Deutsches Institut für Bautechnik
DIBt

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Approval body for construction products and types of construction

Bautechnisches Prüfamt

An institution established by the Federal and Laender Governments

Designated according to Article 29 of Regulation (EU) No 305/2011 and member of EOTA (European Organisation for Technical Assessment)

European Technical Assessment

ETA-17/0715 of 18 July 2018

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	Injection System VMH for rebar connection
Product family to which the construction product belongs	Systems for post-installed rebar connections with mortar
Manufacturer	MKT Metall-Kunststoff-Technik GmbH & Co. KG Auf dem Immel 2 67685 Weilerbach DEUTSCHLAND
Manufacturing plant	Werk 1, D und Werk 2, D
This European Technical Assessment contains	22 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	EAD 330087-00-0601

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Specific Part

1 Technical description of the product

The subject of this European Technical Assessment is the post-installed connection, by anchoring or overlap connection joint, of reinforcing bars (rebars) in existing structures made of normal weight concrete, using the "Injection system VMH for rebar connection" in accordance with the regulations for reinforced concrete construction.

Reinforcing bars made of steel with a diameter ϕ from 8 to 32 mm or the tension anchor ZA from sizes M12 to M24 according to Annex A and injection mortar VMH are used for rebar connections. The rebar is placed into a drilled hole filled with injection mortar and is anchored via the bond between rebar, 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 rebar connection 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 under static and quasi-static loading	See Annex C 1

3.2 Safety in case of fire (BWR 2)

Essential characteristic	Performance
Reaction to fire	Class A1
Resistance to fire	See Annex C 2 and C 3

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

In accordance with European Assessment Document EAD No. 330087-00-0601, the applicable European legal act is: [96/582/EC].

The system(s) to be applied is (are): 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.

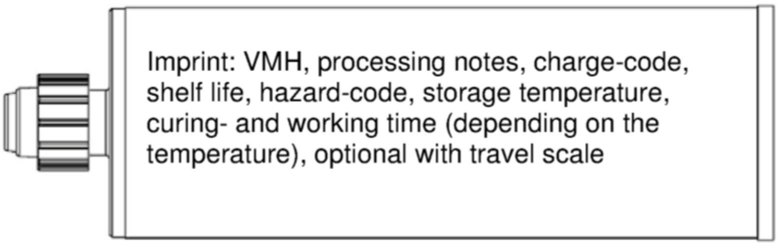
Issued in Berlin on 18 July 2018 by Deutsches Institut für Bautechnik

BD Dipl.-Ing. Andreas Kummerow
Head of Department

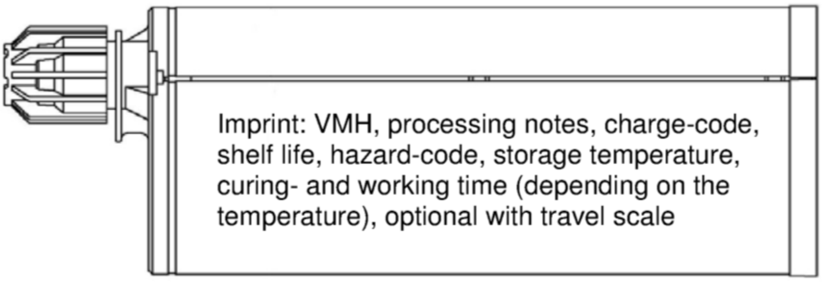
beglaubigt:
Baderschneider

Cartridge: Injection Adhesive VMH

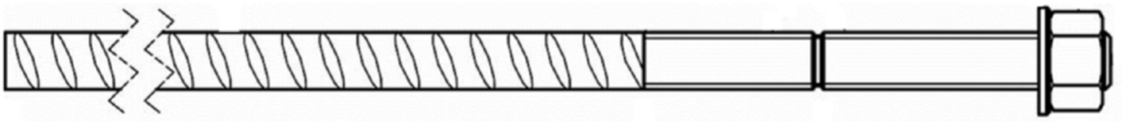
150 ml, 280 ml, 333 ml and 380 ml to 420 ml cartridge (Type: "coaxial")



235 ml, 345 ml and 825ml injection mortar cartridge (Type: "side-by-side")



Tension anchor ZA: M12, M16, M20, M24



Reinforcing bar: Ø8, Ø10, Ø12, Ø14, Ø16, Ø20, Ø22, Ø24, Ø25, Ø28, Ø32

Injection System VHM for rebar connections	
Product description Injection Adhesive with tension anchor ZA or reinforcing bar	**Annex A1**

Application examples reinforcing bar

Figure A1: Overlap joint in slabs and beams

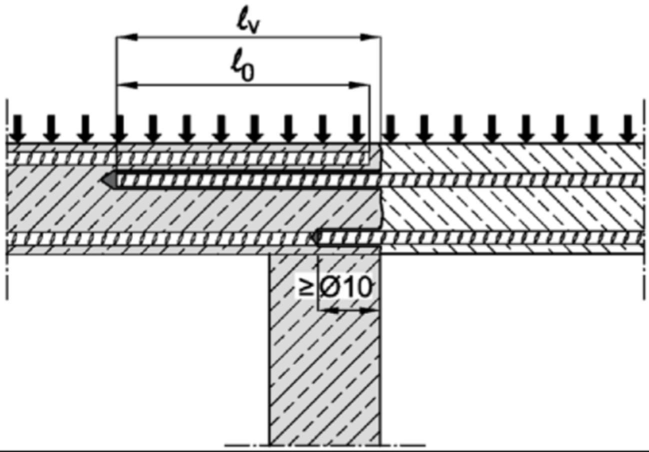


Figure A2: Overlap joint in a foundation of a column or wall where the rebars are stressed in tension

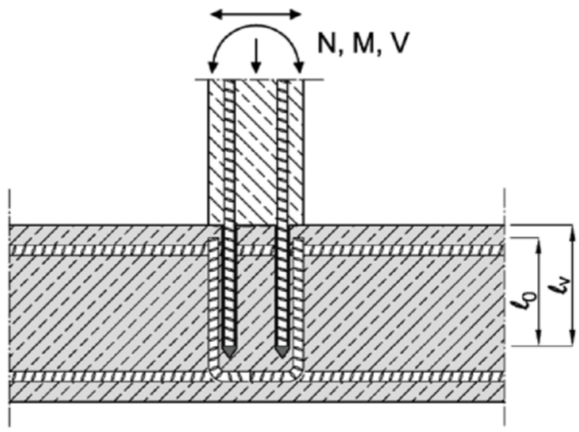


Figure A3: End anchoring of slabs or beams, designed as simply supported

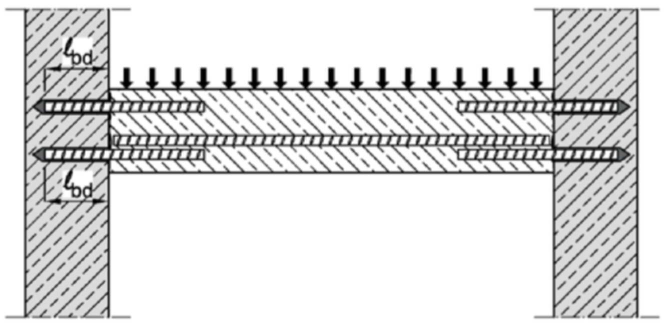


Figure A4: Rebar connection of components stressed primarily in compression. The rebars are stressed in compression.

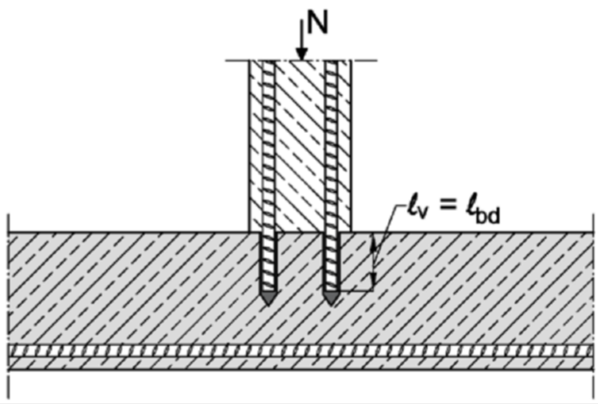
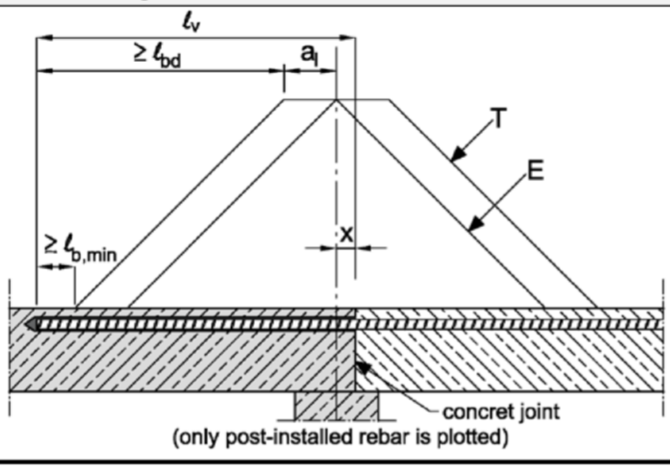


Figure A5: Anchoring of reinforcement to cover the line of acting tensile force



Note to Figure A1 to A5

No transverse reinforcement acc. to EN 1992-1-1:2004+AC:2010 is pictured.
The shear transfer between old and new concrete shall be designed according to EN 1992-1-1:2004+AC:2010.
Notations and definitions of anchorages and overlap joints see Annex B4.

Figure A5:

T= acting tensile force
E= envelope of $M_{Ed}/Z + N_{Ed}$ (see EN 1992-1-1:2004+AC:2010, Figure 9.2)
x= distance between the theoretical point of support and concrete joint

Injection System VHM for rebar connections

Product description
Application examples of post-installed rebar

Annex A2

Application examples (tension anchor ZA)

Figure A6: Overlap joint at the foundation of columns

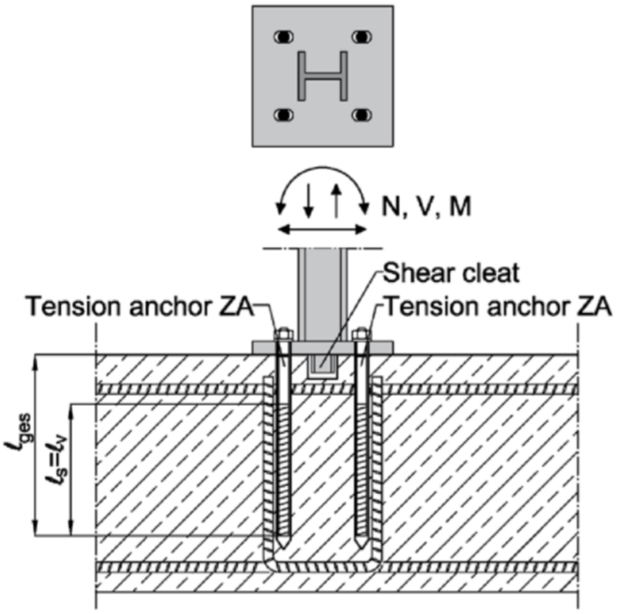


Figure A7: Overlap joint for the anchorage of guardrail posts

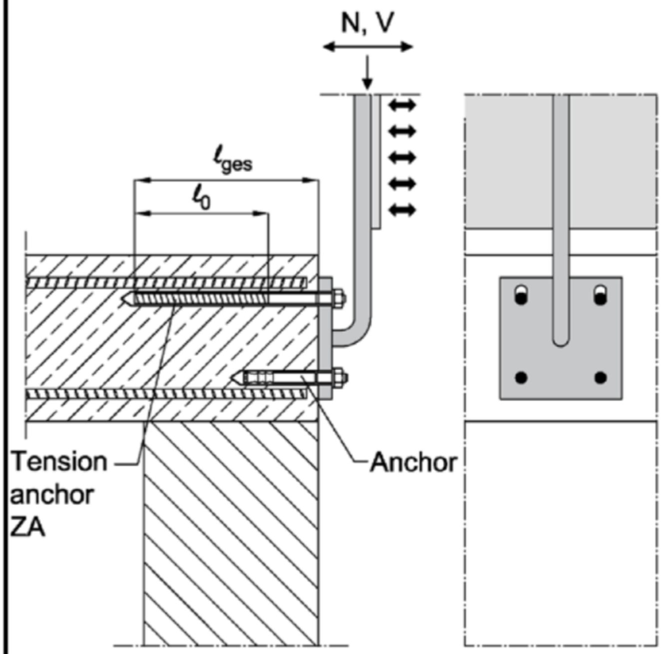
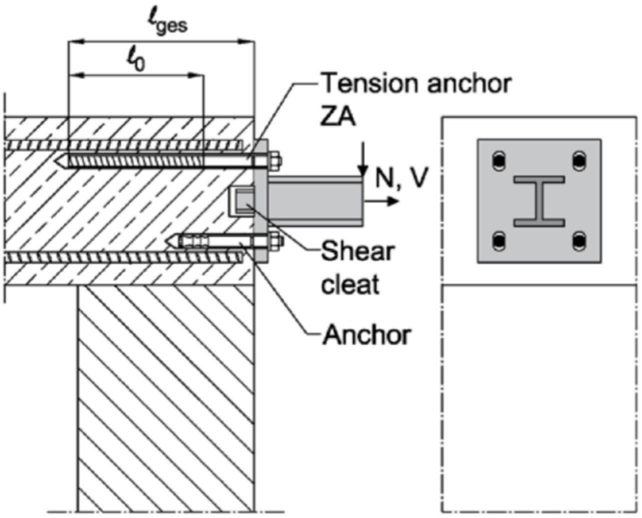


Figure A8: Overlap joint for the anchorage of cantilevers



Note to Figure A6 to A8

No transverse reinforcement according to EN 1992-1-1:2004+AC:2010 is pictured.

Notations and definitions of anchorage and overlap joints see Annex B3.

The tension anchor ZA can only transfer forces towards the bar axis.

Injection System VHM for rebar connections

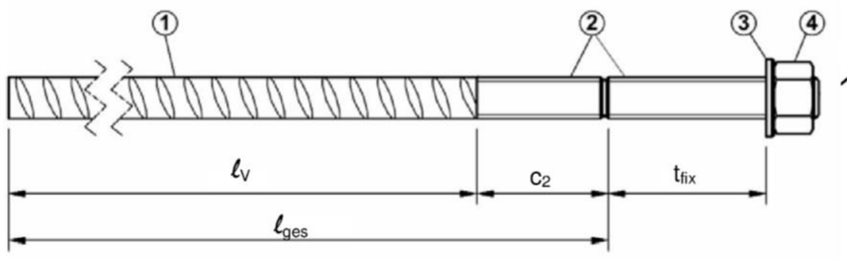
Product description
Application examples of tension anchor ZA

Annex A3

Table A1: Material

Part	Description	Material											
Tension anchor ZA		**ZA vz**				**ZA A4**				**ZA HCR**			
		M12	M16	M20	M24	M12	M16	M20	M24	M12	M16	M20	M24
1	Rebar	Class B according to NDP or NCL acc. to EN 1992-1-1/NA $f_{uk} = f_{tk} = k \cdot f_{yk}$											
2	Threaded rod	Steel, zinc plated acc. to EN 10087:1998 or EN 10263:2001				Stainless steel, 1.4362, 1.4401, 1.4404, 1.4571, EN 10088:2014				High corrosion resistant steel 1.4529, 1.4565, EN 10088:2014			
	f_{yk} [N/mm²]	640				640			560	640			560
3	Washer	Steel, zinc plated				Stainless steel				High corrosion resistant steel			
4	Hexagon nut	Steel, zinc plated acc. to EN 10087:1998 or EN 10263:2001				Stainless steel, 1.4362, 1.4401, 1.4404, 1.4571, EN 10088:2014				High corrosion resistant steel, 1.4529, 1.4565, EN 10088:2014			
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 $f_{uk} = f_{tk} = k \cdot f_{yk}$											

Figure A9: Tension anchor ZA: M12, M16, M20, M24



Marking: e.g. ◇ZA 12 A4

◇	Identifying mark of manufacturing plant
ZA	Product identity
12	Anchor size / thread
A4	for stainless steel A4
HCR	for high corrosion resistant steel

Figure A10: Rebar Ø8, Ø10, Ø12, Ø14, Ø16, Ø20, Ø22, Ø24, Ø25, Ø28, Ø32

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

Injection System VHM for rebar connections	**Annex A4**
Product description Material / Marking	

Specifications of intended use

Anchorages subject to:

Rebar	**Ø8**	**Ø10**	**Ø12**	**Ø14**	**Ø16**	**Ø20**	**Ø22**	**Ø24**	**Ø25**	**Ø28**	**Ø32**
Static or quasi static action	✓										
Fire exposure	✓										

Tension anchor ZA	**M12**	**M16**	**M20**	**M24**
Static or quasi static action	✓			
Fire exposure	✓			

Base material:

- Reinforced or unreinforced normal weight concrete acc. to EN 206-1:2000
- Strength classes C12/15 to C50/60 acc. to EN 206-1:2000
- Maximum chloride concrete of 0,40 % (CL 0,40) related to the cement content acc. to EN 206-1:2000
- Non-carbonated concrete

  Note: In case of a carbonated surface of the existing concrete structure the carbonated layer shall be removed in the area of the post-installed rebar connection with a diameter of ∅ + 60 mm prior to the installation of the new rebar. The depth of concrete to be removed shall correspond to at least the minimum concrete cover in accordance with EN 1992-1-1:2004+AC:2010.
  The foregoing may be neglected if building components are new and not carbonated and if building components are in dry conditions.

Temperature range:

- \- 40 °C to +80 °C (max. short term temperature +80 °C and max. long term temperature +50 °C)

Use conditions (Environmental conditions):

- Structures subject to dry internal conditions
  (zinc plated 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)

Injection System VHM for rebar connections	**Annex B1**
Intended use Specifications of intended use	

Specifications of intended use

Design:

- Verifiable calculation notes and drawings are prepared taking account of the loads to be anchored
- Anchorages are designed under the responsibility of an engineer experienced in anchorages and concrete work
- Anchorages are designed in accordance with EN 1992-1-1:2004+AC:2010, EN1992-1-2:2004+AC:2008 and Annex B3 and B4
- The actual position of the reinforcement in the existing structure shall be determined on the basis of the construction documentation and taken into account when designing

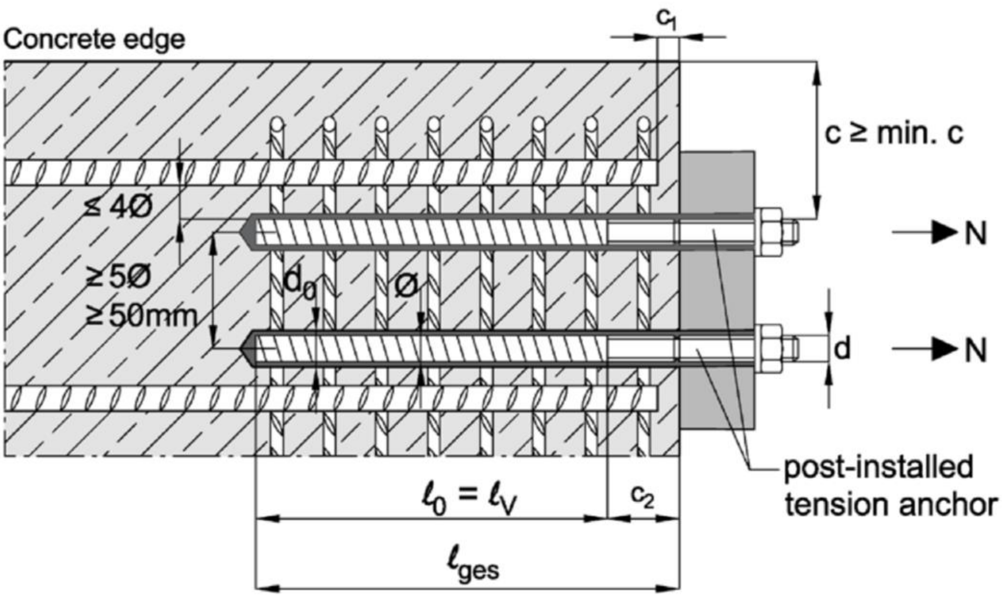
Installation:

- Dry or wet concrete
- Installation in water filled bore holes is not admissible
- Overhead installation admissible
- Hole drilling by hammer drill, vacuum drill or compressed air drill
- Check the position of the existing rebars (if the position of existing rebars is not known, it shall be determined using a rebar detector suitable for this purpose as well as on the basis of the construction documentation and then marked on the building component for the overlap joint)
- The joints for concreting must be roughened to at least such an extent that aggregate protrude
- The installation of post-installed rebar or tension anchor ZA shall be done only by suitable trained installer and under supervision on site; the conditions under which an installer may be considered as suitable trained and the conditions for supervision on site are up to the member states in which the installation is done
- Minimum concrete cover acc. to EN 1992-1-1:2004+AC:2010 must be observed

General construction rules for tension anchor ZA

- The length for the post-installed thread must not be added to the anchoring length
- The tension anchor ZA can only transfer forces towards the bar axis
- Tension forces must be transferred by an overlap joint into the present reinforcement of the member
- The transmission of shear forces must be ensured by additional measures, e.g. by shear cleats or anchors with an European Technical Assessment (ETA)
- In the anchor plate the holes for the tension anchors must be executed as elongated holes with axis in the direction of the shear force
- If the clear distance of overlapping bars is greater than 4Ø, the lap length must be increased by a length equal to the clear space where it exceeds 4Ø

Figure B1: Tension Anchor ZA



c	concrete cover of tension anchor ZA
c_1	concrete cover at front end of cast-in-place rebar
c_2	Length of bonded thread
min c	minimum concrete cover according Table B1 and EN 1992-1-1:2004+AC:2010
Ø	diameter of tension anchor (rebar part)
d	diameter of tension anchor (threaded part)
ℓ_0	lap length acc. to EN 1992-1-1:2004+AC:2010
ℓ_v	embedment depth $\ell_v \geq \ell_0 + c_1$
ℓ_{ges}	overall embedment depth $\ell_{ges} \geq \ell_0 + c_2$
d_0	nominal drill bit diameter according Annex B6, to Table B4

Injection System VHM for rebar connections

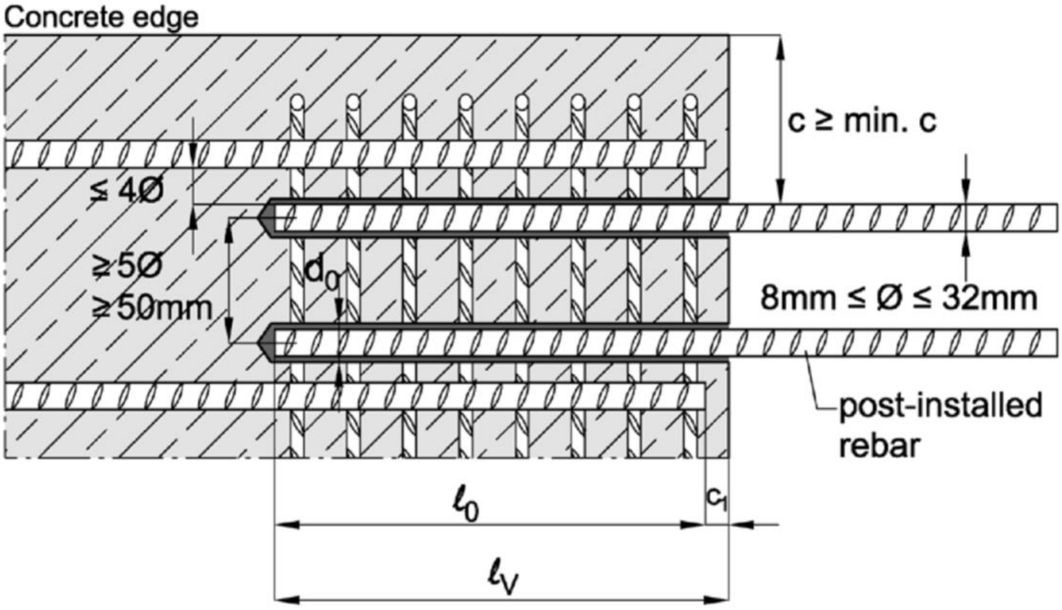
Intended use
General construction rules **(Tension anchor ZA)**

Annex B3

General construction rules for post-installed rebars

- The shear transfer between old and new concrete shall be designed acc. to EN 1992-1-1:2004+AC:2010
- Only tension forces in the axis of the rebar may be transmitted
- If the clear distance of overlapping bars is greater than 4Ø, the lap length must be increased by a length equal to the clear space where it exceeds 4Ø

Figure B2: Post-installed rebars



c	concrete cover of post-installed rebar
c_1	concrete cover at front end of cast-in-place rebar
min c	minimum concrete cover according Table B1 and EN 1992-1-1:2004+AC:2010
Ø	diameter of tension anchor (rebar)
ℓ_0	lap length acc. to EN 1992-1-1:2004+AC:2010
ℓ_v	embedment depth $\ell_v \geq \ell_0 + c_1$
d_0	nominal drill bit diameter according to Annex B6, Table B4

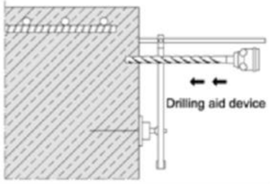
Injection System VHM for rebar connections

Intended use
General construction rules (**post-installed rebar**)

Annex B4

Deutsches Institut für Bautechnik DIBt

Table B1: Minimum concrete cover min c[1)] of post-installed rebar and tension anchor ZA depending on drilling method



Drilling method	Rod diameter	min c (<u>without</u> drilling aid device)	min c (<u>with</u> drilling aid device)
Hammer drilling Vacuum drilling	< 25 mm	30 mm + 0,06 ℓ_v ≥ 2 Ø	30 mm + 0,02 ℓ_v ≥ 2 Ø
	≥ 25 mm	40 mm + 0,06 ℓ_v ≥ 2 Ø	40 mm + 0,02 ℓ_v ≥ 2 Ø
Compressed air drilling	< 25 mm	50 mm + 0,08 ℓ_v	50 mm + 0,02 ℓ_v
	≥ 25 mm	60 mm + 0,08 ℓ_v	60 mm + 0,02 ℓ_v

1) See Annex B3 and B4; Minimum concrete cover acc. to EN 1992-1-1:2004+AC:2010 must be observed

Table B2: Dimensions and installation parameters of tension anchor ZA

Anchor size				**M12**	**M16**	**M20**	**M24**
Thread diameter		d	[mm]	12	16	20	24
Rebar diameter		∅	[mm]	12	16	20	25
Cross section area (threaded part)		A_s	[mm²]	84	157	245	353
Width across nut flats		SW	[mm]	19	24	30	36
Effective embedment depth		ℓ_v	[mm]	according to static calculation			
Length of bonded thread	steel, zinc plated	c_2	[mm]	≥ 20	≥ 20	≥ 20	≥ 20
	A4/HCR			≥ 100	≥ 100	≥ 100	≥ 100
Maximum installation torque		T_{inst}	[Nm]	50	100	150	150

Table B3: Working and curing time

Bore hole temperature	Working time	Minimum curing time dry concrete	Minimum curing time wet concrete
- 5 °C to - 1 °C	50 min	5 h	10 h
0 °C to + 4 °C	25 min	3,5 h	7 h
+ 5 °C to + 9 °C	15 min	2 h	4 h
+ 10 °C to + 14 °C	10 min	1 h	2 h
+ 15 °C to + 19 °C	6 min	40 min	80 min
+ 20 °C to + 29 °C	3 min	30 min	60 min
+ 30 °C to + 40 °C	2 min	30 min	60 min
Cartridge temperature	+5°C to +40°C		

Injection System VHM for rebar connections

Intended use
Minimum concrete cover / Installation parameters ZA / Working and curing time

Annex B5

Deutsches Institut für Bautechnik
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Table B4: Drilling and cleaning

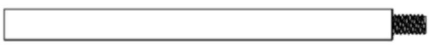
Rebar Ø	Tension anchor ZA	Drill bit diameter	Brush diameter	
			Brush- Ø	min. Brush- Ø
		d_0	d_b	$d_{b,min}$
[mm]	[-]	[mm]	[mm]	[mm]
8		12	14	12,5
10		14	16	14,5
12	M12	16	18	16,5
14		18	20	18,5
16	M16	20	22	20,5
20	M20	25	27	25,5
22		28	30	28,5
24		32	34	32,5
25	M24	32	34	32,5
28		35	37	35,5
32		40	43	40,5

Compressed air hose (min. 6 bar) with air valve

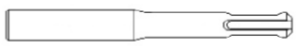
Recommended compressed air tool (min. 6 bar)

Brush RB

Brush extension



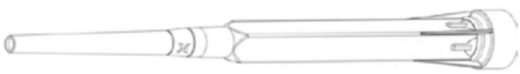
SDS Plus Adapter



Retaining washer VM-IA

Extension pipe

Static mixer



Injection System VHM for rebar connections

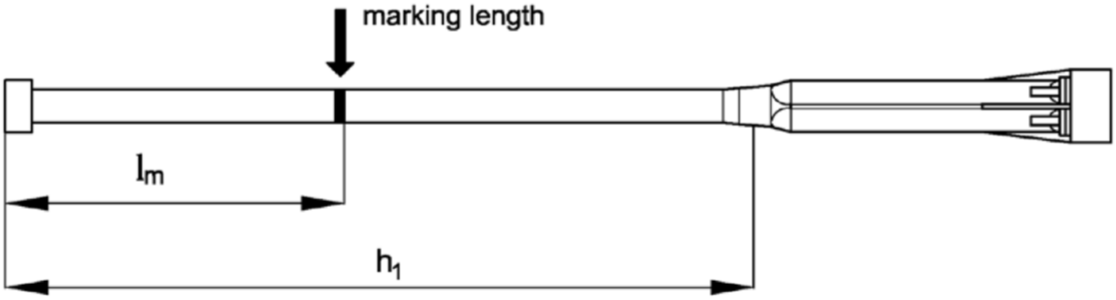
Intended use
Cleaning and installation tools

Annex B6

Table B5: Installation tools and max. embedment depth

Rebar Ø	Tension anchor ZA	Drill bit diameter d_0	Retaining washer[1)]	Cartridges: all formats – Hand- or akku-tool $\ell_{v,max}$	Cartridges: all formats – Hand- or akku-tool Extension pipe	Cartridges: all formats – Compressed air tool $\ell_{v,max}$	Cartridges: all formats – Compressed air tool Extension pipe	Cartridge: side-by-side (825 ml) – Compressed air tool $\ell_{v,max}$	Cartridge: side-by-side (825 ml) – Compressed air tool Extension pipe
[mm]	[-]	[mm]		[cm]		[cm]		[cm]	
8		12	-	70	VM-XE 10	80	VM-XE 10	80	VM-XE 10
10		14	VM-IA 14			100		100	
12	M12	16	VM-IA 16					120	
14		18	VM-IA 18		VM-XE 10 VM-XLE 16		VM-XE 10 VM-XLE 16	140	VM-XLE 16
16	M16	20	VM-IA 20					160	
20	M20	25	VM-IA 25	50		70		200	
22		28	VM-IA 28						
24		32	VM-IA 32			50			
25	M24	32	VM-IA 32						
28		35	VM-IA 35					200	
32		40	VM-IA 40						

1) For horizontal or overhead installation as well as for drill holes deeper than 240mm



On the static mixer and the extension pipe the mortar filling mark l_m and the drill hole depth h_1 must be marked with an adhesive tape or text marker. Rough estimate: $l_m = \frac{1}{3} \cdot h_1$
Fill in the mortar as long until the filling mark l_m will be visible.

Optimal mortar volume: $l_m = h_1 * (1{,}2 * \frac{Ø^2}{d_0^2} - 0{,}2)$ [mm]

l_m Length from the end of the retaining washer to the mark on the mixer extension
h_1 drill hole depth = embedment depth ℓ_v resp. ℓ_{ges})
Ø rebar diameter
d_o nominal drill bit diameter

Injection System VHM for rebar connections

Intended use
Installation tools, max. embedment depth, marking of extension pipe

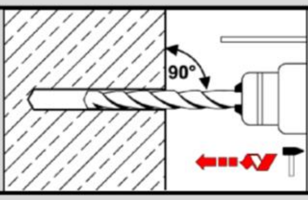
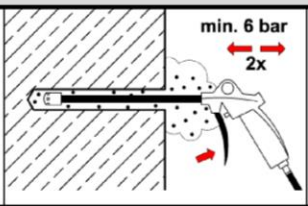
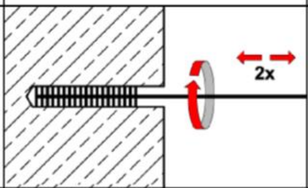
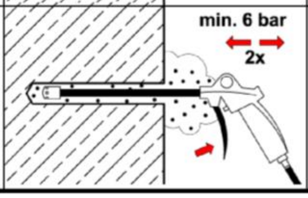
Annex B7

Table B6: Dispensing tools

Cartridge Type	Cartridge Size	Hand tool		Pneumatic tool
coaxial	150, 280, 333 ml	e.g.: VM-P 330		e.g.: VM-P 345 Pneumatic
coaxial	380 to 420 ml	e.g.: VM-P 380 Standard	e.g.: VM-P 380 Profi	e.g.: VM-P 380 Pneumatic
side-by-side	235, 345 ml	e.g.: VM-P 345 Standard	e.g.: VM-P 345 Profi	e.g.: VM-P 345 Pneumatic
side-by-side	825 ml	-	-	e.g.: VM-P 825 Pneumatic

All cartridges can also be extruded by battery tool (e.g. VM-P Akku)

Installation instructions

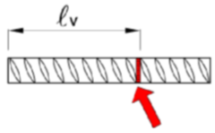
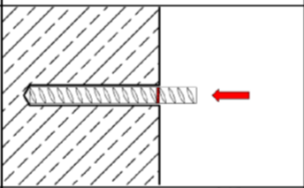
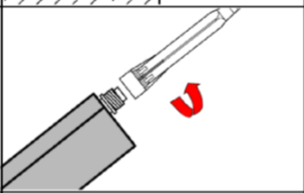
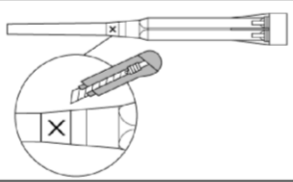
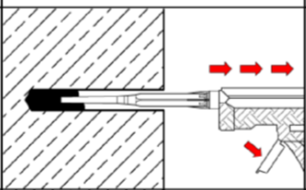
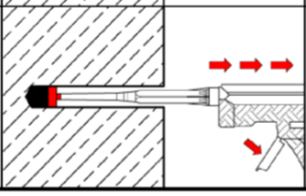
Bore hole drilling			
1.			Drill hole by hammer drilling, vacuum drilling or compressed air drilling (with drill bit diameter according to Annex B7 and selected embedment depth). In case of aborted holes, the bore holes must be filled with mortar.
Cleaning			
2.	2a.		Starting from the bottom or back of the bore hole, blow out the hole with compressed air (min. 6 bar) (Annex B6) a minimum of **two** times until return air stream is free of noticeable dust. If the bore hole ground is not reached, an extension must be used.
	2b.		Brush the hole with an appropriate sized wire brush ≥ $d_{b,min}$ (Table B4, check minimum brush diameter $d_{b,min}$) a minimum of **two** times with rotary motion. If the bore hole ground is not reached, a brush extension must be used.
	2c.		Starting from the bottom or back of the bore hole, blow out the hole with compressed air (min. 6 bar) again a minimum of **two** times until return air stream is free of noticeable dust. If the bore hole ground is not reached, an extension must be used.

Injection System VHM for rebar connections

Intended use
Installation instruction
Bore hole drilling and cleaning

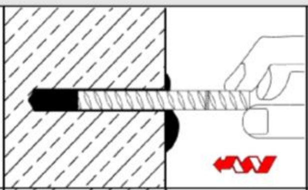
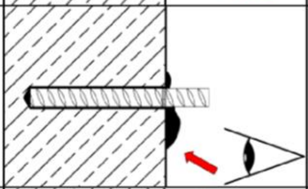
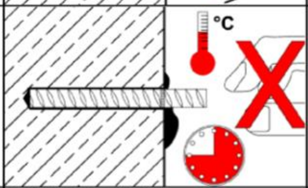
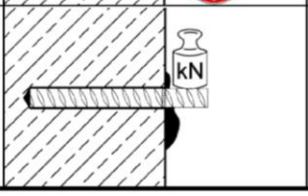
Annex B9

Installation instruction (continuation)

Preparing and injection into borehole		
5		Mark the position of the embedment depth ℓ_v on the rebar.
6		Check drill hole depth by inserting rebar or anchor rod into the empty hole.
7		Prepare cartridge with static mixer (if necessary with extension pipe and retaining washer). Attach the supplied static-mixing nozzle to the cartridge and load the cartridge into the correct dispensing tool (Table B6). For every working interruption longer than the recommended working time (Table B3) as well as for new cartridges, a new static-mixer shall be used.
7a		When extension pipe VM-XLE 16 is used, the tip of the mixer has to be cut off at position „X“.
8		Prior to applying, discard mortar (forerun) until the mortar shows a consistent grey colour, but at least three full strokes. Never use this mortar!
9		Fill in injection mortar from the bottom of the clean borehole approx 2/3 air bubble free. Slowly moving the static mixer out of the borehole prevents the formation of air inclusions. For embedment larger than 190mm an extension pipe (Annex B6) must be used. Observe the working- and curing time given in table B3.
10		For overhead and horizontal installation and embedment larger than 240mm a retaining washer shall be used. Observe the working- and curing time given in table B3.

Injection System VHM for rebar connections	**Annex B10**
Intended use Installation instruction (continuation) Preparing and injection into the borehole	

Installation instruction (continuation)

Installation of rebar or tension anchor		
11		Immediately insert the rebar or tension anchor into the hole while turning slightly until the embedment depth is reached. The bar shall be free of dirt, grease and oil.
12		Excess injection mortar must exceed from the borehole, the annular gap shall be filled completely with mortar. If no mortar exceeds, these requirements are not maintained and the application has to be renewed. For overhead installation fix embedment part (e.g. wedges).
13		Ensure the curing time of the injection mortar according to table B3. Attention: the working time may vary due to different underground temperatures (Table B3). Do not move or load the anchor or rebar until curing time.
14		After the curing time (Table B3) the threaded rod or reinforcing bar can be load.

Minimum anchorage length and minimum lap length

The minimum anchorage length $\ell_{b,min}$ and the minimum lap length $\ell_{0,min}$ according to EN 1992-1-1:2004+AC:2010 ($\ell_{b,min}$ acc. to Eq. 8.6 and Eq. 8.7 and $\ell_{0,min}$ acc. to Eq. 8.11) shall be multiplied by the amplification factor α_{lb} acc. to Table C1.

Table C1: Amplification factor a_{lb} depending on concrete strength class and drilling method

Concrete strength class	Drilling method	Rod diameter	Amplification factor α_{lb} [-]
C12/15 to C50/60	hammer drilling vacuum drilling compressed air drilling	Ø8 to Ø32 ZA-M12 to ZA-M24	1,0

Table C2: Reduction factor k_b for all drilling methods

Rod diameter		Concrete strength class								
		C12/15	C16/20	C20/25	C25/30	C30/37	C35/45	C40/50	C45/55	C50/60
Ø8 to Ø32 ZA-M12 to ZA-M24	k_b [-]	1,0								

Table C3: Design values of the ultimate bond stress $f_{bd,PIR}$ in N/mm² for all drilling methods and for good bond conditions

$$f_{bd,PIR} = k_b \cdot f_{bd}$$

with
f_{bd}: Design value of the ultimate bond stress in N/mm² considering the concrete strength classes and the rebar diameter according to EN 1992-1-1:2004+AC:2010
(for all other bond conditions multiply the values by 0,7)
k_b: Reduction factor according to Table C2

Rod diameter		Concrete strength class								
		C12/15	C16/20	C20/25	C25/30	C30/37	C35/45	C40/50	C45/55	C50/60
Ø8 to Ø32 ZA-M12 to ZA-M24	$f_{bd,PIR}$ [N/mm²]	1,6	2,0	2,3	2,7	3,0	3,4	3,7	4,0	4,3

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Design value of ultimate bond stress $f_{bd,fi}$ under fire exposure for concrete classes C12/15 to C50/60 (all drilling methods):

The design value of ultimate bond stress $f_{bd,fi}$ under fire exposure will be calculated by the following equation:

$$f_{bd,fi} = k_{fi}(\theta) \cdot f_{bd,PIR} \cdot \gamma_c / \gamma_{M,fi}$$

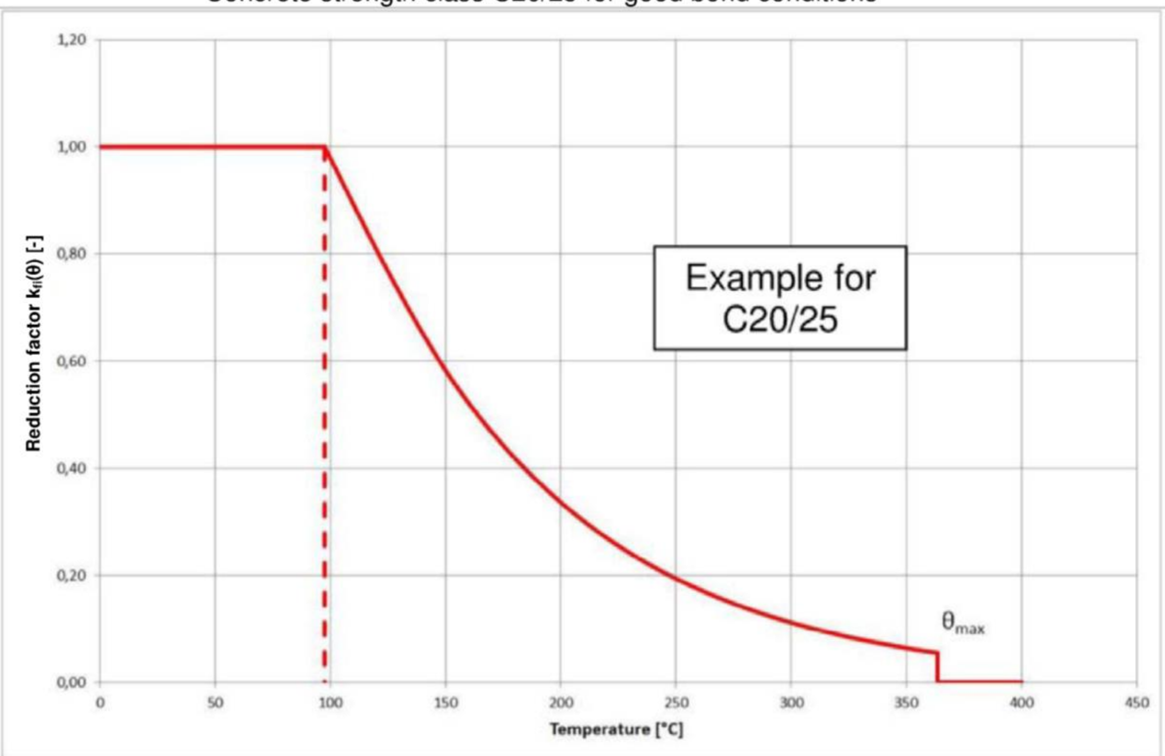
with: $\theta \leq 364°C$: $k_{fi}(\theta) = 30{,}34 * \theta^{(\theta*-0{,}011)} / (f_{bd,PIR} * 4{,}3) \leq 1{,}0$

$\theta > 364°C$: $k_{fi}(\theta) = 0$

$f_{bd,fi}$	design value of ultimate bond stress in case of fire in N/mm²
θ	Temperature in °C in the mortar layer
$k_{fi}(\theta)$	Reduction factor under fire exposure
$f_{bd,PIR}$	Design value of the ultimate bond stress in N/mm² in cold condition according to Table C2 considering concrete class, rebar diameter, drilling method and the bond conditions according to EN 1992-1-1:2004+AC:2010.
γ_c	partial factor acc. to EN 1992-1-1:2004+AC:2010
$\gamma_{M,fi}$	partial factor acc. to EN 1992-1-2:2004+AC:2008

For evidence under fire exposure the anchorage length shall be calculated according to EN 1992-1-1:2004+AC:2010 Equation 8.3 using the temperature-dependent ultimate bond stress $f_{bd,fi}$.

Figure C1: Example graph of reduction factor $k_{fi}(\theta)$
Concrete strength class C20/25 for good bond conditions



Injection System VHM for rebar connections	**Annex C2**
Performances Design value of ultimate bond stress $f_{bd,fi}$ under fire exposure for rebar	

Table C4: Characteristic tension strength in case of fire for tension anchor ZA, concrete strength class C12/15 to C50/60, acc. to Technical Report TR 020

Tension anchor ZA				**M12**	**M16**	**M20**	**M24**
Steel failure							
Steel, zinc plated							
Characteristic tension strength	R30	$\sigma_{Rk,s,fi}$	[N/mm²]	20			
	R60			15			
	R90			13			
	R120			10			
Stainless steel A4, HCR							
Characteristic tension strength	R30	$\sigma_{Rk,s,fi}$	[N/mm²]	30			
	R60			25			
	R90			20			
	R120			16			

Design value of the tension strength $\sigma_{Rd,s,fi}$ under fire exposure for tension anchor ZA

The design value of the steel strength $\sigma_{Rd,s,fi}$ under fire exposure will be calculated by the following equation:

$$\sigma_{Rd,s,fi} = \sigma_{Rk,s,fi} / \gamma_{M,fi}$$

with:

$\sigma_{Rk,s,fi}$ characteristic steel strength acc. to Table C4
$\gamma_{M,fi}$ partial factor under fire exposure acc. to EN 1992-1-2:2004+AC:2008

Injection System VHM for rebar connections

Performances
Steel strength for tension anchor ZA under fire exposure

Annex C3