Deutsches Institut für Bautechnik DIBt

Approval body for construction products and types of construction

Bautechnisches Prüfamt

An institution established by the Federal and Laender Governments

European Technical Assessment

ETA-17/1058 of 8 December 2017

English translation prepared by DIBt - Original version in German language

General Part

Technical Assessment Body issuing the European Technical Assessment:	Deutsches Institut für Bautechnik
Trade name of the construction product	Q Injection system VMU plus für Beton
Product family to which the construction product belongs	Injection system for use in concrete
Manufacturer	Q-railing Europe GmbH & Co. KG Marie-Curie-Straße 8-14 46446 Emmerich am Rhein DEUTSCHLAND
Manufacturing plant	Deutschland, Werk 1 und Werk 2
This European Technical Assessment contains	29 pages including 3 annexes which form an integral part of this assessment
This European Technical Assessment is issued in accordance with Regulation (EU) No 305/2011, on the basis of	ETAG 001 Part 5: "Bonded anchors", April 2013, used as EAD according to Article 66 Paragraph 3 of Regulation (EU) No 305/2011.

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Specific Part

1 Technical description of the product

The Q Injection system VMU plus for concrete is a bonded anchor consisting of a cartridge with injection mortar Q-VMU plus or Q-VMU plus Polar and a steel element. The steel element consist of a threaded rod with washer and hexagon nut in the range of M8 to M30, reinforcing bar in the range of diameter ∅8 to ∅32 mm or internal threaded rod Q-VMU-IG-M6 to Q-VMU-IG-M20.

The steel element is placed into a drilled hole filled with injection mortar and is anchored via the bond between metal part, injection mortar and concrete.

The product description is given in Annex A.

2 Specification of the intended use in accordance with the applicable European Assessment Document

The performances given in Section 3 are only valid if the anchor is used in compliance with the specifications and conditions given in Annex B.

The verifications and assessment methods on which this European Technical Assessment is based lead to the assumption of a working life of the anchor of at least 50 years. The indications given on the working life cannot be interpreted as a guarantee given by the producer, but are to be regarded only as a means for choosing the right products in relation to the expected economically reasonable working life of the works.

3 Performance of the product and references to the methods used for its assessment

3.1 Mechanical resistance and stability (BWR 1)

Essential characteristic	**Performance**
Characteristic resistance tension and shear loads	See Annex C 1 to C 12
Displacements under tension and shear loads	See Annex C 13 / C 14

3.2 Safety in case of fire (BWR 2)

Essential characteristic	**Performance**
Reaction to fire	Anchorages satisfy requirements for Class A1
Resistance to fire	No performance assessed

3.3 Hygiene, health and the environment (BWR 3)

Regarding dangerous substances there may be requirements (e.g. transposed European legislation and national laws, regulations and administrative provisions) applicable to the products falling within the scope of this European Technical Assessment. In order to meet the provisions of Regulation (EU) No 305/2011, these requirements need also to be complied with, when and where they apply.

3.4 Safety in use (BWR 4)

The essential characteristics regarding Safety in use are included under the Basic Works Requirement Mechanical resistance and stability.

4 Assessment and verification of constancy of performance (AVCP) system applied, with reference to its legal base

In accordance with guideline for European technical approval ETAG 001, April 2013 used as European Assessment Document (EAD) according to Article 66 Paragraph 3 of Regulation (EU) No 305/2011 the applicable European legal act is: [96/582/EC].

The system to be applied is: 1

5 Technical details necessary for the implementation of the AVCP system, as provided for in the applicable European Assessment Document

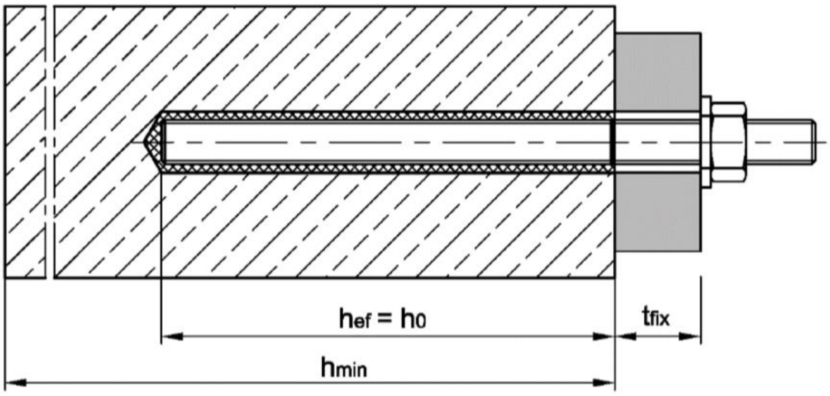
Technical details necessary for the implementation of the AVCP system are laid down in the control plan deposited with Deutsches Institut für Bautechnik.

Issued in Berlin on 8 December 2017 by Deutsches Institut für Bautechnik

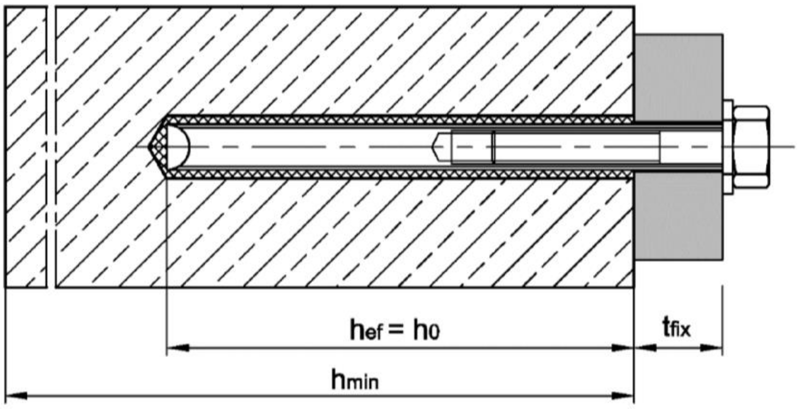
BD Dipl.-Ing. Andreas Kummerow
Head of Department

beglaubigt:
Baderschneider

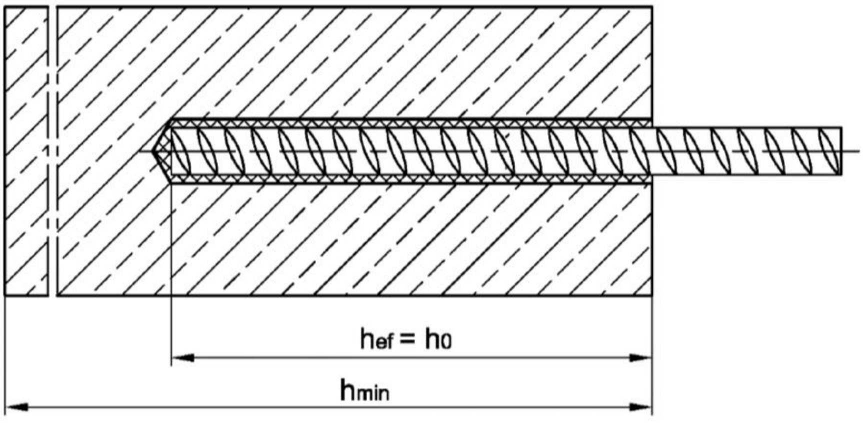
Installation Q-threaded rod M8 to M30



Installation internally threaded anchor rod Q-VMU-IG-M6 to Q-VMU-IG-M20



Installation reinforcing bar Ø8 to Ø32

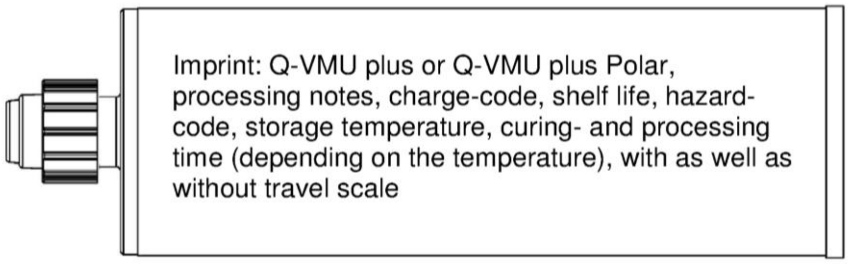


t_{fix} = thickness of fixture
h_{ef} = effective anchorage depth
h_0 = depth of drill hole
h_{min} = minimum thickness of member

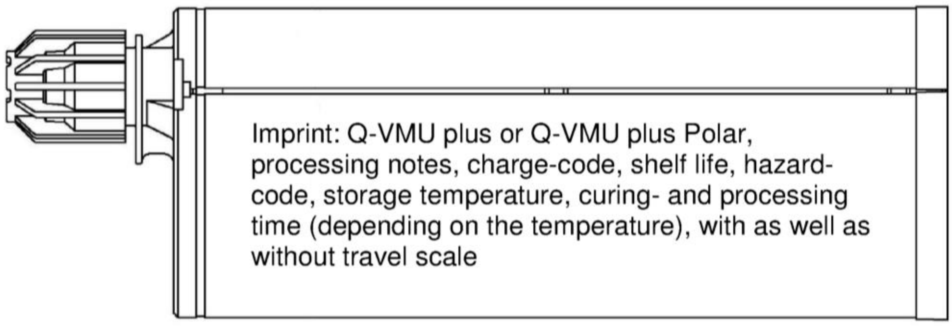
Q Injection system VMU plus for concrete	Annex A1
Product description Installation situation	

Cartridge Q-VMU plus or Q-VMU plus Polar

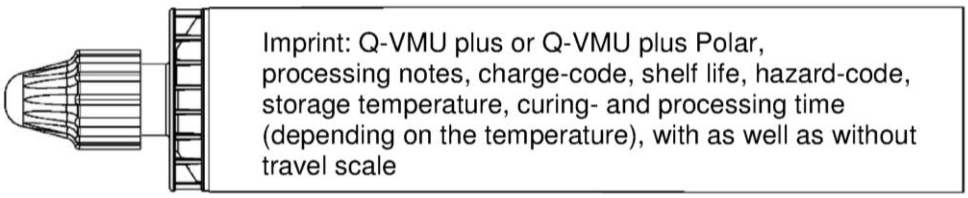
150 ml, 280 ml, 300 ml up to 333 ml and 380 ml up to 420 ml cartidge (Type: coaxial)



235 ml, 345 ml up to 360 ml and 825 ml cartridge (Type: "side-by-side")



165 ml and 300 ml cartridge (Type: "foil tube")



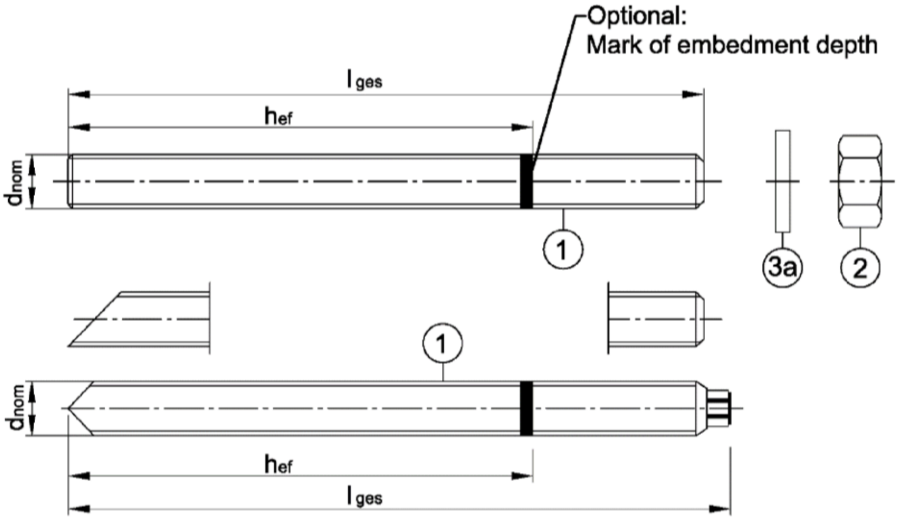
Static mixer

Q Injection system VMU plus for concrete	**Annex A2**
Product description Cartridges and attachments	

Threaded rods

Threaded rod Q-VMU-A, Q-V-A with washer and hexagon nut
M8, M10, M12, M16, M20, M24, M27, M30

Threaded rod Q-VM-A (material sold by the meter, to be cut at the required length)
M8, M10, M12, M16, M20, M24, M27, M30

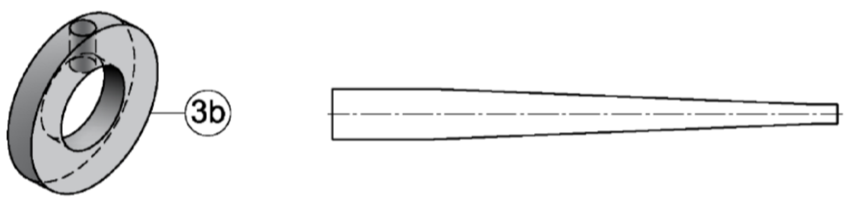


Marking: ◇ M10

◇	Identifying mark of manufacturing plant
M10	Size of thread
A4	additional marking for stainless steel
HCR	additional marking for High corrosion resistant steel

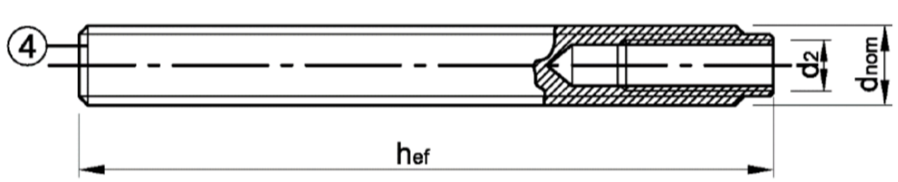
Commercial standard threaded rod with:
- Materials, dimensions and mechanical properties see Table A1
- Inspection certificate 3.1 acc. to EN 10204:2004

Washer with bore and reducing adapter for filling the gap between threaded rod and fixture



Internally threaded anchor rod

Q-VMU-IG M6, Q-VMU-IG M8, Q-VMU-IG M10, Q-VMU-IG M12, Q-VMU-IG M16, Q-VMU-IG M20



Marking e.g.: ◇ M8

◇	Identifying mark of manufacturing plant
I	Internal thread
M8	Size of internal thread
A4	additional marking for stainless steel
HCR	additional marking for high corrosion resistant steel

Q Injection system VMU plus for concrete

Product description
Threaded rods and internally threaded anchor rod

Annex A3

Table A1: Materials

Part	Designation		Material	
Steel, zinc plated electroplated ≥ 5 µm acc. to EN ISO 4042:1999 or hot-dip galvanised ≥ 40 µm acc. to EN ISO 1461:2009, EN ISO 10684:2004+AC:2009 or sherardized ≥ 40µm acc. to EN ISO 17668:2016				
1	Threaded rod	Property class 4.6	f_{uk}≥ 400 N/mm²; f_{yk}≥ 240 N/mm²; A_5 > 8 % fracture elongation	EN 10087:1998, EN 10263:2001; commercial standard threaded rod: EN ISO 898-1:2013
		Property class 4.8	f_{uk}≥ 400 N/mm²; f_{yk}≥ 320 N/mm²; A_5 > 8 % fracture elongation	
		Property class 5.6	f_{uk}≥ 500 N/mm²; f_{yk}≥ 300 N/mm²; A_5 > 8 % fracture elongation	
		Property class 5.8	f_{uk}≥ 500 N/mm²; f_{yk}≥ 400 N/mm²; A_5 > 8 % fracture elongation	
		Property class 8.8	f_{uk}≥ 800 N/mm²; f_{yk}≥ 640 N/mm²; A_5 > 8 % fracture elongation	
2	Hexagon nut		Steel, zinc plated Property class 4 (for class 4.6 or 4.8 rod) Property class 5 (for class 5.6 or 5.8 rod) Property class 8 (for class 8.8 rod)	EN ISO 898-2:2012
3a	Washer		Steel, zinc plated (e.g.: EN ISO 7089:2000, EN ISO 7093:2000 or EN ISO 7094:2000)	
3b	Washer with bore		Steel, zinc plated	
4	Internally threaded anchor rod		Steel, electroplated, A_5 > 8 % fracture elongation Property class 5.8 and 8.8	EN 10087:1998
Stainless steel A4				
1	Threaded rod		Material 1.4401 / 1.4404 / 1.4571 / 1.4578 / 1.4362 / 1.4062	EN 10088-1:2014
		Property class 50	f_{uk}= 500 N/mm²; f_{yk}= 210 N/mm²; A_5 > 8 % fracture elongation	EN ISO 3506-1:2009
		Property class 70	f_{uk}= 700 N/mm²; f_{yk}= 450 N/mm²; A_5 > 8 % fracture elongation M8 to M24	
2	Hexagon nut		Stainless Steel A4 Property class 50 (for class 50 rod) Property class 70 (for class 70 rod; ≤ M24)	EN ISO 3506-2:2009
3a	Washer		Stainless Steel A4 (e.g.: EN ISO 7089:2000, EN ISO 7093:2000 or EN ISO 7094:2000)	EN 10088-1: 2014
3b	Washer with bore		Material 1.4401 / 1.4404 / 1.4571 / 1.4362	
4	Internally threaded anchor rod		Material 1.4401 / 1.4404 / 1.4571 / 1.4362; A_5 > 8 % fracture elongation Property class 50 (IG-M20) Property class 70 (IG-M8 to IG-M16)	EN 10088-1: 2014
High corrosion resistant steel HCR				
1	Threaded rod		Material 1.4529 / 1.4565	EN 10088-1: 2014
		Property class 50	f_{uk}= 500 N/mm²; f_{yk}= 210 N/mm²; A_5 > 8 % fracture elongation	EN ISO 3506-1: 2009
		Property class 70	f_{uk}= 700 N/mm²; f_{yk}= 450 N/mm²; A_5 > 8 % fracture elongation M8 to M24	
2	Hexagon nut		Material 1.4529 / 1.4565 Property class 50 ((for class 50 rod) Property class 70 (for class 70 rod; ≤ M24)	EN 10088-1: 2014 EN ISO 3506-2:2009
3a	Washer		Material 1.4529 / 1.4565 (e.g.: EN ISO 7089:2000, EN ISO 7093:2000 or EN ISO 7094:2000)	EN 10088-1: 2014
3b	Washer with bore		Material 1.4529 / 1.4565	
4	Internally threaded anchor rod		Material 1.4529 / 1.4565, A_5 > 8 % fracture elongation Property class 50 (IG-M20) Property class 70 (IG-M8 to IG-M16)	EN 10088-1: 2014

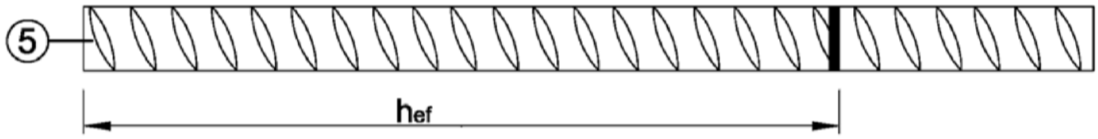
Q Injection system VMU plus for concrete

Product description
Materials threaded rods and internally threaded anchor rod

Annex A4

Reinforcing bar

Ø 8, Ø 10, Ø 12, Ø 14, Ø 16, Ø 20, Ø 25, Ø 28, Ø 32



- Minimum value of related rip area $f_{R,min}$ according to EN 1992-1-1:2004+AC:2010
- Rip height of the bar shall be in the range 0,05d ≤ h ≤ 0,07d
  (d: Nominal diameter of the bar; h: Rip height of the bar)

Table A2: Material rebar

Part	Designation	Material
Rebar		
5	Rebar EN 1992-1-1:2004+AC:2010, Annex C	Bars and de-coiled rods class B or C f_{yk} and k according to NDP or NCL of EN 1992-1-1/NA:2013 $f_{uk} = f_{tk} = k \cdot f_{yk}$

Q Injection system VMU plus for concrete

Product description
Product description and materials reinforcing bar

Annex A5

Specification of intended use

Q Injection System VMU plus	Anchor rod Q-VMU-A, Q-V-A, Q-VM-A, commercial standard threaded rod	Internally threaded anchor rod Q-VMU-IG	rebar
Static or quasi-static action	M8 - M30 (zinc plated, A4, HCR)	IG-M6 - IG-M20 (electroplated, A4, HCR)	Ø8 - Ø32
Seismic action, category C1	M8 - M30 (zinc plated[1)], A4, HCR)	-	Ø8 - Ø32
Base materials	Reinforced or unreinforced normal weight concrete acc. to EN 206-1:2000 Strength classes acc. to EN 206-1:2000:C20/25 to C50/60 Cracked and uncracked concrete		
Temperature Range I -40 °C to +40 °C	max long term temperature +24 °C and max short term temperature +40 °C		
Temperature Range II -40 °C to +80 °C	max long term temperature +50 °C and max short term temperature +80 °C		
Temperature Range III -40 °C to +120 °C	max long term temperature +72 °C and max short term temperature +120 °C		

[1)] except hot-dip galvanised

Use conditions (Environmental conditions):
- Structures subject to dry internal conditions
  (zinc coated steel, stainless steel or high corrosion resistant steel).
- Structures subject to external atmospheric exposure (including industrial and marine environment) and to permanently damp internal condition, if no particular aggressive conditions exist
  (stainless steel or high corrosion resistant steel).
- Structures subject to external atmospheric exposure and to permanently damp internal condition, if other particular aggressive conditions exist
  (high corrosion resistant steel).

  Note: Particular aggressive conditions are e.g. permanent, alternating immersion in seawater or the splash zone of seawater, chloride atmosphere of indoor swimming pools or atmosphere with extreme chemical pollution (e.g. in desulphurization plants or road tunnels where de-icing materials are used).

Design:
- Verifiable calculation notes and drawings are prepared taking account of the loads to be anchored. The position of the anchor is indicated on the design drawings (e. g. position of the anchor relative to reinforcement or to supports, etc.).
- Anchorages are designed under the responsibility of an engineer experienced in anchorages and concrete work.
- Anchorages under static or quasi-static actions are designed in accordance with:
  - EOTA Technical Report TR 029 "Design of bonded anchors", Edition September 2010 or
  - CEN/TS 1992-4:2009
- Anchorages under seismic actions (cracked concrete) are designed in accordance with:
  - EOTA Technical Report TR 045 "Design of Metal Anchors under Seismic Action", Edition February 2013
  - Anchorages shall be positioned outside of critical regions (e.g. plastic hinges) of the concrete structure.
  - Fastenings in stand-off installation or with a grout layer are not allowed.

Installation:
- Dry or wet concrete: M8 to M30, IG-M6 to IG-M20, Rebar Ø8 to Ø32.
- Flooded holes (not sea water): M8 to M16, IG-M6 to IG-M10, Rebar Ø8 to Ø16.
- Hole drilling by hammer or compressed air drill mode or vacuum drill mode.
- Overhead installation allowed.
- Anchor installation carried out by appropriately qualified personnel and under the supervision of the person responsible for technical matters of the site.

Q Injection system VMU plus for concrete	Annex B1
Intended Use Specifications	

Table B1: Installation parameters for threaded rod

Threaded rod			M8	M10	M12	M16	M20	M24	M27	M30
Nominal drill hole diameter	d_0 =	[mm]	10	12	14	18	24	28	32	35
Effective anchorage depth	$h_{ef,min}$	[mm]	60	60	70	80	90	96	108	120
	$h_{ef,max}$	[mm]	160	200	240	320	400	480	540	600
Diameter of clearance hole in the fixture[1]	$d_f \leq$	[mm]	9	12	14	18	22	26	30	33
Installation torque	$T_{inst} \leq$	[Nm]	10	20	40	80	120	160	180	200
Minimum thickness of member	h_{min}	[mm]	h_{ef} + 30 mm ≥ 100 mm			$h_{ef} + 2d_0$				
Minimum spacing	s_{min}	[mm]	40	50	60	80	100	120	135	150
Minimum edge distance	c_{min}	[mm]	40	50	60	80	100	120	135	150

[1] For larger clearance hole see TR029 section 1.1; for application under seismic loading the diameter of clearance hole in the fixture shall be at maximum d_{nom} + 1mm or alternatively the annular gap between fixture and threaded rod shall be completely filled with mortar

Table B2: Installation parameters for internally threaded anchor rod

Internally threaded anchor rod			IG-M 6	IG-M 8	IG-M 10	IG-M 12	IG-M 16	IG-M 20
Inner diameter of threaded rod	d_2 =	[mm]	6	8	10	12	16	20
Outer diameter of threaded rod[2]	d_{nom} =	[mm]	10	12	16	20	24	30
Nominal drill hole diameter	d_0 =	[mm]	12	14	18	24	28	35
Effective anchorage depth	$h_{ef,min}$	[mm]	60	70	80	90	96	120
	$h_{ef,max}$	[mm]	200	240	320	400	480	600
Diameter of clearance hole in the fixture[1]	$d_f \leq$	[mm]	7	9	12	14	18	22
Installation torque	$T_{inst} \leq$	[Nm]	10	10	20	40	60	100
Minimum screw-in depth	l_{IG}	[mm]	8	8	10	12	16	20
Minimum thickness of member	h_{min}	[mm]	h_{ef} + 30 mm ≥ 100 mm		$h_{ef} + 2d_0$			
Minimum spacing	s_{min}	[mm]	50	60	80	100	120	150
Minimum edge distance	c_{min}	[mm]	50	60	80	100	120	150

[1] For larger clearance hole see TR029 section 1.1
[2] With metric thread acc. to EN 1993-1-8:2005+AC:2009

Table B3: Installation parameters for rebar

Rebar			Ø 8	Ø 10	Ø 12	Ø 14	Ø 16	Ø 20	Ø 25	Ø 28	Ø 32
Nominal drill hole diameter	d_0 =	[mm]	12	14	16	18	20	24	32	35	40
Effective anchorage depth	$h_{ef,min}$	[mm]	60	60	70	75	80	90	100	112	128
	$h_{ef,max}$	[mm]	160	200	240	280	320	400	500	560	640
Minimum thickness of member	h_{min}	[mm]	h_{ef} + 30 mm ≥ 100 mm		$h_{ef} + 2d_0$						
Minimum spacing	s_{min}	[mm]	40	50	60	70	80	100	125	140	160
Minimum edge distance	c_{min}	[mm]	40	50	60	70	80	100	125	140	160

Q Injection system VMU plus for concrete

Intended Use
Installation parameters

Annex B2

Table B4: Parameter cleaning and setting tools

Threaded rod	Internally threaded anchor rod	Rebar	Drill bit Ø	Brush Ø	min. Brush Ø	Retaining washer	Installation direction and use of retaining washer		
[-]	[-]	Ø [mm]	d_0 [mm]	d_b [mm]	$d_{b,min}$ [mm]	[-]	⬇	➡	⬆
M8			10	12	10,5	No **retaining washer** required			
M10	Q-VMU-IG M 6	8	12	14	12,5				
M12	Q-VMU-IG M 8	10	14	16	14,5				
		12	16	18	16,5				
M16	Q-VMU-IG M10	14	18	20	18,5	VM-IA 18	h_{ef} > 250mm	h_{ef} > 250mm	all
		16	20	22	20,5	VM-IA 20			
M20	Q-VMU-IG M12	20	24	26	24,5	VM-IA 24			
M24	Q-VMU-IG M16		28	30	28,5	VM-IA 28			
M27		25	32	34	32,5	VM-IA 32			
M30	Q-VMU-IG M20	28	35	37	35,5	VM-IA 35			
		32	40	41,5	40,5	VM-IA 40			

Blow-out pump (volume 750ml)
Drill bit diameter (d_0): 10 mm to 20 mm
Anchorage depth (h_{ef}): ≤ 10 d_{nom}
for uncracked concrete

Recommended compressed air tool (min 6 bar)
All applications

Retaining washer for overhead or horizontal installation
Drill bit diameter (d_0):
18 mm to 40 mm

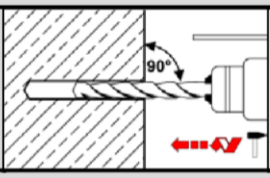
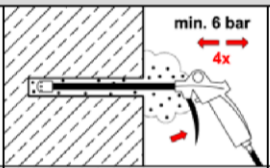
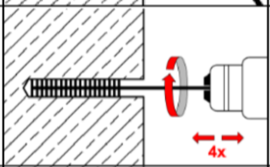
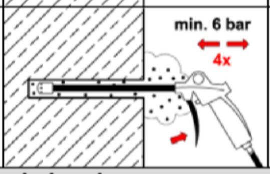
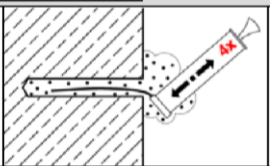
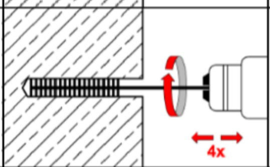
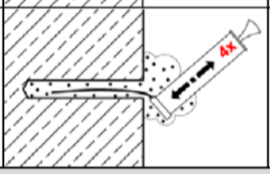
Steel brush
Drill bit diameter (d_0): all diameters

Q Injection system VMU plus for concrete

Intended Use
Cleaning and setting tools

Annex B3

Installation instructions

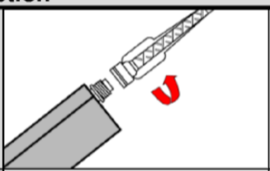
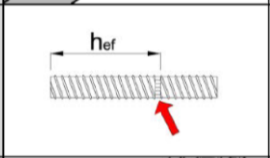
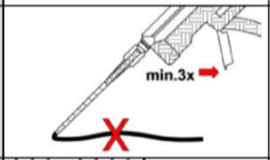
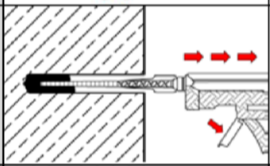
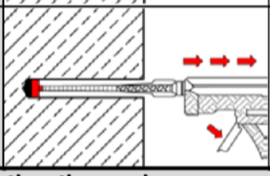
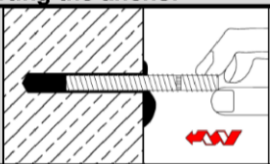
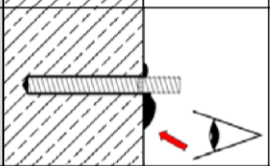
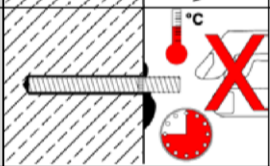
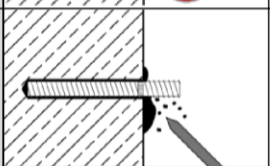
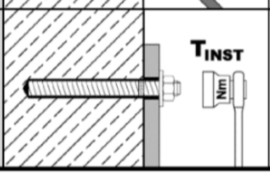
Drilling of the hole		
1.		Drill the borehole by apllying the drilling method acc. to Annex B1, the drill bit diameter (Table B4) and the selected borehole depth. In case of aborted drill hole, the drill hole shall be filled with mortar
Cleaning		
2.		**Attention! Standing water in the bore hole must be removed before cleaning!**
		<u>**Cleaning with compressed air**</u> (all diameters, cracked and uncracked concrete)
2a.		Starting from the bottom or back of the bore hole, blow out the hole with compressed air (min. 6 bar) **four** times. If the bore hole ground is not reached, an extension must be used.
2b.		Attach the brush to a drilling machine or a battery screwdriver. Brush the hole with an appropriate sized wire brush > $d_{b,min}$ (Table B4) **four** times. If the bore hole ground is not reached, a brush extension shall be used.
2c.		Finally blow the hole clean again with compressed air (min. 6 bar) **four** times. If the bore hole ground is not reached an extension shall be used.
		<u>**Manual cleaning**</u> <u>Uncracked concrete:</u> Bore hole diameter $d_0 \leq$ 20mm and effective anchorage depth $h_{ef} \leq 10\ d_{nom}$ <u>Cracked concrete:</u> Bore hole diameter: 14mm $\leq d_0 \leq$ 20mm and effective anchorage depth $h_{ef} \leq 10\ d_{nom}$
2a.		Starting from the bottom or back of the bore hole, blow the hole clean with the blow-out pump **four** times.
2b.		Attach the brush to a drilling machine or a battery screwdriver. Brush the hole with an appropriate sized wire brush > $d_{b,min}$ (Table B4) **four** times. If the bore hole ground is not reached, a brush extension shall be used.
2c.		Finally blow the hole clean again with the blow-out pump **four** times.
		After cleaning, the bore hole has to be protected against re-contamination in an appropriate way, until dispensing the mortar in the bore hole. If necessary, the cleaning has to be repeated directly before dispensing the mortar. In-flowing water must not contaminate the bore hole again.

Q Injection system VMU plus for concrete

Intended Use
Installation instructions

Annex B4

Installation instructions (continuation)

Injection		
3.		Attach a supplied static-mixing nozzle to the cartridge and load the cartridge into the correct dispensing tool. For every working interruption longer than the recommended working time (Table B5 or Table B6) as well as for new cartridges, a new static-mixer shall be used.
4.		Before injecting the mortar, mark the required anchorage depth on the fastening element.
5.		Prior to dispensing into the drill hole, squeeze out separately a minimum of three full strokes and discard non-uniformly mixed adhesive components until the mortar shows a consistent grey colour. For tubular film cartridges dismiss a minimum of six full strokes.
6a.		Starting from the bottom or back of the cleaned drill hole fill the hole up to approximately two-thirds with adhesive. Slowly withdraw the static mixing nozzle as the hole fills to avoid air pockets. For embedment larger than 190mm an extension nozzle shall be used. Observe the gel-/ working times given in Table B5 or Table B6.
6b.		Retaining washer and mixer nozzle extensions shall be used according to Annex B3 for the following applications: • Horizontal installation (horizontal direction) and ground installation (vertical downwards direction): Drill bit-Ø $d_0 \geq 18$ mm and embedment depth $h_{ef} > 250$mm • Overhead installation: Drill bit-Ø $d_0 \geq 18$ mm
Inserting the anchor		
7.		Push the threaded rod into the hole while turning slightly to ensure proper distribution of the adhesive until the embedment depth is reached. The anchor shall be free of dirt, grease, oil or other foreign material.
8.		Make sure that the anchor is fully seated up to the full embedment depth and that excess mortar is visible at the top of the hole. If these requirements are not maintained, pull out the rod immediately and start again with step 6. For overhead installation, the anchor should be fixed (e.g. by wedges).
9.		Allow the adhesive to cure to the specified time prior to applying any load or torque. Do not move or load the anchor until it is fully cured (Table B5 or Table B6).
10.		Remove excess mortar.
11.		The fixture can be mounted after curing time. Apply installation torque Tinst according to Table B1or B2 by using a calibrated torque wrench. Optionally, the annular gap between anchor rod and attachment can be filled with mortar. Therefor replace the regular washer by washer with bore and plug on reducing adapter on static mixer. Annular gap is completely filled, when excess mortar seeps out.

Q Injection system VMU plus for concrete

Intended Use
Installation instructions (continuation)

Annex B5

Table B5: Maximum processing time and minimum curing time, Q-VMU plus

Concrete temperature	Maximum processing time	Minimum curing time in dry concrete[1)]
-10°C to -6°C	90 min[2)]	24 h[2)]
-5°C to -1°C	90 min	14 h
0°C to +4°C	45 min	7 h
+5°C to +9°C	25 min	2 h
+10°C to +19°C	15 min	80 min
+20°C to +29°C	6 min	45 min
+30°C to +34°C	4 min	25 min
+35°C to +39°C	2 min	20 min
+ 40°C	1,5 min	15 min
Cartridge temperature	+ 5°C to + 40°C	

1) In wet concrete the curing time must be doubled.
2) Cartridge temperature must be at min. + 15°C.

Table B6: Maximum processing time and minimum curing time, Q-VMU plus Polar

Concrete temperature	Maximum processing time	Minimum curing time in dry concrete[1)]
- 20°C to -16°C	75 min	24 h
-15°C to -11°C	55 min	16 h
-10°C to -6°C	35 min	10 h
-5°C to -1°C	20 min	5 h
0°C to +4°C	10 min	2,5 h
+5°C to +9°C	6 min	80 min
+10°C	6 min	60 min
Cartridge temperature	- 20°C to + 10°C	

1) In wet concrete the curing time must be doubled.

Table C1: Characteristic **steel resistances** for **threaded rods** under tension and shear loads

Threaded rod				M 8	M 10	M 12	M 16	M 20	M 24	M 27	M 30
Steel failure											
Tension load											
Characteristic tension resistance	Steel, Property class 4.6 and 4.8	$N_{Rk,s}$	[kN]	15	23	34	63	98	141	184	224
	Steel, Property class 5.6 and 5.8	$N_{Rk,s}$	[kN]	18	29	42	78	122	176	230	280
	Steel, Property class 8.8	$N_{Rk,s}$	[kN]	29	46	67	125	196	282	368	449
	Stainless steel A4 and HCR, Property class 50	$N_{Rk,s}$	[kN]	18	29	42	79	123	177	230	281
	Stainless steel A4 and HCR, Property class 70	$N_{Rk,s}$	[kN]	26	41	59	110	171	247	-	-
Partial factor	Steel, Property class 4.6	$\gamma_{Ms,N}$	[-]	2,0							
	Steel, Property class 4.8	$\gamma_{Ms,N}$	[-]	1,5							
	Steel, Property class 5.6	$\gamma_{Ms,N}$	[-]	2,0							
	Steel, Property class 5.8	$\gamma_{Ms,N}$	[-]	1,5							
	Steel, Property class 8.8	$\gamma_{Ms,N}$	[-]	1,5							
	Stainless steel A4 and HCR, Property class 50	$\gamma_{Ms,N}$	[-]	2,86							
	Stainless steel A4 and HCR, Property class 70	$\gamma_{Ms,N}$	[-]	1,87						-	-
Shear load											
Steel failure without lever arm											
Characteristic shear resistance	Steel, Property class 4.6 and 4.8	$V_{Rk,s}$	[kN]	7	12	17	31	49	71	92	112
	Steel, Property class 5.6 and 5.8	$V_{Rk,s}$	[kN]	9	15	21	39	61	88	115	140
	Steel, Property class 8.8	$V_{Rk,s}$	[kN]	15	23	34	63	98	141	184	224
	Stainless steel A4 and HCR, Property class 50	$V_{Rk,s}$	[kN]	9	15	21	39	61	88	115	140
	Stainless steel A4 and HCR, Property class 70	$V_{Rk,s}$	[kN]	13	20	30	55	86	124	-	-
Steel failure with lever arm											
Characteristic bending moment	Steel, Property class 4.6 and 4.8	$M_{Rk,s}$	[Nm]	15	30	52	133	260	449	666	900
	Steel, Property class 5.6 and 5.8	$M_{Rk,s}$	[Nm]	19	37	65	166	324	560	833	1123
	Steel, Property class 8.8	$M_{Rk,s}$	[Nm]	30	60	105	266	519	896	1333	1797
	Stainless steel A4 and HCR, Property class 50	$M_{Rk,s}$	[Nm]	19	37	66	167	325	561	832	1125
	Stainless steel A4 and HCR, Property class 70	$M_{Rk,s}$	[Nm]	26	52	92	232	454	784	-	-
Partial factor	Steel, Property class 4.6	$\gamma_{Ms,V}$	[-]	1,67							
	Steel, Property class 4.8	$\gamma_{Ms,V}$	[-]	1,25							
	Steel, Property class 5.6	$\gamma_{Ms,V}$	[-]	1,67							
	Steel, Property class 5.8	$\gamma_{Ms,V}$	[-]	1,25							
	Steel, Property class 8.8	$\gamma_{Ms,V}$	[-]	1,25							
	Stainless steel A4 and HCR, Property class 50	$\gamma_{Ms,V}$	[-]	2,38							
	Stainless steel A4 and HCR, Property class 70	$\gamma_{Ms,V}$	[-]	1,56						-	-

Q Injection system VMU plus for concrete

Performance
Characteristic steel resistances for **threaded rods** under **tension** and **shear loads**

Annex C1

Table C2: Characteristic values for **threaded rods** under **tension loads** in **cracked concrete**

Threaded rod				M8	M10	M12	M16	M20	M24	M27	M30
Steel failure											
Characteristic tension resistance		$N_{Rk,s}$	[kN]	see table C1							
Combined pull-out and concrete cone failure											
Characteristic bond resistance in cracked concrete C20/25											
Temperature range I: 40°C/24°C	dry and wet concrete	$\tau_{Rk,cr}$	[N/mm²]	4,0	5,0	5,5	5,5	5,5	5,5	6,5	6,5
	flooded bore hole	$\tau_{Rk,cr}$	[N/mm²]	4,0	4,0	5,5	5,5	no performance determined (NPD)			
Temperature range II: 80°C/50°C	dry and wet concrete	$\tau_{Rk,cr}$	[N/mm²]	2,5	3,5	4,0	4,0	4,0	4,0	4,5	4,5
	flooded bore hole	$\tau_{Rk,cr}$	[N/mm²]	2,5	3,0	4,0	4,0	no performance determined (NPD)			
Temperature range III: 120°C/72°C	dry and wet concrete	$\tau_{Rk,cr}$	[N/mm²]	2,0	2,5	3,0	3,0	3,0	3,0	3,5	3,5
	flooded bore hole	$\tau_{Rk,cr}$	[N/mm²]	2,0	2,5	3,0	3,0	no performance determined (NPD)			
Increasing factor for $\tau_{Rk,cr}$		ψ_c	C25/30	1,02							
			C30/37	1,04							
			C35/45	1,07							
			C40/50	1,08							
			C45/55	1,09							
			C50/60	1,10							
Factor according to CEN/TS 1992-4-5		k_8	[-]	7,2							
Concrete cone failure											
Factor according to CEN/TS 1992-4-5		k_{cr}	[-]	7,2							
Edge distance		$c_{cr,N}$	[mm]	1,5 h_{ef}							
Axial distance		$s_{cr,N}$	[mm]	3,0 h_{ef}							
Installation factor (dry and wet concrete)		$\gamma_2 = \gamma_{inst}$	[-]	1,0	1,2						
Installation factor (flooded bore hole)		$\gamma_2 = \gamma_{inst}$	[-]	1,4				no performance determined (NPD)			

Q Injection system VMU plus for concrete

Performance
Characteristic values for **threaded rods** under **tension loads** in **cracked concrete**

Annex C2

Table C3: Characteristic values for **threaded rods** under **tension loads** in **uncracked concrete**

Threaded rod				**M8**	**M10**	**M12**	**M16**	**M20**	**M24**	**M27**	**M30**
Steel failure											
Characteristic tension resistance		$N_{Rk,s}$	[kN]	see table C1							
Combined pull-out and concrete cone failure											
Characteristic bond resistance in uncracked concrete C20/25											
Temperature range I: 40°C/24°C	dry and wet concrete	$\tau_{Rk,ucr}$	[N/mm²]	10	12	12	12	12	11	10	9
	flooded bore hole	$\tau_{Rk,ucr}$	[N/mm²]	7,5	8,5	8,5	8,5	no performance determined (NPD)			
Temperature range II: 80°C/50°C	dry and wet concrete	$\tau_{Rk,ucr}$	[N/mm²]	7,5	9	9	9	9	8,5	7,5	6,5
	flooded bore hole	$\tau_{Rk,ucr}$	[N/mm²]	5,5	6,5	6,5	6,5	no performance determined (NPD)			
Temperature range III: 120°C/72°C	dry and wet concrete	$\tau_{Rk,ucr}$	[N/mm²]	5,5	6,5	6,5	6,5	6,5	6,5	5,5	5,0
	flooded bore hole	$\tau_{Rk,ucr}$	[N/mm²]	4,0	5,0	5,0	5,0	no performance determined (NPD)			
Increasing factor for $\tau_{Rk,ucr}$		ψ_c	C25/30	1,02							
			C30/37	1,04							
			C35/45	1,07							
			C40/50	1,08							
			C45/55	1,09							
			C50/60	1,10							
Factor according to CEN/TS 1992-4-5		k_8	[-]	10,1							
Concrete cone failure											
Factor according to CEN/TS 1992-4-5		k_{ucr}	[-]	10,1							
Edge distance		$c_{cr,N}$	[mm]	1,5 h_{ef}							
Axial distance		$s_{cr,N}$	[mm]	3,0 h_{ef}							
Splitting failure											
Edge distance for		$c_{cr,sp}$	[mm]	$1{,}0 \cdot h_{ef} \le 2 \cdot h_{ef}\left(2{,}5-\frac{h}{h_{ef}}\right) \le 2{,}4 \cdot h_{ef}$							
Axial distance		$s_{cr,sp}$	[mm]	2 $c_{cr,sp}$							
Installation factor (dry and wet concrete)		$\gamma_2 = \gamma_{inst}$	[-]	1,0	1,2						
Installation factor (flooded bore hole)		$\gamma_2 = \gamma_{inst}$	[-]	1,4				no performance determined (NPD)			

Table C4: Characteristic values for **threaded rods** under **shear loads** in **cracked and uncracked concrete**

Threaded rod			M8	M10	M12	M16	M20	M24	M27	M30
Steel failure without lever arm										
Characteristic shear resistance	$V_{Rk,s}$	[kN]	see table C1							
Ductility factor acc. to CEN/TS 1992-4-5	k_2	[-]	0,8							
Steel failure with lever arm										
Characteristic bending moment	$M^0_{Rk,s}$	[Nm]	see table C1							
Concrete pry-out failure										
Factor k acc. to TR 029 or k_3 acc. to CEN/TS 1992-4-5	$k_{(3)}$	[-]	2,0							
Concrete edge failure										
Effective length of anchor	l_f	[mm]	$l_f = \min(h_{ef}; 8\ d_{nom})$							
Outside diameter of anchor	d_{nom}	[mm]	8	10	12	16	20	24	27	30
Installation factor	$\gamma_2 = \gamma_{inst}$	[-]	1,0							

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Table C5: Characteristic values for **threaded rods** under **seismic action, category C1**

Threaded rod				**M8**	**M10**	**M12**	**M16**	**M20**	**M24**	**M27**	**M30**
Tension load											
Steel failure											
Characteristic tension resistance		$N_{Rk,s,seis}$	[kN]	$1{,}0 \cdot N_{Rk,s}$ (see table C1)							
Combined pull-out and concrete cone failure											
Characteristic bond resistance in concrete C20/25 to C50/60											
Temperature range I: 40°C/24°C	dry and wet concrete	$\tau_{Rk,seis}$	[N/mm²]	2,5	3,1	3,7	3,7	3,7	3,8	4,5	4,5
	flooded bore hole	$\tau_{Rk,seis}$	[N/mm²]	2,5	2,5	3,7	3,7	no performance determined (NPD)			
Temperature range II: 80°C/50°C	dry and wet concrete	$\tau_{Rk,seis}$	[N/mm²]	1,6	2,2	2,7	2,7	2,7	2,8	3,1	3,1
	flooded bore hole	$\tau_{Rk,seis}$	[N/mm²]	1,6	1,9	2,7	2,7	no performance determined (NPD)			
Temperature range III: 120°C/72°C	dry and wet concrete	$\tau_{Rk,seis}$	[N/mm²]	1,3	1,6	2,0	2,0	2,0	2,1	2,4	2,4
	flooded bore hole	$\tau_{Rk,seis}$	[N/mm²]	1,3	1,6	2,0	2,0	no performance determined (NPD)			
Increasing factor for $\tau_{Rk,seis}$		ψ_c	[-]	1,0							
Installation factor (dry and wet concrete)		$\gamma_2 = \gamma_{inst}$	[-]	1,0	1,2						
Installation factor (flooded bore hole)		$\gamma_2 = \gamma_{inst}$	[-]	1,4				no performance determined (NPD)			
Shear load											
Steel failure without lever arm											
Characteristic shear resistance		$V_{Rk,s,seis}$	[kN]	$0{,}7 \cdot V_{Rk,s}$ (see table C1)							
Steel failure with lever arm											
Characteristic bending moment		$M^0_{Rk,s,seis}$	[Nm]	No Performance Determined (NPD)							

Q Injection system VMU plus for concrete

Performance
Characteristic values for **threaded rods** under **seismic action**, category **C1**

Annex C5

Table C6: Characteristic values of **tension loads** for **internally threaded anchor rods** in **cracked concrete**

Internally threaded anchor rod				**IG-M 6**	**IG-M 8**	**IG-M 10**	**IG-M 12**	**IG-M 16**	**IG-M20**
Steel failure [1)]									
Characteristic shear resistance Steel, strength class 5.8		$N_{Rk,s}$	[kN]	10	18	29	42	79	123
Partial factor		$\gamma_{Ms,N}$	[-]	1,5					
Characteristic shear resistance Steel, strength class 8.8		$N_{Rk,s}$	[kN]	16	27	46	67	121	196
Partial factor		$\gamma_{Ms,N}$	[-]	1,5					
Characteristic shear resistance Stainless steel A4 / HCR, strength class 70		$N_{Rk,s}$	[kN]	14	26	41	59	110	124 [2)]
Partial factor		$\gamma_{Ms,N}$	[-]	1,87					2,86
Combined pull-out and concrete cone failure									
Characteristic bond resistance in **cracked** concrete C20/25									
Temperature range I: 40°C/24°C	dry and wet concrete	$\tau_{Rk,cr}$	[N/mm²]	5,0	5,5	5,5	5,5	5,5	6,5
	flooded bore hole	$\tau_{Rk,cr}$	[N/mm²]	4,0	5,5	5,5	no performance determined (NPD)		
Temperature range II: 80°C/50°C	dry and wet concrete	$\tau_{Rk,cr}$	[N/mm²]	3,5	4,0	4,0	4,0	4,0	4,5
	flooded bore hole	$\tau_{Rk,cr}$	[N/mm²]	3,0	4,0	4,0	no performance determined (NPD)		
Temperature range III: 120°C/72°C	dry and wet concrete	$\tau_{Rk,cr}$	[N/mm²]	2,5	3,0	3,0	3,0	3,0	3,5
	flooded bore hole	$\tau_{Rk,cr}$	[N/mm²]	2,5	3,0	3,0	no performance determined (NPD)		
Increasing factor for $\tau_{Rk,cr}$		ψ_c	C25/30	1,02					
			C30/37	1,04					
			C35/45	1,07					
			C40/50	1,08					
			C45/55	1,09					
			C50/60	1,10					
Factor according to CEN/TS 1992-4-5		k_8	[-]	7,2					
Concrete cone failure									
Factor according to CEN/TS 1992-4-5		k_{cr}	[-]	7,2					
Edge distance		$c_{cr,N}$	[mm]	1,5 h_{ef}					
Spacing		$s_{cr,N}$	[mm]	3,0 h_{ef}					
Installation factor (dry and wet concrete)		$\gamma_2 = \gamma_{inst}$	[-]	1,2					
Installation factor (flooded bore hole)		$\gamma_2 = \gamma_{inst}$	[-]	1,4			no performance determined (NPD)		

1) Fastening screws or threaded rods (incl. nut and washer) must compley with the appropriate material and property class of the internally threaded anchor rod. The characteristic tension resistance for steel failure of the given strength class are valid for the internally threaded anchor rod and the fastening element

2)) For IG M20: Internally threaded rod: strength class 50; Fastening screws or threaded rods (incl. nut and washer): strength class 70

Q Injection system VMU plus for concrete

Performance
Characteristic values for **internally threaded anchor rods** under **tension loads** in **cracked concrete**

Annex C6

Table C7: Characteristic values of **tension loads** for **internally threaded anchor rods** in **uncracked concrete**

Internally threaded anchor rod				IG-M 6	IG-M 8	IG-M 10	IG-M 12	IG-M 16	IG-M 20
Steel failure [1]									
Characteristic shear resistance Steel, strength class 5.8		$N_{Rk,s}$	[kN]	10	18	29	42	79	123
Partial factor		$\gamma_{Ms,N}$	[-]	1,5					
Characteristic shear resistance Steel, strength class 8.8		$N_{Rk,s}$	[kN]	16	27	46	67	121	196
Partial factor		$\gamma_{Ms,N}$	[-]	1,5					
Characteristic shear resistance Stainless steel A4 / HCR, strength class 70		$N_{Rk,s}$	[kN]	14	26	41	59	110	124 [2]
Partial factor		$\gamma_{Ms,N}$	[-]	1,87					2,86
Combined pull-out and concrete cone failure									
Characteristic bond resistance in **uncracked** concrete C20/25									
Temperature range I: 40°C/24°C	dry and wet concrete	$\tau_{Rk,ucr}$	[N/mm²]	12	12	12	12	11	9,0
	flooded bore hole	$\tau_{Rk,ucr}$	[N/mm²]	8,5	8,5	8,5	no performance determined		
Temperature range II: 80°C/50°C	dry and wet concrete	$\tau_{Rk,ucr}$	[N/mm²]	9,0	9,0	9,0	9,0	8,5	6,5
	flooded bore hole	$\tau_{Rk,ucr}$	[N/mm²]	6,5	6,5	6,5	no performance determined		
Temperature range III: 120°C/72°C	dry and wet concrete	$\tau_{Rk,ucr}$	[N/mm²]	6,5	6,5	6,5	6,5	6,5	5,0
	flooded bore hole	$\tau_{Rk,ucr}$	[N/mm²]	5,0	5,0	5,0	no performance determined		
Increasing factor for $\tau_{Rk,ucr}$		ψ_c	C25/30	1,02					
			C30/37	1,04					
			C35/45	1,07					
			C40/50	1,08					
			C45/55	1,09					
			C50/60	1,10					
Factor according to CEN/TS 1992-4-5		k_8	[-]	10,1					
Concrete cone failure									
Factor according to CEN/TS 1992-4-5		k_{ucr}	[-]	10,1					
Edge distance		$c_{cr,N}$	[mm]	1,5 h_{ef}					
Spacing		$s_{cr,N}$	[mm]	3,0 h_{ef}					
Splitting failure									
Edge distance	$h/h_{ef} \geq 2{,}0$	$c_{cr,sp}$	[mm]	1,0 h_{ef}					
	$2{,}0 > h/h_{ef} > 1{,}3$			2 * h_{ef} (2,5 – h / h_{ef})					
	$h/h_{ef} \leq 1{,}3$			2,4 h_{ef}					
Spacing		$s_{cr,sp}$	[mm]	2 $c_{cr,sp}$					
Installation factor (dry and wet concrete)		$\gamma_2 = \gamma_{inst}$	[-]	1,2					
Installation factor (flooded bore hole)		$\gamma_2 = \gamma_{inst}$	[-]	1,4			no performance determined		

[1] Fastening screws or threaded rods (incl. nut and washer) must compley with the appropriate material and property class of the internally threaded anchor rod. The characteristic tension resistance for steel failure of the given strength class are valid for the internally threaded anchor rod and the fastening element.

[2] For IG M20: Internally threaded rod: strength class 50; Fastening screws or threaded rods (incl. nut and washer): strength class 70

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Performance
Characteristic values for **internally threaded anchor rods** under **tension loads** in **uncracked concrete**

Annex C7

Table C8: Characteristic values for **internally threaded anchor rods** under **shear loads** in **cracked and uncracked concrete**

Internally threaded anchor rod			IG-M 6	IG-M 8	IG-M 10	IG-M 12	IG-M 16	IG-M 20
Steel failure without lever arm[1)]								
Characteristic shear resistance Steel, strength class 5.8	$V_{Rk,s}$	[kN]	5	9	15	21	39	61
Partial factor	$\gamma_{Ms,V}$	[-]	1,25					
Characteristic shear resistance Steel, strength class 8.8	$V_{Rk,s}$	[kN]	8	14	23	34	60	98
Partial factor	$\gamma_{Ms,V}$	[-]	1,25					
Characteristic shear resistance Stainless steel A4 / HCR, strength class 70	$V_{Rk,s}$	[kN]	7	13	20	30	55	62 [2)]
Partial factor	$\gamma_{Ms,V}$	[-]	1,56					2,38
Ductility factor according to CEN/TS 1992-4-5	k_2	[-]	0,8					
Steel failure with lever arm[1)]								
Characteristic bending moment, Steel, strength class 5.8	$M^0_{Rk,s}$	[Nm]	8	19	37	66	167	325
Partial factor	$\gamma_{Ms,V}$	[-]	1,25					
Characteristic bending moment, Steel, strength class 8.8	$M^0_{Rk,s}$	[Nm]	12	30	60	105	267	519
Partial factor	$\gamma_{Ms,V}$	[-]	1,25					
Characteristic bending moment, Stainless steel A4 / HCR, strength class 70	$M^0_{Rk,s}$	[Nm]	11	26	53	92	234	643 [2)]
Partial factor	$\gamma_{Ms,V}$	[-]	1,56					2,38
Concrete pry-out failure								
Factor k acc. to TR 029 or k_3 acc. to CEN/TS 1992-4-5	$k_{(3)}$	[-]	2,0					
Concrete edge failure								
Effective length of anchor	l_f	[mm]	$l_f = \min(h_{ef}; 8\ d_{nom})$					
Outside diameter of anchor	d_{nom}	[mm]	10	12	16	20	24	30
Installation factor	$\gamma_2 = \gamma_{inst}$	[-]	1,0					

[1)] Fastening screws or threaded rods (incl. nut and washer) must compley with the appropriate material and property class of the internally threaded anchor rod. The characteristic shear resistance for steel failure of the given strength class are valid for the internally threaded anchor rod and the fastening element

[2)] For IG M20: Internally threaded rod: strength class 50; Fastening screws or threaded rods (incl. nut and washer): strength class 70

Table C9: Characteristic values for **rebar** under **tension loads** in **cracked concrete**

Rebar				Ø 8	Ø 10	Ø 12	Ø 14	Ø 16	Ø 20	Ø 25	Ø 28	Ø 32
Steel failure												
Characteristic tension resistance		$N_{Rk,s}$	[kN]	$A_s \cdot f_{uk}$ [1)]								
Combined pull-out and concrete cone failure												
Characteristic bond resistance in cracked concrete C20/25												
Temperature range I: 40°C/24°C	dry and wet concrete	$\tau_{Rk,cr}$	[N/mm²]	4,0	5,0	5,5	5,5	5,5	5,5	5,5	6,5	6,5
	flooded bore hole	$\tau_{Rk,cr}$	[N/mm²]	4,0	4,0	5,5	5,5	5,5	no performance determined (NPD)			
Temperature range II: 80°C/50°C	dry and wet concrete	$\tau_{Rk,cr}$	[N/mm²]	2,5	3,5	4,0	4,0	4,0	4,0	4,0	4,5	4,5
	flooded bore hole	$\tau_{Rk,cr}$	[N/mm²]	2,5	3,0	4,0	4,0	4,0	no performance determined (NPD)			
Temperature range III: 120°C/72°C	dry and wet concrete	$\tau_{Rk,cr}$	[N/mm²]	2,0	2,5	3,0	3,0	3,0	3,0	3,0	3,5	3,5
	flooded bore hole	$\tau_{Rk,cr}$	[N/mm²]	2,0	2,5	3,0	3,0	3,0	no performance determined (NPD)			
Increasing factors for $\tau_{Rk,cr}$		ψ_c	C25/30	1,02								
			C30/37	1,04								
			C35/45	1,07								
			C40/50	1,08								
			C45/55	1,09								
			C50/60	1,10								
Factor acc. to CEN/TS 1992-4-5		k_8	[-]	7,2								
Concrete cone failure												
Factor acc. to CEN/TS 1992-4-5		k_{cr}	[-]	7,2								
Edge distance		$c_{cr,N}$	[mm]	1,5 h_{ef}								
Axial distance		$s_{cr,N}$	[mm]	3,0 h_{ef}								
Installation factor (dry and wet concrete)		$\gamma_2 = \gamma_{inst}$	[-]	1,0	1,2							
Installation factor (flooded bore hole)		$\gamma_2 = \gamma_{inst}$	[-]	1,4					no performance determined (NPD)			

1) $f_{uk} = f_{tk} = k \cdot f_{yk}$

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Performance
Characteristic values for **rebar** under **tension loads** in **cracked concrete**

Annex C9

Table C10: Characteristic values for **rebar** under **tension loads** in **uncracked concrete**

Rebar				**Ø 8**	**Ø 10**	**Ø 12**	**Ø 14**	**Ø 16**	**Ø 20**	**Ø 25**	**Ø 28**	**Ø 32**
Steel failure												
Characteristic tension resistance		$N_{Rk,s}$	[kN]	$A_s \cdot f_{uk}$ 1)								
Combined pull-out and concrete cone failure												
Characteristic bond resistance in uncracked concrete C20/25												
Temperature range I: 40°C/24°C	dry and wet concrete	$\tau_{Rk,ucr}$	[N/mm²]	10	12	12	12	12	12	11	10	8,5
	flooded bore hole	$\tau_{Rk,ucr}$	[N/mm²]	7,5	8,5	8,5	8,5	8,5	no performance determined (NPD)			
Temperature range II: 80°C/50°C	dry and wet concrete	$\tau_{Rk,ucr}$	[N/mm²]	7,5	9,0	9,0	9,0	9,0	9,0	8,0	7,0	6,0
	flooded bore hole	$\tau_{Rk,ucr}$	[N/mm²]	5,5	6,5	6,5	6,5	6,5	no performance determined (NPD)			
Temperature range III: 120°C/72°C	dry and wet concrete	$\tau_{Rk,ucr}$	[N/mm²]	5,5	6,5	6,5	6,5	6,5	6,5	6,0	5,0	4,5
	flooded bore hole	$\tau_{Rk,ucr}$	[N/mm²]	4,0	5,0	5,0	5,0	5,0	no performance determined (NPD)			
Increasing factors for $\tau_{Rk,ucr}$		ψ_c	C25/30	1,02								
			C30/37	1,04								
			C35/45	1,07								
			C40/50	1,08								
			C45/55	1,09								
			C50/60	1,10								
Factor acc. to CEN/TS 1992-4-5		k_8	[-]	10,1								
Concrete cone failure												
Factor acc. to CEN/TS 1992-4-5		k_{ucr}	[-]	10,1								
Edge distance		$c_{cr,N}$	[mm]	$1{,}5\ h_{ef}$								
Axial distance		$s_{cr,N}$	[mm]	$3{,}0\ h_{ef}$								
Splitting failure												
Edge distance for		$c_{cr,sp}$	[mm]	$1{,}0 \cdot h_{ef} \le 2 \cdot h_{ef}\left(2{,}5 - \frac{h}{h_{ef}}\right) \le 2{,}4 \cdot h_{ef}$								
Axial distance		$s_{cr,sp}$	[mm]	$2\ c_{cr,sp}$								
Installation factor (dry and wet concrete)		$\gamma_2 = \gamma_{inst}$	[-]	1,0	1,2							
Installation factor (flooded bore hole)		$\gamma_2 = \gamma_{inst}$	[-]	1,4					no performance determined (NPD)			

1) $f_{uk} = f_{tk} = k \cdot f_{yk}$

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Performance
Characteristic values for **rebar** under **tension loads** in **uncracked concrete**

Annex C10

Table C11: Characteristic values for **rebar** under **shear loads** in **cracked and uncracked concrete**

Rebar			**Ø 8**	**Ø 10**	**Ø 12**	**Ø 14**	**Ø 16**	**Ø 20**	**Ø 25**	**Ø 28**	**Ø 32**
Steel failure without lever arm											
Characteristic shear resistance	$V_{Rk,s}$	[kN]	$0{,}50 \cdot A_s \cdot f_{uk}$ [1)]								
Ductility factor according to CEN/TS 1992-4-5	k_2	[-]	0,8								
Steel failure with lever arm											
Characteristic bending moment	$M^0_{Rk,s}$	[Nm]	$1{,}2 \cdot W_{el} \cdot f_{uk}$ [1)]								
Concrete pry-out failure											
Factor k acc. to TR 029 or k_3 acc. to CEN/TS 1992-4-5	$k_{(3)}$	[-]	2,0								
Concrete edge failure											
Effective length of anchor	l_f	[mm]	$l_f = \min(h_{ef};\ 8\ d_{nom})$								
Outside diameter of anchor	d_{nom}	[mm]	8	10	12	14	16	20	25	28	32
Installation factor	$\gamma_2 = \gamma_{inst}$	[-]	1,0								

1) $f_{uk} = f_{tk} = k \cdot f_{yk}$

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Performance
Characteristic values for **rebar** under **shear loads** in **cracked and uncracked concrete**

Annex C11

Table C12: Characteristic values for **rebar** under **seismic action**, category **C1**

Rebar				Ø 8	Ø 10	Ø 12	Ø 14	Ø 16	Ø 20	Ø 25	Ø 28	Ø 32
Tension load												
Steel failure												
Characteristic tension resistance		$N_{Rk,s,seis}$	[kN]	$A_s \cdot f_{uk}$ [1)]								
Combined pull-out and concrete cone failure												
Characteristic bond resistance in concrete C20/25 to C50/60												
Temperature range I: 40°C/24°C	dry and wet concrete	$\tau_{Rk,seis}$	[N/mm²]	2,5	3,1	3,7	3,7	3,7	3,7	3,8	4,5	4,5
	flooded bore hole	$\tau_{Rk,seis}$	[N/mm²]	2,5	2,5	3,7	3,7	3,7	no performance determined (NPD)			
Temperature range II: 80°C/50°C	dry and wet concrete	$\tau_{Rk,seis}$	[N/mm²]	1,6	2,2	2,7	2,7	2,7	2,7	2,8	3,1	3,1
	flooded bore hole	$\tau_{Rk,seis}$	[N/mm²]	1,6	1,9	2,7	2,7	2,7	no performance determined (NPD)			
Temperature range III: 120°C/72°C	dry and wet concrete	$\tau_{Rk,seis}$	[N/mm²]	1,3	1,6	2,0	2,0	2,0	2,0	2,1	2,4	2,4
	flooded bore hole	$\tau_{Rk,seis}$	[N/mm²]	1,3	1,6	2,0	2,0	2,0	no performance determined (NPD)			
Increasing factor for $\tau_{Rk,seis}$		ψ_c	[-]	1,0								
Installation factor (dry and wet concrete)		$\gamma_2 = \gamma_{inst}$	[-]	1,0	1,2							
Installation factor (flooded bore hole)		$\gamma_2 = \gamma_{inst}$	[-]	1,4					no performance determined (NPD)			
Shear load												
Steel failure without lever arm												
Characteristic shear resistance		$V_{Rk,s,seis}$	[kN]	$0,35 \cdot A_s \cdot f_{uk}$ [1)]								
Steel failure with lever arm												
Characteristic bending moment		$M^0_{Rk,s,seis}$	[Nm]	no performance determined (NPD)								

1) $f_{uk} = f_{tk} = k \cdot f_{yk}$

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Performance
Characteristic values for **rebar** under **seismic action**, category **C1**

Annex C12

Table C13: **Displacements** under **tension loads**[1)]
(threaded rod and internally threaded anchor rod)

Threaded rod			**M8**	**M10 IG-M6**	**M12 IG-M8**	**M16 IG- M10**	**M20 IG-M12**	**M24 IG-M16**	**M27**	**M30 IG-M20**
Uncracked concrete C20/25										
Temperature range I: 40°C/24°C	δ_{N0}-factor	[mm/(N/mm²)]	0,021	0,023	0,026	0,031	0,036	0,041	0,045	0,049
	$\delta_{N\infty}$-factor	[mm/(N/mm²)]	0,030	0,033	0,037	0,045	0,052	0,060	0,065	0,071
Temperature range II: 80°C/50°C	δ_{N0}-factor	[mm/(N/mm²)]	0,050	0,056	0,063	0,075	0,088	0,100	0,110	0,119
	$\delta_{N\infty}$-factor	[mm/(N/mm²)]	0,072	0,081	0,090	0,108	0,127	0,145	0,159	0,172
Temperature range III: 120°C/72°C	δ_{N0}-factor	[mm/(N/mm²)]	0,050	0,056	0,063	0,075	0,088	0,100	0,110	0,119
	$\delta_{N\infty}$-factor	[mm/(N/mm²)]	0,072	0,081	0,090	0,108	0,127	0,145	0,159	0,172
Cracked concrete C20/25										
Temperature range I: 40°C/24°C	δ_{N0}-factor	[mm/(N/mm²)]	0,090		0,070					
	$\delta_{N\infty}$-factor	[mm/(N/mm²)]	0,105		0,105					
Temperature range II: 80°C/50°C	δ_{N0}-factor	[mm/(N/mm²)]	0,219		0,170					
	$\delta_{N\infty}$-factor	[mm/(N/mm²)]	0,255		0,245					
Temperature range III: 120°C/72°C	δ_{N0}-factor	[mm/(N/mm²)]	0,219		0,170					
	$\delta_{N\infty}$-factor	[mm/(N/mm²)]	0,255		0,245					

1) Calculation of the displacement
$\delta_{N0} = \delta_{N0}$-Faktor $\cdot \tau$; τ: acting bond stress for tension load
$\delta_{N\infty} = \delta_{N\infty}$-Faktor $\cdot \tau$;

Table C14: **Displacements** under **shear load**[1)]
(threaded rod and internally threaded anchor rod)

Threaded rod			**M8**	**M10 IG-M6**	**M12 IG-M8**	**M16 IG- M10**	**M20 IG-M12**	**M24 IG-M16**	**M27**	**M30 IG-M20**
Uncracked concrete C20/25										
All temperature ranges	δ_{V0}-factor	[mm/(kN)]	0,06	0,06	0,05	0,04	0,04	0,03	0,03	0,03
	$\delta_{V\infty}$-factor	[mm/(kN)]	0,09	0,08	0,08	0,06	0,06	0,05	0,05	0,05
Cracked concrete C20/25										
All temperature ranges	δ_{V0}-factor	[mm/(kN)]	0,12	0,12	0,11	0,10	0,09	0,08	0,08	0,07
	$\delta_{V\infty}$-factor	[mm/(kN)]	0,18	0,18	0,17	0,15	0,14	0,13	0,12	0,10

1) Calculation of the displacement
$\delta_{V0} = \delta_{V0}$-factor $\cdot V$; V: acting shear load
$\delta_{V\infty} = \delta_{V\infty}$-factor $\cdot V$;

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Performance
Displacements (threaded rod and internally threaded anchor rod)

Annex C13

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Table C15: Displacements under tension load[1] (rebar)

Rebar			Ø 8	Ø 10	Ø 12	Ø 14	Ø 16	Ø 20	Ø 25	Ø 28	Ø 32
Uncracked concrete C20/25											
Temperature range I: 40°C/24°C	δ_{N0}-factor	[mm/(N/mm²)]	0,021	0,023	0,026	0,028	0,031	0,036	0,043	0,047	0,052
	$\delta_{N\infty}$-factor	[mm/(N/mm²)]	0,030	0,033	0,037	0,041	0,045	0,052	0,061	0,071	0,075
Temperature range II: 80°C/50°C	δ_{N0}-factor	[mm/(N/mm²)]	0,050	0,056	0,063	0,069	0,075	0,088	0,104	0,113	0,126
	$\delta_{N\infty}$-factor	[mm/(N/mm²)]	0,072	0,081	0,090	0,099	0,108	0,127	0,149	0,163	0,181
Temperature range III: 120°C/72°C	δ_{N0}-factor	[mm/(N/mm²)]	0,050	0,056	0,063	0,069	0,075	0,088	0,104	0,113	0,126
	$\delta_{N\infty}$-factor	[mm/(N/mm²)]	0,072	0,081	0,090	0,099	0,108	0,127	0,149	0,163	0,181
Cracked concrete C20/25											
Temperature range I: 40°C/24°C	δ_{N0}-factor	[mm/(N/mm²)]	0,090		0,070						
	$\delta_{N\infty}$-factor	[mm/(N/mm²)]	0,105		0,105						
Temperature range II: 80°C/50°C	δ_{N0}-factor	[mm/(N/mm²)]	0,219		0,170						
	$\delta_{N\infty}$-factor	[mm/(N/mm²)]	0,255		0,245						
Temperature range III: 120°C/72°C	δ_{N0}-factor	[mm/(N/mm²)]	0,219		0,170						
	$\delta_{N\infty}$-factor	[mm/(N/mm²)]	0,255		0,245						

[1] Calculation of the displacement
$\delta_{N0} = \delta_{N0}$-Faktor $\cdot\ \tau$; τ: acting bond stress for tension load
$\delta_{N\infty} = \delta_{N\infty}$-Faktor $\cdot\ \tau$;

Table C16: Displacements under shear load[1] (rebar)

Rebar			Ø 8	Ø 10	Ø 12	Ø 14	Ø 16	Ø 20	Ø 25	Ø 28	Ø 32
Uncracked concrete C20/25											
All temperature ranges	δ_{V0}-factor	[mm/(kN)]	0,06	0,05	0,05	0,04	0,04	0,04	0,03	0,03	0,03
	$\delta_{V\infty}$-factor	[mm/(kN)]	0,09	0,08	0,08	0,06	0,06	0,05	0,05	0,04	0,04
Cracked concrete C20/25											
All temperature ranges	δ_{V0}-factor	[mm/(kN)]	0,12	0,12	0,11	0,11	0,10	0,09	0,08	0,07	0,06
	$\delta_{V\infty}$-factor	[mm/(kN)]	0,18	0,18	0,17	0,16	0,15	0,14	0,12	0,11	0,10

[1] Calculation of the displacement
$\delta_{V0} = \delta_{V0}$-factor $\cdot$ V; V: acting shear load
$\delta_{V\infty} = \delta_{V\infty}$-factor $\cdot$ V;

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Performance
Displacements (rebar)

Annex C14