences, Vienna Department of Structural Engineering and Natural Hazards Institute of Structural Engineering Accredited Testing Laboratory, Februar 2005.

2.2 General Literature

[G1] European Organisation for Technical Approvals (EOTA): ETAG 001: - Guideline for European Technical Approval of Metal Anchors for Use in Concrete. Part 2: Torque-Controlled Expansion Anchors, 1st Amended November 2006, 2nd Amended October 2012.

[G2] ESR 29-48 fischer FAZ II, FAZ II A4 and FAZ II C metric wedge anchor for anchoring in cracked and non-cracked concrete, ICC Evaluation Services.

[G3] ETAG 001 Guidline For European Technical Approval of Metal Anchors for Use In Concrete, Annex: A Details of Tests, Brussels, April 2013

[G4] Owen, D.: Handbook of Statistical Tables, Addison/Wesley Publishing Company Inc., 1962.

[G5] Nichtrostende Stähle - Teil 1 bis Teil 5: Teil 1: Verzeichnis der nichtrostenden Stähle; Deutsche Fassung EN 10088-1:2014

[G6] DIN EN ISO 898-1 - Mechanische Eigenschaften von Verbindungselementen aus Kohlenstoffstahl und legiertem Stahl.

[G7] European Organisation for Standardisation: CEN/TC 250, FprEN 1992-4 Eurocde 2: Design of concrete structrues, Part 4 Design of fastenings for use in concrete, 24.04.2015.

[G8] European Technical Assessment, ETA-05/0069, fischer Bolzenanker FAZ II-Kraftkontrolliert spreizender Dübel in den Größen M8, M10, M12, M16, M20 und M24 zur Verankerung im Beton vom 5. August 2016, Deutsches Institut für Bautechnik, Berlin.

[G9] EN 206-1:2000, Festlegung, Eigenschaften, Herstellung und Konformität; Deutsche Fassung EN 206-1:2000/A1:2004, Deutsches Institut für Normung, Berlin.

[G10] DIN EN ISO 3506-1:2010-04, Mechanische Eigenschaften von Verbindungs-elementen aus nichtrostenden Stählen - Teil 1: Schrauben (ISO 3506-1:2009), Deutsches Institut für Normung, Berlin.

[G11] DIN EN ISO 4042:2001-01, Verbindungselemente - Galvanische Überzüge (ISO 4042:1999); Deutsche Fassung EN ISO 4042:1999, Deutsches Institut für Normung, Berlin.

[G12] FprEN 19924 Eurocode 2 Design of concrete structures - Part 4 Design of fastenings for use in concrete.

3 DESCRIPTION OF THE PRODUCT

3.1 Functioning of the anchor

The anchors consist of a conical bolt with external thread, a single-layer expansion sleeve, a washer and a hexagonal nut as shown in Figrue 3-2. Detailed drawings of the anchors are to be found in the third party inspections drawings or in [G8]. The anchor bolt and the expansion sleeve of the FAZ II are made of galvanised steel, stainless steel or high corrosion resistance steel.

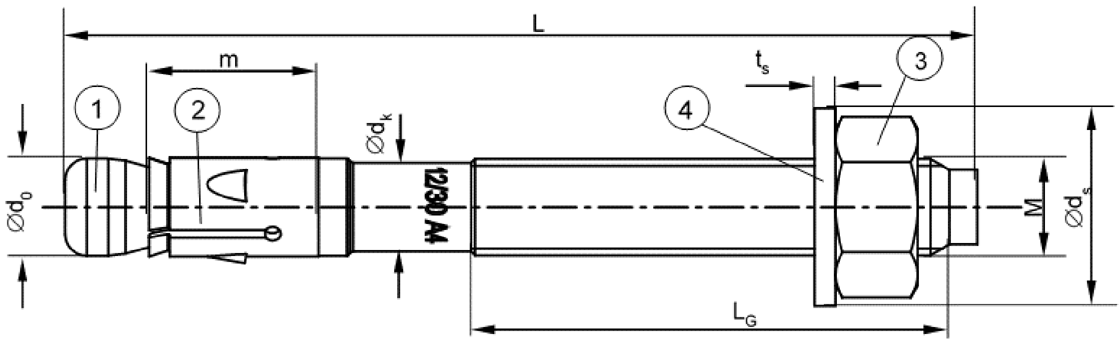

Figure 3-1: Drawing and dimensions of an FAZ II anchor.

The conical bolts of all sizes are provided with a special slip coating. This coating ensures the post expansion of the anchor during its product lifetime and reduces the friction forces while installation. The letter-code of the marking (frontal area of the cone bolt) and maximum thickness of fixture t_{fix} is given in the ETA. The version with a reduced embedment depth can be identified by the lower case letters used for $h_{ef, red}$ instead of capital letters used for the standard embedment depth.

Teil	Bezeichnung			FAZ II, FAZ II A4, FAZ II C					
				M8	**M10**	**M12**	**M16**	**M20**	**M24**
1	Konusbolzen	Gewindegröße M		M8	M10	M12	M16	M20	M24
		$\varnothing$ d_0		7,8	9,8	11,8	15,7	19,8	23,5
		$\varnothing$ d_k		7,1	8,9	10,7	14,5	18,2	21,8
		L_G	≥	19	26	31	40	50	57
2	Spreizclip	m		17,8	20,0	20,6	27,5	33,4	40,2
		Blechdicke		1,3	1,4	1,6	2,4	2,4	3,0
3	Sechskantmutter	Schlüsselweite		13	17	19	24	30	36
4	Unterlegscheibe	t_S	≥	1,4	1,8	2,3	2,7	2,7	3,7
		$\varnothing$ d_S	≥	15	19	23	29	36	43
Dicke des Anbauteils		t_{fix}	≥	0	0	0	0	0	0
			≤	200	250	300	400	500	600
Dübellänge		L_{min}	=	54,5	64,5	79	102	141	174
		L_{max}	=	267	336	401	525	644	777

Table 3-1: Summary of the installation parameters, see [G2].

The hexagonal nuts of the sizes M8 and M10 are also coated with a special functional coting. Aim of this coating is to reduce friction in the thread and between nut and washer and to guarantee uniform friction conditions. Thus, the coating is needed only during the installation of the anchors. Explanations concerning the construction of the anchors, leading dimensions and installation parameters are given in the Table 3-2. Further details are given in [G1, R2]. All carbon steel parts have a minimum 5µm (0.0002 inch) zinc plating according to DIN EN ISO 4042 [G11]. The material of the stainless steels anchors is given in [G5, G5, G10].

3.2 Installation of the product

Installation parameters are provided in [G8] and are summarised in this section. The FAZ II anchors must be installed according to the manufacturer's published instructions and this report. Anchors must be installed in holes drilled into the concrete using carbide tipped masonry drill bits complying with the requirements of Table 3-2. The minimum drilled hole depth, embedment, spacing and edge distances, and member thickness are given in [G8].

The predrilled hole must be cleaned free of dust and debris using a hand pump, compressed air or a vacuum. The anchor must be hammered into the predrilled hole until the proper nominal embedment depth is achieved. The nut must be tightened against the washer until the torque values T_{inst} specified in Table 3-2 are reached. The installation does not change and therefore the current installation instruction can be applied for the reduced embedment depths.

Anchor type / size		**FAZ II, FAZ II A4, FAZ II C**					
		M8	**M10**	**M12**	**M16**	**M20**	**M24**
Nominal diameter	d_0 = [mm]	8	10	12	16	20	24
Diameter of the drill	d_{cut} ≤ [mm]	8,45	10,45	12,5	16,5	20,55	24,55
Embedment depth (Standard)	$h_{ef,sta}$ ≥ [mm]	45	60	70	85	100	125
Depth of the bore hole $h_{ef,sta}$	$h_{1,sta}$ ≥ [mm]	55	75	90	110	125	155
Embedment depth (Reduced)	$h_{ef,red}$ ≥ [mm]	35	40	50	65	-	-
Depth of the bore hole $h_{ef,red}$	$h_{1,red}$ ≥ [mm]	45	55	70	90	-	-
Diameter of the hole in the fixture	d_f ≤ [mm]	9	12	14	18	22	26
Installation torque moment	T_{inst} = [Nm]	20	45	60	110	200	270

Table 3-2: Installation information and installation parameters.

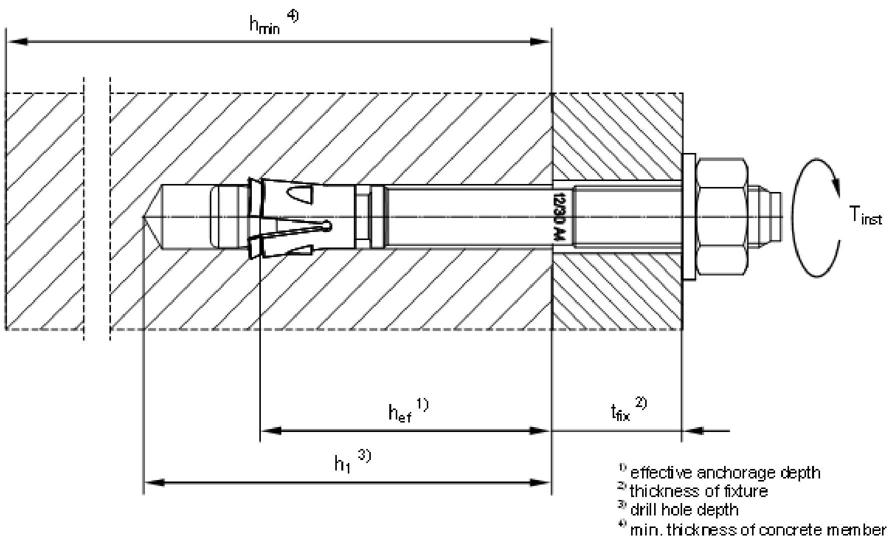

Figure 3-2: Drawing of an installed FAZ II anchor, definition of h_{ef}, h_{min}, t_{fix} and bore hole depth h_1.

The installation according to the MPII can be described in four different steps:

Step 1: Drill the hole by using the correct metric drill bit diameter, drill the hole to the minimum required hole depth.

Step 2: Remove drilling debris with a blowout bulb or with compressed air or drill with the vacuum driller.

Step 3: Use a hammer, tap the anchor through the part being fastened into the drilled hole until the washer is in contact with the fastened part.

Step 4: Use a torque wrench to apply the specified installation torque moments.

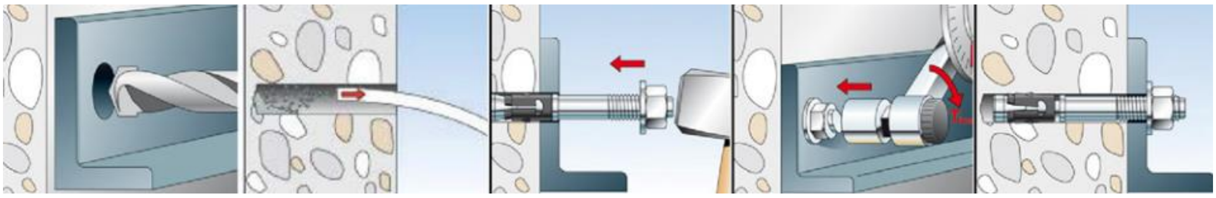

Figure 3-3: Installation procedure for the FAZ II anchor.

3.3 Applied admissible service conditions

The fischer FAZ II expansion anchor is designed to resist static loads, quasi-static loads (e.g. from wind) as well as tension and shear loads caused by fire or earth-quakes. The anchor can be used in cracked and non-cracked concrete having a specified compressive strength ($f_{c,cylinder}$) of 20 MPa to 50 MPa (strength classes C20/25 to C50/60). The company fischerwerke GmbH & Co. KG wants to enlarge the range of application in cracked and non-cracked concrete to a specified compressive strength ($f_{c,cylinder}$) of 12 MPa to 80 MPa. Therefore, additional tests are performed to enlarge the range of admissible service conditions (see section 4). The tests shall be performed in test specimens with a concrete strength that corresponds to the following strength classes:

- C12/15: f_{cm} = 15 - 25 N/mm² (cube 150x150x150)
- C20/25: f_{cm} = 25 - 35 N/mm² (cube 150x150x150)
- C50/60: f_{cm} = 60 - 70 N/mm² (cube 150x150x150)
- C80/95: f_{cm} = 95 - 105 N/mm² (cube 150x150x150)
-

The admissible service conditions are given in the following table:

<table>
<tr><td colspan="2">Embedment depth (Standard)</td><td colspan="6">✓</td></tr>
<tr><td colspan="2">FAZ II, FAZ II A4, FAZ II C</td><td>M8</td><td>M10</td><td>M12</td><td>M16</td><td>M20</td><td>M24</td></tr>
<tr><td colspan="2">Static and quasi static loading</td><td colspan="6">✓</td></tr>
<tr><td colspan="2">Cracked and non-cracked concrete</td><td colspan="6">✓</td></tr>
<tr><td colspan="2">Fire exposure</td><td colspan="6">✓</td></tr>
<tr><td rowspan="2">Seismic loading category</td><td>C1</td><td colspan="6">✓</td></tr>
<tr><td>C2[1)]</td><td>-</td><td colspan="4">✓</td><td>-</td></tr>
<tr><td colspan="2">Embedment depth (reduced)</td><td colspan="4">✓</td><td colspan="2" rowspan="7">-</td></tr>
<tr><td colspan="2">Bolzenanker FAZ II, FAZ II A4, FAZ II C</td><td>M8[2)]</td><td>M10</td><td>M12</td><td>M16</td></tr>
<tr><td colspan="2">Static and quasi static loading</td><td colspan="4">✓</td></tr>
<tr><td colspan="2">Cracked and non-cracked concrete</td><td colspan="4">✓</td></tr>
<tr><td colspan="2">Fire exposure</td><td colspan="4">✓</td></tr>
<tr><td rowspan="2">Seismic loading category</td><td>C1</td><td>-</td><td colspan="3">✓</td></tr>
<tr><td>C2[1)]</td><td>-</td><td colspan="3">✓</td></tr>
</table>

[1)] FAZ II C: only valid for the cold formed version
[2)] The application is limited to static not determined systems

Table 3-3: Summary of the admissible service conditions

Base material for anchorage:

- Reinforced or non-reinforced concrete (cracked or non-cracked) according to EN 206-1:2000

- Concrete strength class C12/15 to C80/95 according to EN 206-1:2000

Admissible service conditions (environmental exposure):

- Dry internal conditions (FAZ II, FAZ II A4, FAZ II C)
- Exposure and humid and wet conditions (including industry atmosphere or sea climate) or humid rooms, if no special aggressive environmental conditions are present (FAZ II A4, FAZ II C)
- Exposure und humid and wet conditions if special aggressive environmental conditions are present (FAZ II C). Aggressive environmental conditions are present in cyclic wet and dry sea water, areas with high chloride content like swimming halls or atmosphere with chemical pollution

4 SUMMARY

The company fischerwerke GmbH Co. KG wants to enlarge the admissible service conditions regarding the concrete strength to low strength concrete C12/15 and high strength concrete C80/95. The geometry and material specifications of the anchor are not changed.

To extend the range of application to concrete strength class C12/15 and C80/95 internal tests under supervision were performed. All tests normally performed in C20/25 were performed in C12/15 except of test series A14, A20, F5 and F6. All tests normally performed in C50/60 were performed in C80/95 except of test series A2, A4 and F8. The detailed test program is given in section 4. The results of the performed tests in C12/15 and C80/95 are evaluated and summarised in this report in section 5 to section 7.

The results show that the anchors are suitable for C12/15 and C80/95. The results of the suitability tests indicate that the reductions due to different influences (increased crack width) in C12/15 and C20/25 are equivalent. This is valid also for the influences tested in C80/95 (installation safety and increased crack width). The behaviour of the anchor in concrete C80/95 is comparable to the behaviour in concrete C50/60.

The admissible service condition tests show that the pull-out capacity in C12/15 is reduced compared to C20/25. Furthermore for the omitted test series the reduced tensile strength of a concrete C12/15 is considered by increased splitting distance ($c_{Cr,sp}$) and larger minimum spacing's and edge distances. In addition, the theoretical N_p loads are reduced and considered as a new upper limit for the characteristic resistance. For concrete C80/95 the characteristic resistance is limited to the characteristic resistance of the anchor in C50/60. A summary of the evaluated values is given in the annex.

Prof. Dr.-Ing. Jan Hofmann

Minimum member thickness, min. spacing, min. edge distance for anchors with **standard embedment depth ($h_{ef,\ sta}$)**

	Anchor / size		FAZ II, FAZ II A4, FAZ II C					
			M8	**M10**	**M12**	**M16**	**M20**	**M24**
Embedment depth		$h_{ef,sta} \geq$ [mm]	**45**	**60**	**70**	**85**	**100**	**125**
Thickness of the concrete member $\geq 2 \times h_{ef,sta}$	**Minimum member thickness**	$h_{min,\ 1}$ [mm]	**100**	**120**	**140**	**170**	**200**	**250**
	cracked concrete							
	Min. spacing	s_{min} [mm]	40	40	50	65	95	100
		for c ≥ [mm]	50	60	70	95	180	200
	Min. edge distance	c_{min} [mm]	40	45	55	65	95	135
		for s ≥ [mm]	100	80	110	150	190	235
	Non-cracked concrete							
	Min. spacing	s_{min} [mm]	35	40	50	65	95	100
		for c ≥ [mm]	50	55	70	95	140	170
	Min. edge distance	c_{min} [mm]	40	45	55	65	85	100
		for s ≥ [mm]	70	80	110	150	190	220
Thickness of the concrete member $< 2 \times h_{ef,sta}$	**Minimum member thickness**	$h_{min,\ 2}$ [mm]	**80**	**100**	**120**	**140**	**160**	**200**
	Cracked and non-cracked concrete							
	Min. spacing	s_{min} [mm]	35	40	50	80	125	150
		for c ≥ [mm]	70	100	90	130	220	230
	Min. edge distance	c_{min} [mm]	40	60	60	65	125	135
		for s ≥ [mm]	100	90	120	180	230	235

Intermediate values are allowed to interpolated for s_{min} and c_{min} but only within the same member thickness

Minimum member thickness, min. spacing, min. edge distance for anchors with **reduced embedment depth ($h_{ef,\ sta}$)**

	Anchor / size		FAZ II, FAZ II A4, FAZ II C			
			M8	**M10**	**M12**	**M16**
Embedment depth		$h_{ef,red} \geq$ [mm]	**35**[1)]	**40**	**50**	**65**
Thickness of the concrete member $\geq 2 \times h_{ef,sta}$	**Minimum member thickness**	$h_{min,\ 3}$ [mm]	**80**	**80**	**100**	**140**
	Non-cracked concrete					
	Min. spacing	s_{min} [mm]	40	40	50	65
		for c ≥ [mm]	100	100	110	130
	Min. edge distance	c_{min} [mm]	45	45	55	65
		for s ≥ [mm]	180	180	220	250
	cracked concrete					
	Min. spacing	s_{min} [mm]	40	40	50	65
		for c ≥ [mm]	90	90	110	130
	Min. edge distance	c_{min} [mm]	45	45	55	65
		for s ≥ [mm]	180	180	220	250

Intermediate values are allowed to interpolated for s_{min} and c_{min} but only within the same member thickness

1) The application is limited to nonstructural systems

Characteristic resistances for tension and **standard embedment depth** for static and quasi-static loading (design method A, according to ETAG 001, Annex C or CEN/TS 1992-4:2009) **for concrete strength classes larger than C12/15**

Type / Size				**FAZ II, FAZ II A4, FAZ II C**					
				M8	**M10**	**M12**	**M16**	**M20**	**M24**
Steel failure for standard embedment depth									
Characteristic resistance	FAZ II	$N_{Rk,s}$	[kN]	16,0	27,0	41,5	66,0	111,0	150,0
	FAZ II A4/C	$N_{Rk,s}$	[kN]	17,0	27,2	44,3	70,6	111,0	160,8
Partial safety factor		γ_{Ms}		1,5					
Pull out for standard embedment depth									
Effective anchorage depth		$h_{ef,sta} \geq$	[mm]	45	60	70	85	100	125
Characteristic resistance in cracked concrete C12/15		$N_{Rk,p}$	[kN]	5	7,5	13,0	18,0	23,0	32,5
Characteristic resistance in uncracked concrete C12/15		$N_{Rk,p}$	[kN]	10,5	11,0	14,5	28,0	26,5	-
Increasing factors for $N_{Rk,p}$ for cracked and uncracked concrete		ψ_c	C16/20	1,15					
Installation safety factor		γ_2 3) = γ_{inst} 4)		1,0					
Concrete cone failure and splitting for application in a member thickness ≥ 2x $h_{ef,sta}$									
Effective anchorage depth		h_{ef}	[mm]	45	60	70	85	100	125
Factor for uncracked concrete		k_{ucr} 4)	[-]	10,1					
Factor for cracked concrete		k_{cr}	[-]	7,2					
Min. thickness of concrete member		$h_{min,1}$	[mm]	100	120	140	170	200	250
Characteristic spacing		$s_{cr,N}$	[mm]	3,0 h_{ef}					
Characteristic edge distance		$c_{cr,N}$	[mm]	1,5 h_{ef}					
Spacing (splitting failure) 2)		$s_{cr,sp}$	[mm]	160	210	240	290	420	530
Edge distance (splitting failure) 2)		$c_{cr,sp}$	[mm]	80	105	125	145	210	265
Concrete cone failure and splitting for application in a member thickness < 2x $h_{ef,sta}$									
Effective anchorage depth		h_{ef}	[mm]	45	60	70	85	100	125
Factor for uncracked concrete		k_{ucr} 4)	[-]	10,1					
Factor for cracked concrete		k_{cr}	[-]	7,2					
Min. thickness of concrete member		$h_{min,2}$	[mm]	80	100	120	140	160	200
Characteristic spacing		$s_{cr,N}$	[mm]	3 h_{ef}					
Characteristic edge distance		$c_{cr,N}$	[mm]	1,5 h_{ef}					
Spacing (splitting failure) 2)		$s_{cr,sp}$	[mm]	210	280	320	400	540	620
Edge distance (splitting failure) 2)		$c_{cr,sp}$	[mm]	105	140	160	200	270	310

1) Pullout failure not relevant.
2) Intermediate values for $s_{cr,sp}$ and $c_{cr,sp}$ between concrete thickness $h_{min,1}$ and $h_{min,21}$ by linear interpolation.
3) Parameter relevant for design according to ETAG 001. Annex C
4) Parameter relevant for design according to CEN/TS 1992-4:2009

Characteristic resistances for tension and **standard embedment depth** for static and quasi-static loading (design method A, according to ETAG 001, Annex C or CEN/TS 1992-4:2009) **for C20/25 to C80/95**

Type / Size				FAZ II, FAZ II A4, FAZ II C					
				M8	**M10**	**M12**	**M16**	**M20**	**M24**
Steel failure for standard embedment depth									
Characteristic resistance	FAZ II	$N_{Rk,s}$	[kN]	16,0	27,0	41,5	66,0	111,0	150,0
	FAZ II A4/C	$N_{Rk,s}$	[kN]	17,0	27,2	44,3	70,6	111,0	160,8
Partial safety factor				1,5					
Pull out for standard embedment depth									
Effective anchorage depth		$h_{ef,sta} \geq$	[mm]	45	60	70	85	100	125
Characteristic resistance in cracked concrete C20/25		$N_{Rk,p}$	[kN]	7,5	12,0	20,0	- 1)		
Characteristic resistance in uncracked concrete C20/25		$N_{Rk,p}$	[kN]	14,0	22,5	- 1)			
Increasing factors for $N_{Rk,p}$ for cracked and uncracked concrete		ψ_c	C25/30	1,10					
			C30/37	1,22					
			C35/45	1,34					
			C40/50	1,41					
			C45/55	1,48					
			C50/60 bis C80/95	1,55					
Installation safety factor		γ_2 3) = γ_{inst} 4)		1,0					
Concrete cone failure and splitting for application in a member thickness ≥ 2x $h_{ef,sta}$									
Effective anchorage depth		h_{ef}	[mm]	45	60	70	85	100	125
Factor for uncracked concrete		k_{ucr} 4)	[-]	10,1					
Factor for cracked concrete		k_{cr}	[-]	7,2					
Min. thickness of concrete member		$h_{min,1}$	[mm]	100	120	140	170	200	250
Characteristic spacing		$s_{cr,N}$	[mm]	3 h_{ef}					
Characteristic edge distance		$c_{cr,N}$	[mm]	1,5 h_{ef}					
Spacing (splitting failure) 2)		$s_{cr,sp}$	[mm]	140	180	210	260	370	430
Edge distance (splitting failure) 2)		$c_{cr,sp}$	[mm]	70	90	105	130	185	215
Concrete cone failure and splitting for application in a member thickness < 2x $h_{ef,sta}$									
Effective anchorage depth		h_{ef}	[mm]	45	60	70	85	100	125
Factor for uncracked concrete		k_{ucr} 4)	[-]	10,1					
Factor for cracked concrete		k_{cr}	[-]	7,2					
Min. thickness of concrete member		$h_{min,2}$	[mm]	80	100	120	140	160	200
Characteristic spacing		$s_{cr,N}$	[mm]	3 h_{ef}					
Characteristic edge distance		$c_{cr,N}$	[mm]	1,5 h_{ef}					
Spacing (splitting failure) 2)		$s_{cr,sp}$	[mm]	180	240	280	340	480	550
Edge distance (splitting failure) 2)		$c_{cr,sp}$	[mm]	90	120	140	170	240	275

1) Pullout failure not relevant.
2) Intermediate values for $s_{cr,sp}$ and $c_{cr,sp}$ between concrete thickness $h_{min,1}$ and $h_{min,21}$ by linear interpolation.
3) Parameter relevant for design according to ETAG 001. Annex C
4) Parameter relevant for design according to CEN/TS 1992-4:2009

Characteristic resistances for tension and **reduced embedment depth** for static and quasi-static loading (design method A, according to ETAG 001, Annex C or CEN/TS 1992-4:2009) **for concrete strength classes larger than C12/15**

Type / Size				FAZ II, FAZ II A4, FAZ II C			
				M8	**M10**	**M12**	**M16**
Steel failure for reduced embedment depth							
Characteristic resistance	FAZ II	$N_{Rk,s}$	[kN]	16,0	27,0	41,5	66,0
	FAZ II A4/C	$N_{Rk,s}$	[kN]	17,0	27,2	44,3	70,6
Partial safety factor				1,5			
Pull out for reduced embedment depth							
Effective anchorage depth		$h_{ef,red} \geq$	[mm]	35 [2)]	40	50	65
Characteristic resistance in cracked concrete C12/15		$N_{Rk,p}$	[kN]	3,5	- [1)]		
Characteristic resistance in uncracked concrete C12/15		$N_{Rk,p}$	[kN]	- [1)]			
Increasing factors for $N_{Rk,p}$ for cracked and uncracked concrete		ψ_c	C16/20	1,15			
Installation safety factor		γ_2[3)] = γ_{inst}[4)]		1,0			
Concrete cone failure and splitting							
Effective anchorage depth		h_{ef}	[mm]	35 [2)]	40	50	65
Factor for uncracked concrete		k_{ucr}[4)]	[-]	10,1			
Factor for cracked concrete		k_{cr}[4)]	[-]	7,2			
Min. thickness of concrete member		$h_{min,3}$	[mm]	80	80	100	140
Characteristic spacing		$s_{cr,N}$	[mm]	3 h_{ef}			
Characteristic edge distance		$c_{cr,N}$	[mm]	1,5 h_{ef}			
Spacing (splitting failure) [2)]		$s_{cr,sp}$	[mm]	160	180	240	300
Edge distance (splitting failure)[2)]		$c_{cr,sp}$	[mm]	80	90	120	150

[1)] Pullout failure not relevant.
[2)] Use restricted to anchoring of structural components which are statically indeterminate
[3)] Parameter relevant for design according to ETAG 001. Annex C
[4)] Parameter relevant for design according to CEN/TS 1992-4:2009

Characteristic resistances for tension and **reduced embedment depth** for static and quasi-static loading (design method A, according to ETAG 001, Annex C or CEN/TS 1992-4:2009) **for C20/25 to C80/95**

Type / Size				FAZ II, FAZ II A4, FAZ II C			
				M8	**M10**	**M12**	**M16**
Steel failure for reduced embedment depth							
Characteristic resistance	FAZ II	$N_{Rk,s}$	[kN]	16,0	27,0	41,5	66,0
	FAZ II A4/C	$N_{Rk,s}$	[kN]	17,0	27,2	44,3	70,6
Partial safety factor		γ_{Ms}		1,5			
Pull out for for reduced embedment depth							
Effective anchorage depth		$h_{ef,red} \geq$	[mm]	35 [2)]	40	50	65
Characteristic resistance in cracked concrete C20/25		$N_{Rk,p}$	[kN]	5,0	- [1)]		
Characteristic resistance in uncracked concrete C20/25		$N_{Rk,p}$	[kN]	- [1)]			
Increasing factors for $N_{Rk,p}$ for cracked and uncracked concrete		ψ_c	C25/30	1,10			
			C30/37	1,22			
			C35/45	1,34			
			C40/50	1,41			
			C45/55	1,48			
			C50/60 bis C80/95	1,55			
Installation safety factor		γ_2 [3)] = γ_{inst} [4)]		1,0			
Concrete cone failure and splitting for reduced embedment depth							
Effective anchorage depth		h_{ef}	[mm]	35 [2)]	40	50	65
Factor for uncracked concrete		k_{ucr} [4)]	[-]	10,1			
Factor for cracked concrete		k_{cr} [4)]	[-]	7,2			
Min. thickness of concrete member		$h_{min,3}$	[mm]	80	80	100	140
Characteristic spacing		$s_{cr,N}$	[mm]	3 h_{ef}			
Characteristic edge distance		$c_{cr,N}$	[mm]	1,5 h_{ef}			
Spacing (splitting failure) [2)]		$s_{cr,sp}$	[mm]	140	160	200	260
Edge distance (splitting failure) [2)]		$c_{cr,sp}$	[mm]	70	80	100	130

[1)] Pullout failure not relevant.
[2)] Use restricted to anchoring of structural components which are statically indeterminate
[3)] Parameter relevant for design according to ETAG 001. Annex C
[4)] Parameter relevant for design according to CEN/TS 1992-4:2009

Characteristic shear resistances for **standard** and **reduced embedment depth** for static and quasi-static loading (design method A, according to ETAG 001, Annex C or CEN/TS 1992-4:2009) **for C12/15 to C80/95**

Type / Size				FAZ II, FAZ II A4, FAZ II C					
				M8	**M10**	**M12**	**M16**	**M20**	**M24**
Steel failure without lever arm									
Characteristic resistance	FAZ II	$V_{Rk,s}$	[kN]	12,0	20,0	29,5	55,0	70,0	86,0
	FAZ II A4/C	$V_{Rk,s}$	[kN]	17,6	23,8	36,5	70,9	94,4	138,2
Partial safety factor		γ_{Ms}		1,25					
Factor for ductility		k_2 [2)]	[-]	1,0					
Standard anchorage depth									
Steel failure with lever arm									
Characteristic resistance	FAZ II	$M^0_{Rk,s}$	[Nm]	26	52	92	233	487	769
	FAZ II A4/C	$M^0_{Rk,s}$	[Nm]	29	56	94	256	454	785
Partial safety factor		γ_{Ms}		1,25					
Factor for ductility		k_2 [2)]	[-]	1,0					
Concrete pryout failure									
Factor k according to ETAG 001, Annex C or k_3, according to CEN/TS 1992-4		k [1)] $= k_{(3)}$ [2)]	[-]	2,2		2,4	2,8		
Concrete edge failure									
Effective length of the anchor		l_f	[mm]	45	60	70	85	100	125
Diameter		d_{nom}	[mm]	8	10	12	16	20	24
Installation safety factor		γ_2 [1)] $= \gamma_{inst}$ [2)]		1,0					
Reduced anchorage depth									
Steel failure with lever arm									
Characteristic resistance	FAZ II	$M^0_{Rk,s}$	[Nm]	15	38,3	89	171	-	-
	FAZ II A4/C	$M^0_{Rk,s}$	[Nm]	18,9	38,3	90,7	179,5	-	-
Partial safety factor		γ_{Ms}		1,25					
Factor for ductility		k_2 [2)]	[-]	1,0					
Concrete pryout failure									
Factor k according to ETAG 001, Annex C or k_3, according to CEN/TS 1992-4		k [1)] $= k_{(3)}$ [2)]	[-]	1,0	2,0	2,3		-	-
Concrete edge failure									
Effective length of the anchor		l_f	[mm]	35	40	50	65	-	-
Diameter		d_{nom}	[mm]	8	10	12	16	-	-

1) Parameter relevant for design according to ETAG 001. Annex C
2) Parameter relevant for design according to CEN/TS 1992-4:2009

Displacements for **standard** and **reduced embedment depth** for (Design method A) for static and quasi-static loading (design method A, according to ETAG 001, Annex C or CEN/TS 1992-4:2009) **for C12/15 to C80/95**

Type / Size			FAZ II, FAZ II A4, FAZ II C					
			M8	**M10**	**M12**	**M16**	**M20**	**M24**
Standard anchorage depth								
Tension load in cracked concrete	N	[kN]	2,3	4,2	7,5	13,2	16,4	22,9
Displacement	δ_{N0}	[mm]	0,5	0,5	0,7	1,0	1,2	1,2
	$\delta_{N\infty}$	[mm]	1,8	1,7	1,4	1,2	1,4	1,5
Tension load in uncracked concrete	N	[kN]	4,2	7,5	11,7	18,7	23,3	32,5
Displacement	δ_{N0}	[mm]	0,3	0,3	0,5	0,7	1,2	1,2
	$\delta_{N\infty}$	[mm]	1,2				1,4	1,5
Recued embedment depth								
Tension load in cracked concrete	N	[kN]	2,3	4,2	6,0	9,0	-	-
Displacement	δ_{N0}	[mm]	0,5	0,5	0,7	1,0		
	$\delta_{N\infty}$	[mm]	1,2					
Tension load in uncracked concrete	N	[kN]	4,2	5,7	8,5	12,6	-	-
Displacement	δ_{N0}	[mm]	0,3	0,3	0,5	0,7		
	$\delta_{N\infty}$	[mm]	1,2					

Type / Size			FAZ II					
			M8	**M10**	**M12**	**M16**	**M20**	**M24**
Shear load in cracked and uncracked concrete	V	[kN]	6,9	11,4	16,9	31,4	39,4	48,5
Displacement	δ_{V0}	[mm]	2,4	4,2	4,5	3,0	3,6	3,6
	$\delta_{V\infty}$	[mm]	3,6	6,3	6,8	4,5	5,4	5,4
Type / Size			**FAZ II A4, FAZ II C**					
			M8	**M10**	**M12**	**M16**	**M20**	**M24**
Shear load in cracked and uncracked concrete	V	[kN]	10,1	13,6	20,9	40,5	53,9	79,0
Displacement	δ_{V0}	[mm]	1,8	2,0	2,2	3,0	1,9	4,7
	$\delta_{V\infty}$	[mm]	2,7	3,0	3,4	4,5	2,9	7,1