Deutsches Institut für Bautechnik

Public-law institution jointly founded by the federal states and the Federation

European Technical Assessment Body for construction products

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European Technical Assessment ETA-10/0006 of 6 January 2026

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	VBT BE 1 to 16
Product family to which the construction product belongs	Tensioning systems (external strand tensioning method)
Manufacturer	Gleitbau Ges. m.b. H. VBT-Systems Itzlinger Hauptstraße 105 5020 SALZBURG ÖSTERREICH
Manufacturing plant	Gleitbau Ges. m.b. H. VBT-Systems Itzlinger Hauptstraße 105 5020 SALZBURG ÖSTERREICH
This European Technical Assessment contains	35 pages including 27 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 160004-00-0301
This version replaces	ETA-10/0006 issued on 1 September 2015

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Specific Part

1 Technical description of the product

1.1 Definition of the construction product

The present European technical assessment applies to a kit:

VBT-BE External Bondless Strand Post-Tensioning System

consisting of 1 to 16 strands with a nominal tensile strength 1770 N/mm² or 1860 N/mm² (Y1770S7 or Y1860S7), nominal diameter 15,7 mm (0,62“ - 150 mm²) which are used in normal-weight concrete with following anchorages (stressing anchor and fixed anchor; see Annex 1):

1 Stressing (active) anchor and fixed (passive) anchor with anchor plate (type P) and anchor block for tendons of 1, 2, 4, 8, 12 and 16 strands.

Additional components of the present Post-tensioning system are:

1 Bursting reinforcement (helixes and additional reinforcement/stirrups)
2 Corrosion protection
3 Deviation Saddles

The anchorage of the strands in anchor blocks is done by means of wedges.

The components and the system setup of the product are given in Annex A.

1.2 Designation

End anchorages can be used as stressing and fixed anchors.

e.g.: VBT-BE 4x4-150-1860 or
VBT-BE 16-150-1860

The first number of the designation identifies the number of strands (16) or the number of strand for each band and the number of bands (4x4). An additional first letter of designation defines the type of anchorage (P - plate anchorage). The nominal cross section area of single strand is given by the following number (e.g. "150" for 150 mm²) and the strength of the strands is given by the last number (e.g. "1860" for Y1860S7).

The components (including helix and additional reinforcement) fit for tendons with both nominal section area and steel grade of strands.

1.3 Strands

Only 7-wire stands shall be used in accordance with national provisions with the characteristics given in Table 1.

Table 1: Dimensions and properties of 7-wire strands

Designation	Symbol	Unit	Value
Tensile strength	R_m	MPa	1770 or 1860
Strand			
Nominal diameter	D	mm	15.7
Nominal cross section	A_p	mm²	150
Nominal mass	M	g/m	1172
Individual wires			
External wire diameter	d	mm	5.2 ± 0.04
Core wire diameter	d'	mm	1.02 to 1.04 d

If the use of strands with R_m = 1860 N/mm² is intended on site, these shall solely be used there.

Only prestressing strands with very low relaxation shall be used.

The prestressing strands are equipped with corrosion protection, consisting of grease and the protection sheath (sheath 1) of high-density polyethylene.

The sheath has defined minimum initial wall thicknesses (see Annex B, section 4.3.2). The manufacturer covers these mono strands with a second outer protection sheath (sheath 2) of high-density polyethylene of a thickness of 3 mm (see Annex A 2), which can encompass two or four mono strands into one band.

The sheath 2 is cut open in the middle of one of both narrow sides in longitudinal direction and the mono strands (2 or 4 see Annex A 2) are embedded. Afterwards the sheath 2 is closed by mirror-imaged welding or by V-welds again. Welding works shall be carried out only by plastic welders instructed by the manufacturer.

1.4 Ring wedges

Ring wedges (see Annex A 8) consisting of three parts are used. Single parts are fixed together by a spring ring.

1.5 Anchor blocks

The anchor blocks of stressing and fixed anchorages are identical. Determination is only needed due to execution of construction works.

The conical drills of the anchor blocks shall be clean, stainless and provided with grease.

1.6 Anchor plate

The anchor plates have a quadratic form (see Annex A 5 and Annex A 10).

1.7 Helixes and additional reinforcement (stirrups)

The steel grade and dimensions of the helixes and of the additional reinforcement shall comply with the values given in Annex A 12. The central position in the structural concrete member on site shall be ensured according Annex B, section 3.1.3.

Each end of the helix shall be welded to a closed ring. The welding of inner end of helix can be omitted if the length of helix is increased by 1 ½ additional turns.

1.8 Trumpets

The trumpets at stressing and fixed anchors are manufactured from 8 mm thick PE-Material (see Annex A 4). If the trumpets are made of steel special requirements on the mono strand wall thickness or inserts are necessary (see Annex B, 4.3.1).

The trumpets shall be designed such that the angular deviation of the strands from the anchor blocks must not exceed 2.9°. Apart from that the tendon path must to be without kink.

In addition to the well-planned length of the straight part of the trumpet $l_{straight}$ (see Annex A 4 and Annex B section 4.3.2.1, Table B6) the trumpet-like expansions about the length D_a (see Annex 4) are to be intended at the end to allow variations of the tendon from the well-planed position. The value from $D_a = \Delta\alpha * R$ depends on the radius of curvature R and the angle $\Delta\alpha$ [radian]. If at the place of the use no other regulation is valid $\Delta\alpha = 0.05$ rad (corresponds to 3°) is recommended. The radius R shall not be less than the appropriate minimum radius given in Annex B, section 4.3.2.1.

1.9 Corrosion protection

If corrosion protection in the area of anchorages is done by grout according to EN 445:2007 it shall be proceeded according to EN 447:2007.

If corrosion protection is done by special filling materials only for the system applicable greases shall be used. The greases shall comply with EAD 1600027-00-0301 and with national provisions. Parts of the prestressing strands at the end anchors, which are not protected through a high-density polyethylene sheath (protective sheath 1), shall be completely covered by transitions pipes, protections caps, cover pipes etc (see Annex A 6).

At the final stage the length of overlapping of protective sheath 1 into the transition pipes shall be ≥ 200 mm (see Annex A 6) and the length of overlapping of protective sheath 2 into the trumpet shall be ≥ 500 mm (see Annex A 4). If these lengths cannot be provided special measures has to be carried out in respect to the project conditions.

Appropriate sealants shall be applied accurately. The cavities shall be completely filled with grease (see Annex A 13).

1.10 Corrosion protection of uncovered steel parts

Any steel parts, which are not protected by concrete, cement grout or corrosion protection grease, shall be, unless made of stainless steel, protected against corrosion by one of the following protections systems of EN ISO 12944-5:

a) without metallic coating: A5M.02, A5M.04, A5M.06, A5M.07

b) galvanized: A7.10, A7.11, A7.12, A7.13

Surface preparation shall be carried out in accordance with EN ISO 12944-4; corrosion protection operations shall be carried out in accordance with EN ISO 12944-7. Local assessed and well-known corrosion protection principles can be used instead.

1.11 Description of the Prestressing System

Construction of the tendons, design of the anchors, deviation saddles, anchoring elements and corrosion protection shall be in accordance with the descriptions and drawings in the attached Annexes. The measurements and material parameters as well as the production process of tendons and corrosion protection shall comply with the described details.

The tendons can be tensioned from one or both sides.

1.12 Deviation Saddles

Deviations saddles shall be designed as specified in Annex A 9. Especially the minimum radii in Annex B, section 4.3.2.1 in every case shall be kept.

Deviation saddles may be covered by a sliding agent in the areas touched by tendons before the installation of the tendons, to assist more far-reaching outside sliding.

In addition to the well-planned length of the deviation saddles trumpet-like expansions about the length D_a (see Annex A 9) are to be intended at the ends to allow variations of the tendon from the well-planed position. The value from $D_a = \Delta\alpha * R$ depends on the radius of curvature R and the angle $\Delta\alpha$ [radian]. If at the place of the use no other regulation is valid $\Delta\alpha = 0.05$ rad (corresponds to 3°) is recommended. The radius R shall not be less than the appropriate minimum radius given in Annex B, section 4.3.2.1.

1.13 Protection cap

The protection caps are made of plastics or metal sheets and fitted by screws onto the anchor block.

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 PT-System is used in compliance with the specifications and conditions given in Annex B.

2.1 Specification

Specific details for installation and use are given in Annex B.

2.2 working life

The verifications and assessment methods on which this European Technical Assessment is based lead to the assumption of a working life of the PT-System of at least 100 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 structure.

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

3.1 Mechanical resistance and stability (BWR 1)

No.	Essential characteristic	Performance
1	Resistance to static load	The acceptance criterion to EAD 160004-00-03-01 clause 2.2.1 is fulfilled, see Annex B1
2	Resistance to fatigue	The acceptance criterion to EAD 160004-00-03-01 clause 2.2.2 is fulfilled, see Annex B1, at the tendon deviations, a stress range of 35 N/mm² at 2×10^6 load cycles can be assumed as verified
3	Load transfer to structure	The acceptance criterion to EAD 160004-00-03-01 clause 2.2.3 is fulfilled, see Annex B1
4	Friction coefficient	The acceptance criterion to EAD 160004-00-03-01 clause 2.2.4 is fulfilled, see Annex C
5	Deviation/ deflection (limits) for internal bonded and internal unbonded tendon	No performance assessed
6	Deviation/ deflection (limits) for external tendon	The acceptance criterion to EAD 160004-00-03-01 clause 2.2.6 is fulfilled, see Annex B1
7	Assessment of assembly	No performance assessed
8	Resistance to static load under cryogenic conditions for applications with anchorage/coupling outside the possible cryogenic zone	No performance assessed
9	Resistance to static load under cryogenic conditions for applications with anchorage/coupling inside the possible cryogenic zone	No performance assessed
10	Material properties, component performance, system performance of plastic duct	No performance assessed
11	Material properties, component performance, system performance of plastic duct to provide an encapsulated tendon	No performance assessed
12	Material properties, component performance, system performance of plastic duct to provide an electrically isolated tendon	No performance assessed
13	Corrosion protection	No performance assessed

Monostrand, sheating base material		
14	Melt index	No performance assessed
15	Density	No performance assessed
16	Carbon black	No performance assessed
17	Tensile strenght	No performance assessed
18	Elongation	No performance assessed
19	Thermal stability	No performance assessed
Monostrand, manufactured sheating		
20	Tensile strenght	No performance assessed
21	Elongation	No performance assessed
22	Surface of sheating	No performance assessed
23	Environtal stress cracking	No performance assessed
24	Temperatur resistance	No performance assessed
25	Resistance to externally applied agents (mineral oil, acid, base, solvents and salt water)	No performance assessed
26	Sheating minimum thickness	No performance assessed
Monostrand, manufactured monostrand		
27	External diameter of sheating	No performance assessed
28	Mass of sheating per metre	No performance assessed
29	Mass of filling material per metre	No performance assessed
30	Alteration of dropping point caused by monostrand manufacturing	No performance assessed
31	Alteration of oil separation caused by monostrand facturing	No performance assessed
32	Impact resistance	No performance assessed
33	Friction between shealting and strand	No performance assessed
34	Leak tightness	No performance assessed

3.2 Safety in case of fire (BWR 2)

No.	Essential characteristic	Performance
35	Reaction to fire	No performance assessed

3.3 Hygiene, health and the environment (BWR 3)

No.	Essential characteristic	Performance
36	Content, emmission and/or release of dangerous substances	No performance assessed

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

In accordance with the European assessment document EAD 160004-00-0301 the applicable European legal act is: [98/456/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 EAD

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 6 January 2026 by Deutsches Institut für Bautechnik

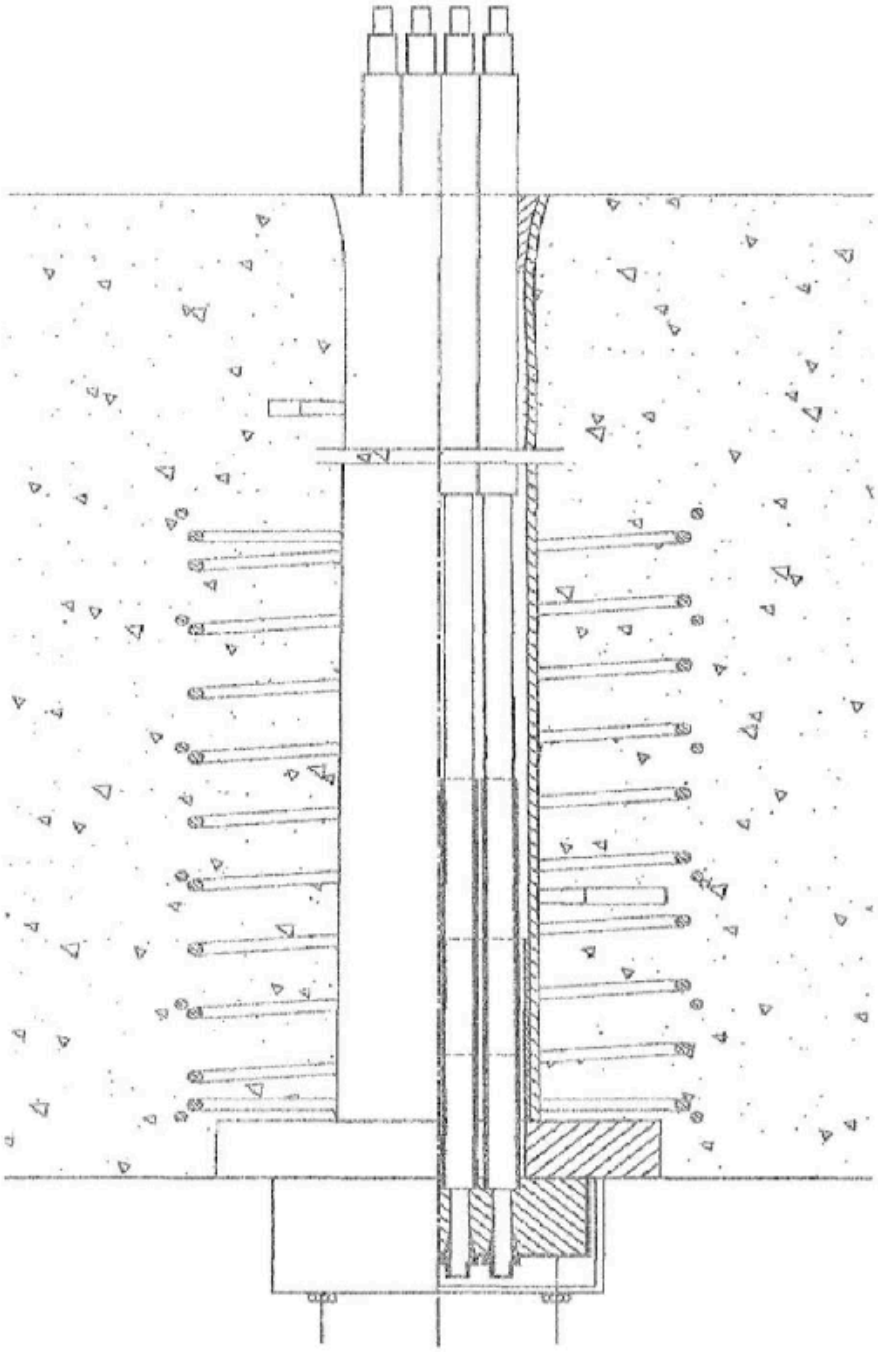
Dr. -Ing. Lars Eckfeldt
Head of Section

beglaubigt:
Knischewski

Deutsches Institut für Bautechnik

DIBt

FIXED AND STRESSING ANCHORAGE



VBT BE 1 to 16

Description of the product
Overview

Annex A 1

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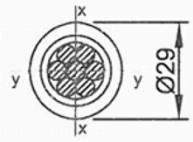
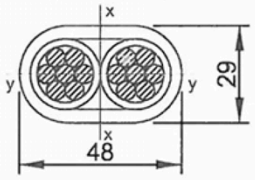
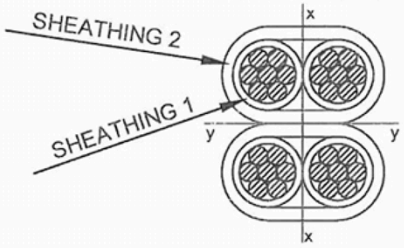
VBT-BE 1-150



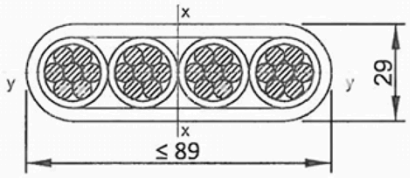
VBT-BE 2-150



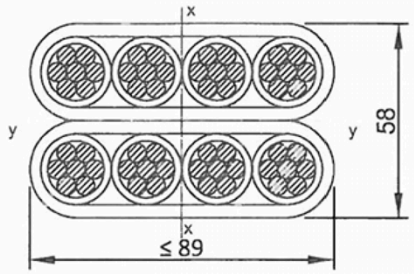
VBT-BE 2x2-150



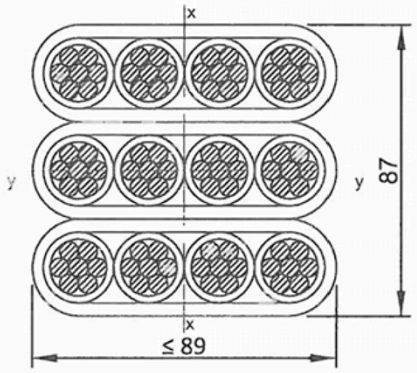
VBT-BE 4-150



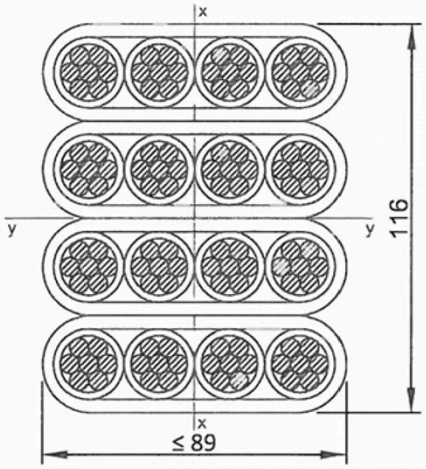
VBT-BE 2x4-150



VBT-BE 3x4-150



VBT-BE 4x4-150



ALL MEASURES IN [mm]

Thickness of Sheating 1 [mm]	Width of Band [mm]
2	89
1,75	87
1,5	85
1,25	83
1	81

VBT BE 1 to 16

Description of the product
Tendons, Types of Bands

Annex A 2

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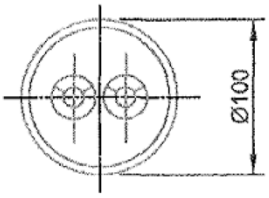
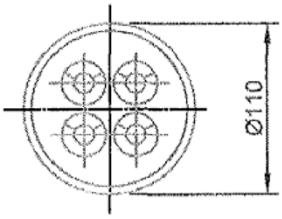
VBT-BE 1-150

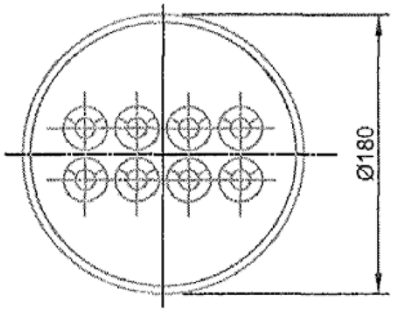
VBT-BE 2-150



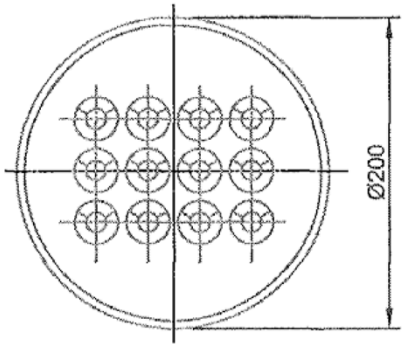
VBT-BE 4-150
VBT-BE 2x2-150



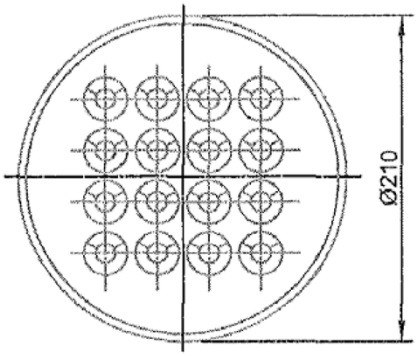
VBT-BE 2x4-150
VBT-BE 4x2-150



VBT-BE 3x4-150



VBT-BE 4x4-150



VBT BE 1 to 16

Annex A 3

Description of the product
Types of Anchor Blocks

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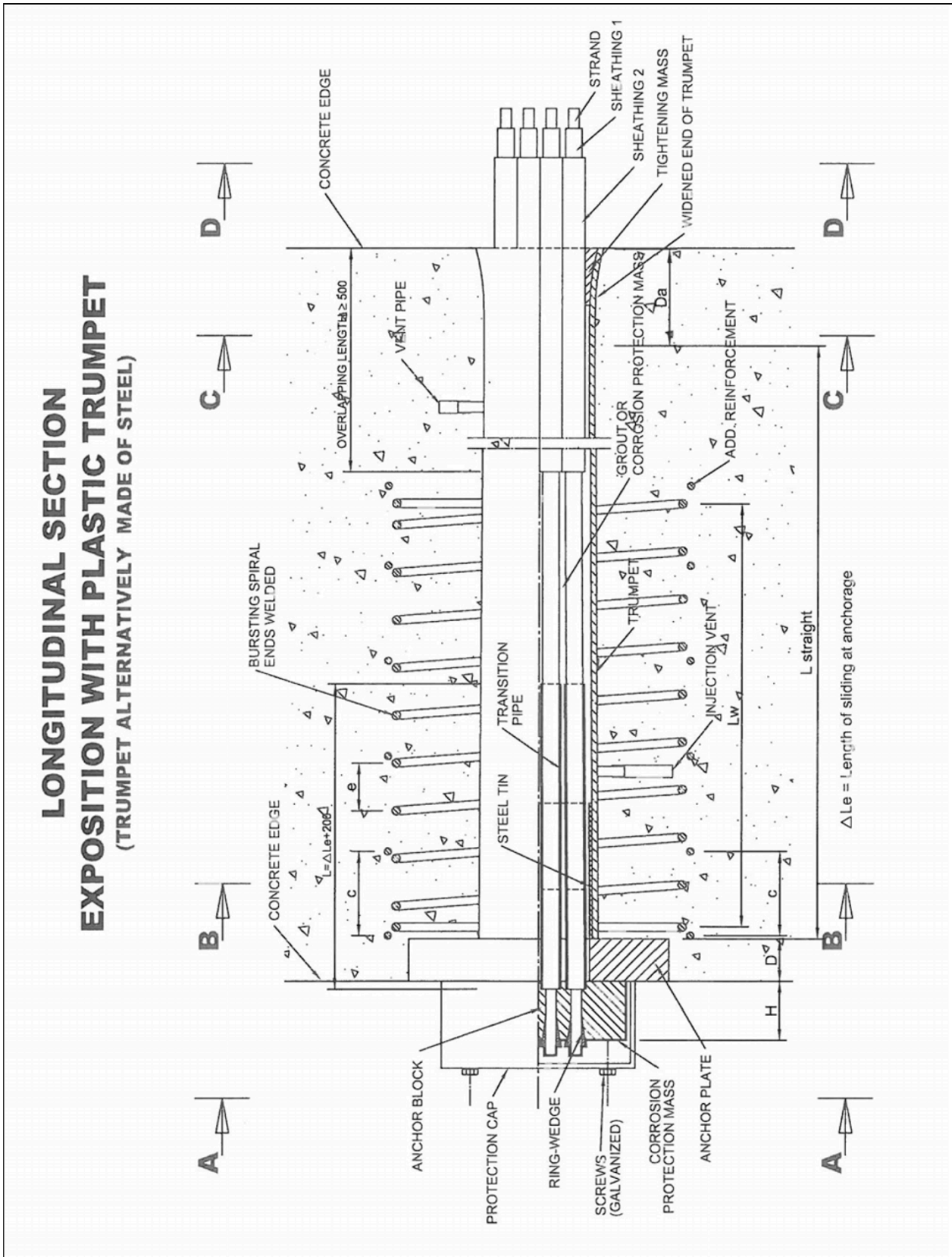

VBT BE 1 to 16

Description of the product
Longitudinal Section Anchorage

Annex A 4

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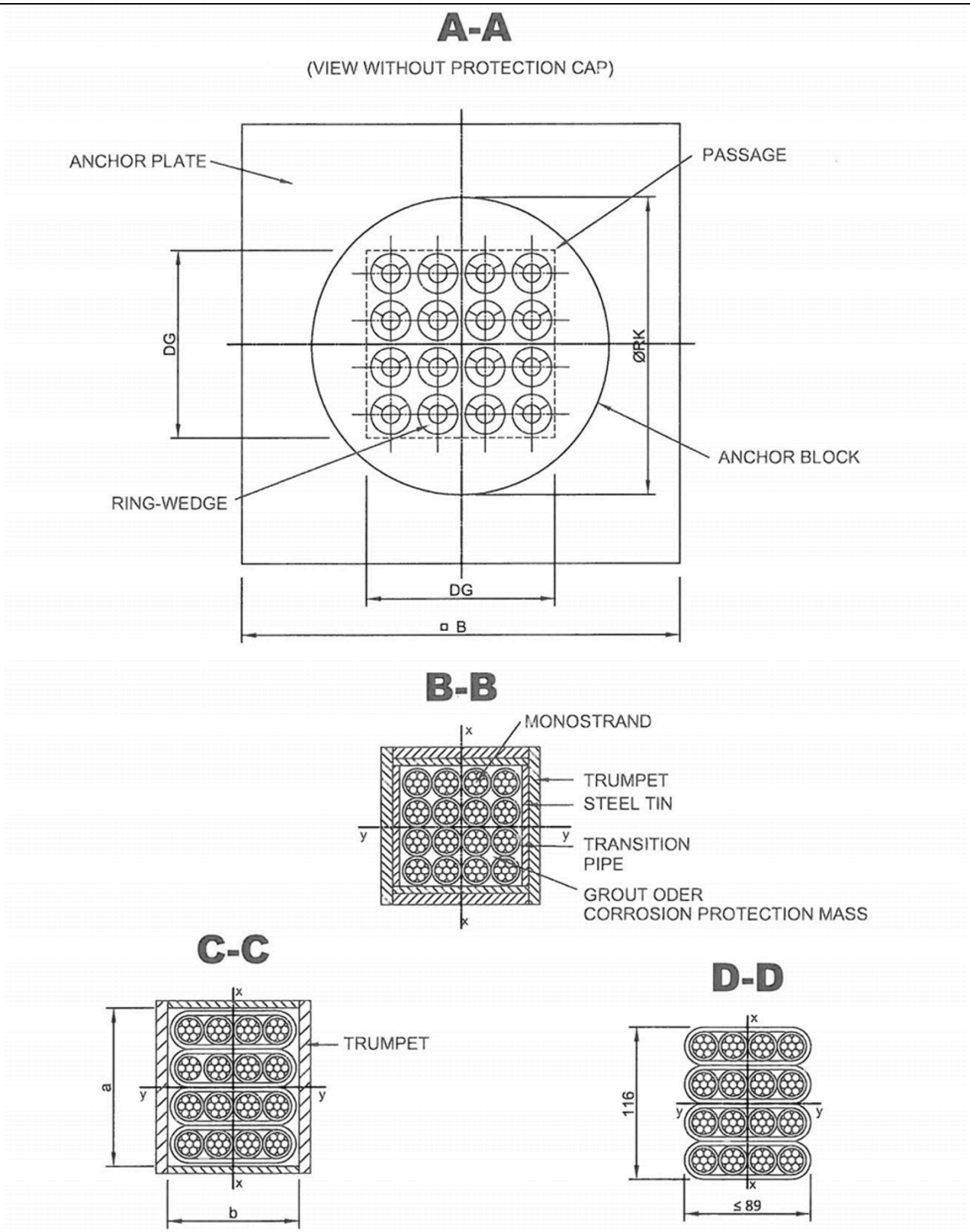

VBT BE 1 to 16

Description of the product
Cross Section Anchorage

Annex A 5

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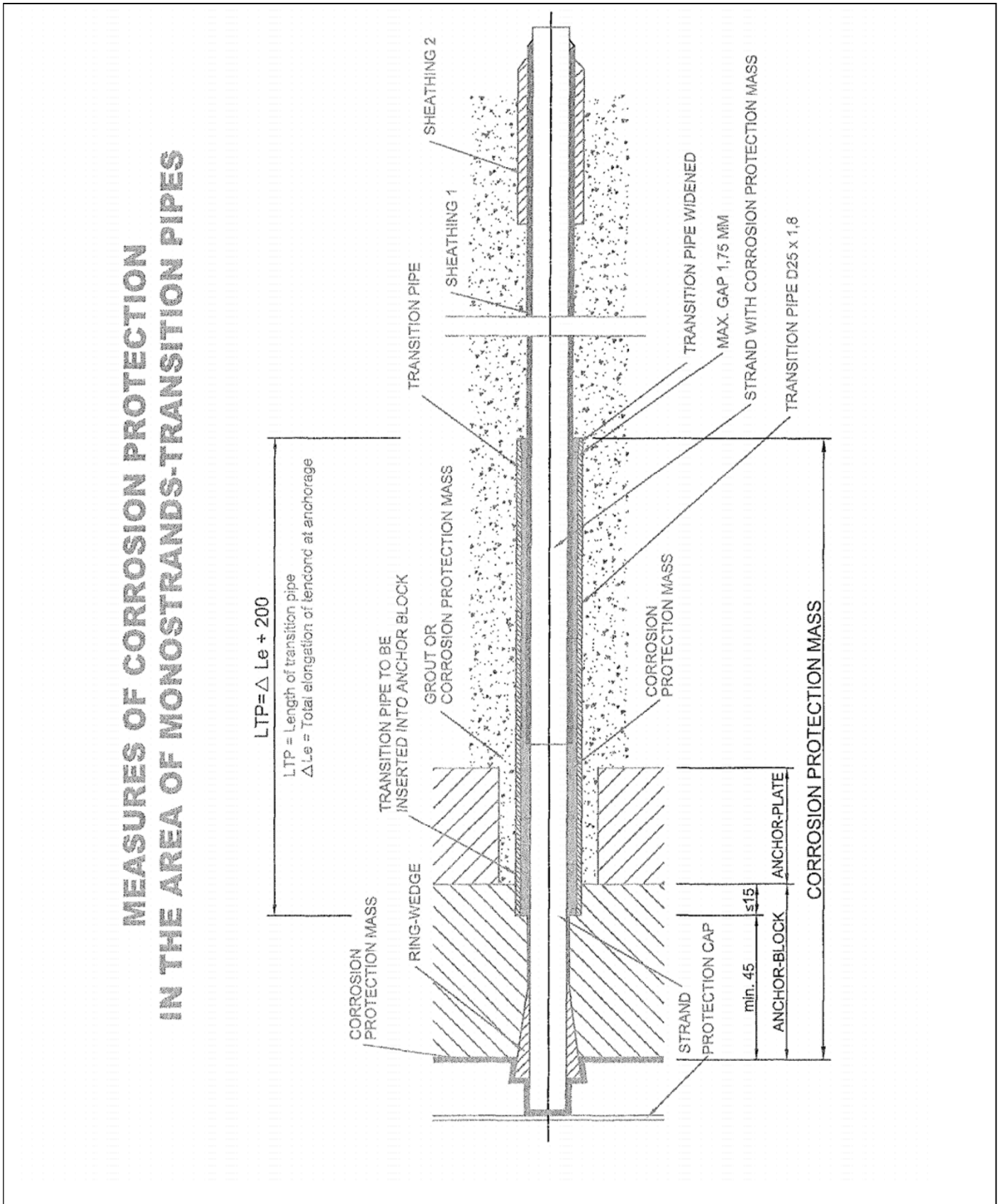

VBT BE 1 to 16

Description of the product
Measures of Corrosion
Protection in the Area of Monostrand-Transition Pipe

Annex A 6

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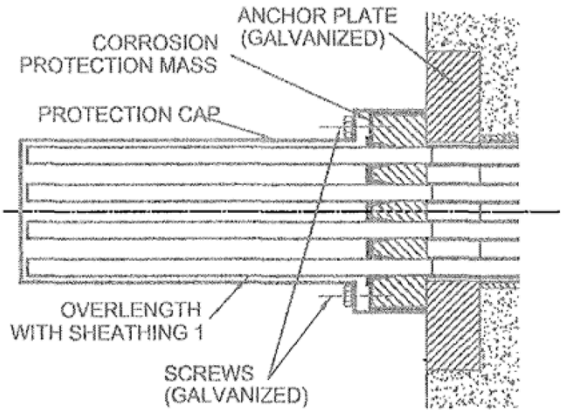
RESTRESSABLE ANCHORAGES

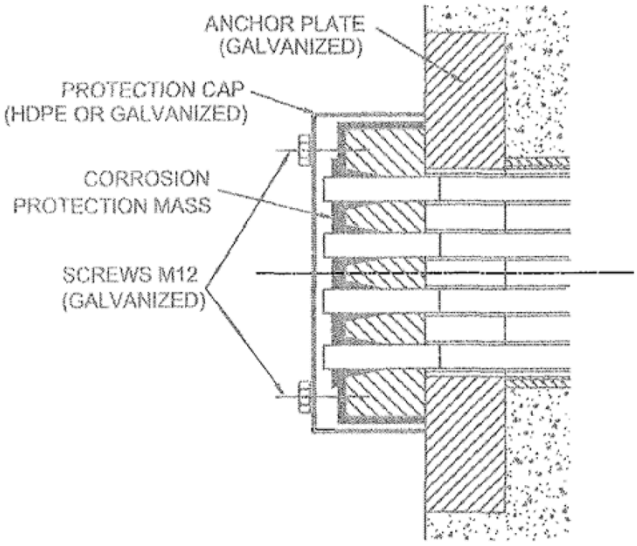
OVERLENGTH FOR RESTRESSING

TENDON TYPE	OVERLENGTH*
1-150	65cm
2-150 bis 4x4-150	65cm
2x4-150 bis 4x4-150	38cm**

* THE OVERLENGTH IS RELATED TO THE TYPE OF THE JACK AND NEEDS TO BE COORDINATED WITH THE MANUFACTURER OF THE TENDON SYSTEM
\pt4.038;** WITH SPECIAL JACK



NON-RESTRESSABLE ANCHORAGES



VBT BE 1 to 16

Description of the product
Corrosion Protection in the Area of Anchorage and Overlenght of Strands

Annex A 7

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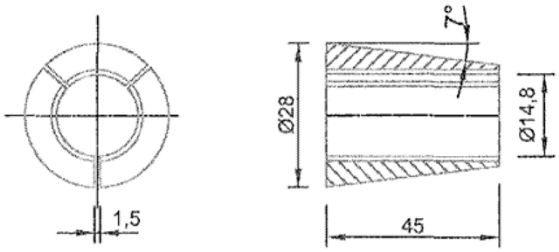
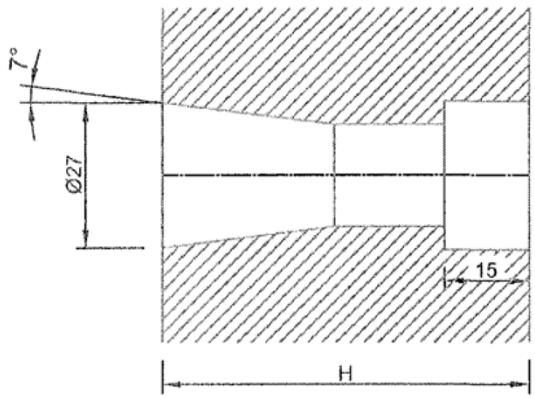
RING WEDGE



CONICAL DRILLING



VBT BE 1 to 16

Description of the product
Detail Drawings

Annex A 8

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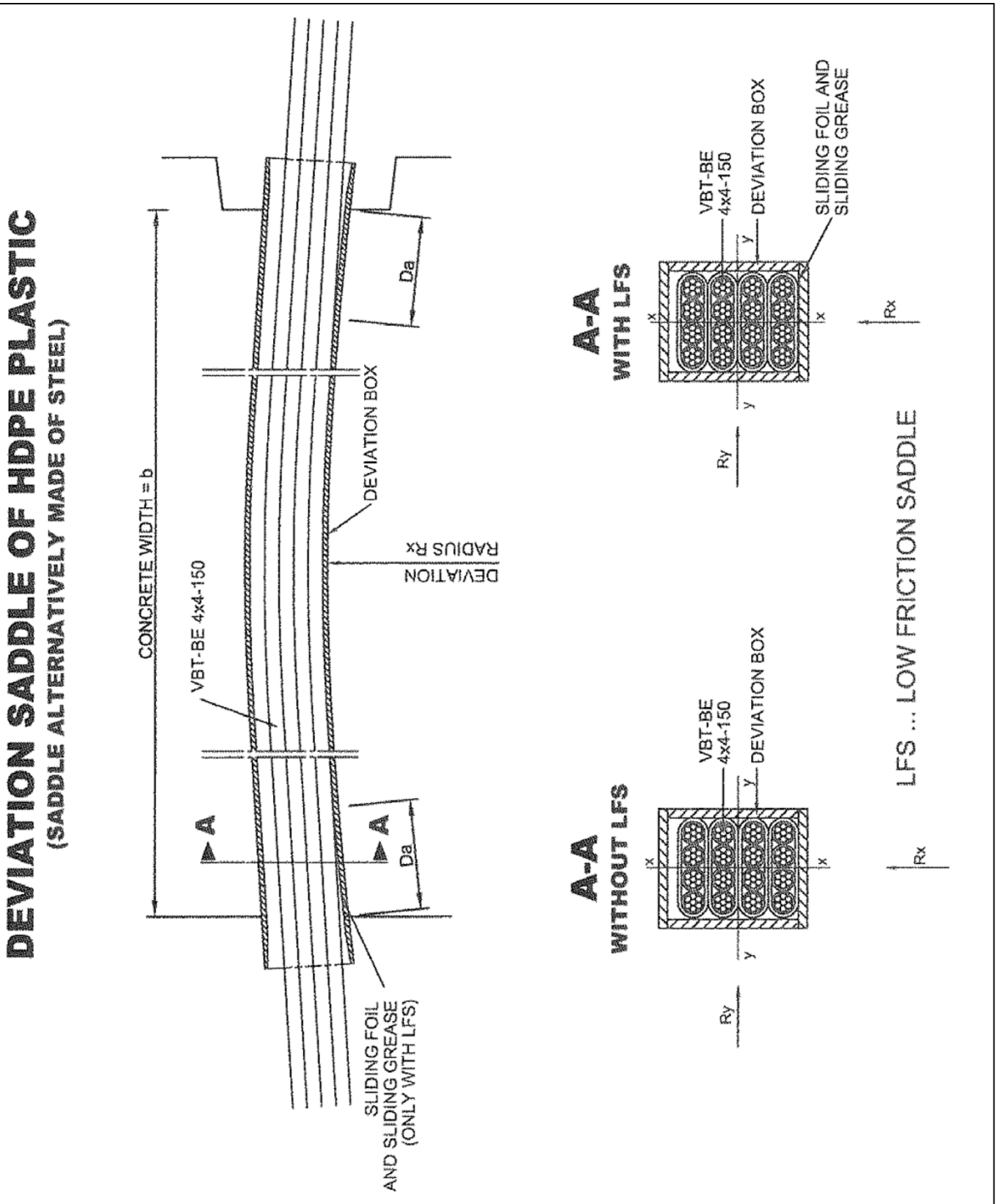

VBT BE 1 to 16	Annex A 9
Description of the product PE Deviation Saddle	

DIMENSION OF ANCHORAGES [MM]

System	**VBT-BE**	**1-150**	**2-150**	**2x2-150**	**4-150**	**2x4-150**	**3x4-150**	**4x4-150**
Dimension of bands see Annex 2								
Anchor plate								
Length	BxB	100	120	170	170	230	280	310
Thickness	D	15	15	20	20	30	40	50
Passage	DG	34x34	34x64	64x64	64x64	64x128	98x128	128x128
Anchor block								
Diameter	ØRK	50	100	110	110	180	200	210
Height	H	60	60	60	60	60	60	70
Trumpet								
Wall thickness HDPE/S235JR		8/3	8/3	8/3	8/3	8/3	8/3	8/3
min. length explanation see Annex 10, Table 3	$l_{straight}$	600	750	750	1000	1190	1310	1440
Protection cap								
inside diameter	ØSK	60	110	120	120	190	210	220

VBT BE 1 to 16

Description of the product
Dimension of Bands and Anchorages

Annex A 10

Deutsches Institut für Bautechnik DIBt

DIMENSION OF BANDS AND FORCES [MM]

System VBT-BE	1-150	2-150	2x2-150	4-150	2x4-150	3x4-150	4x4-150

Band types	**1x1**	**1x2**	**2x2**	**1x4**	**2x4**	**3x4**	**4x4**
Number of strands [-]	1	2	4	4	8	12	16
Number of layers [-]	1	1	2	1	2	3	4
Weight per meter [kg]							
A_p=150mm² per Strand	1,17	2,34	4,69	4,69	9,38	14,06	18,75
Nominal cross section [mm²]							
Ap=150mm² per Strand	150	300	600	600	1200	1800	2400

Permitted prestressing force [kN]														
Steel grade Y1770S7/Y1860S7	1770	1860	1770	1860	1770	1860	1770	1860	1770	1860	1770	1860	1770	1860
A_p=150mm²														
Ultimate Force F_{pk}	266	279	532	558	1064	1116	1064	1116	2128	2232	3192	3348	4256	4464
Max. Prestress Force 0.9 $F_{p0,1k}$	205	216	410	432	821	864	821	864	1642	1728	2462	2592	3283	3456

VBT BE 1 to 16

Description of the product
Dimension of Bands and Anchorages

Annex A 11

Deutsches Institut für Bautechnik

DIBt

BURSTING SPIRALS UND ADDITIONAL REINFORCEMENT [MM]

Band type		1x1	1x2	2x2 und 1x4	2x4	3x4	4x4
Spiral B500B							
Wire	Ø min.	-	-	12	14	14	16
Distance of windings	e	-	-	40	50	50	50
Length	min. Lw	-	-	240	325	400	450
Outer	Ø min. a						
$f_{cm0,cube,150}$ ≥ 34N/mm² (*)		-	-	230	310	370	420
$f_{cm0,cube,150}$ ≥ 42N/mm² (*)		-	-	200	270	330	380
Additional Reinforcement B500B							
Diameter	Ø	5Ø12	5Ø12	6Ø12	6Ø14	7Ø14	8Ø14
Distance	c	40	40	60	60	50	70
bxb							
$f_{cm0,cube,150}$ ≥ 34N/mm² (*)		120	150	230	310	370	420
$f_{cm0,cube,150}$ ≥ 42N/mm² (*)		110	140	200	270	330	380

MINIMAL CENTRE AND EDGE DISTANCES OF ANCHORAGE [MM]

Band type	1x1	1x2	2x2 und 1x4	2x4	3x4	4x4
min. distance of anchorage (**)						
for $f_{cm0,cube,150}$ ≥ 34N/mm² (*)						
Distance of axis	140	170	250	330	395	455
Distant from edge(***)	0.5* distance of axis + concrete cover - 10mm					
	≥ 95	≥ 105	≥ 145	≥ 185	≥ 215	≥ 240

min. distance of anchorage (**)						
for $f_{cm0,cube,150}$ ≥ 42N/mm² (*)						
Distance of axis	130	160	220	290	375	440
Distant from edge (***)	0.5*Achsabstand+ Betondeckung - 10mm					
	≥ 90	≥ 100	≥ 130	≥ 165	≥ 195	≥ 220

(*) Minimum actual concrete strength at stressing [N/mm²]
(**) The minimum centre and edge distances may be reduced up to 15% of the given values in one direction, if increased correspondingly in the other direction
(***) Concrete cover of spiral and additional reinforcement shall be taken into account

VBT BE 1 to 16

Description of the product
Dimension of Bands and Anchorages

Annex A 12

Dimensions and Properties of 7-wire Strands

Designation	Symbol	Unit	Value	
Tensile strength	R_m/F_{pk}	MPa	1770 or 1860	
Strand				
Nominal diameter	D	mm	15.3	15.7
Nominal cross section	A_p	mm²	140	150
Nominal mass	M	g/m	1093	1172
Surface configuration	-	-	plain	
Strength at 0.1%	$f_{p0,1k}$	MPa	1560 or 1640 *	
Strength at 0.2%	$f_{p0,2}$	MPa	1570 or 1660	
Modulus of elasticity	E	MPa	≈ 195 000	
Individual Strands				
External wire diameter	d	mm	5.0 ± 0.04	5.2 ± 0.04
Core wire diameter	d'	mm	1.02 to 1.04 d	1.02 to 1.04 d

* The indicated values are maximum values. The actual values are determined by the applicable standards and regulations valid at the place of use.

As long as prEN 10138-3:2009-08 has not been adopted, 7-wire strands will be used in accordance with national provisions and the characteristics given in the table above.

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1 Intended use

The Post-Tensioning System is assumed to be used for external prestressing of normal-weight concrete structures or elements.

The tendon path shall be placed outside the cross section of the concrete element but inside its envelope.
Optional categories of use:

Restressable tendon

Exchangeable tendon

Tendon for use in structural steel or composite construction as external tendon.

When used in steel structures, the zone of force transfer has to be designed to resist 1.1 F_{pk}. The structural members used to be designed in accordance with national regulations.

2 Methods of verification

2.1 General

The structural members prestressed by means of the VBT-BE External Bondless Strand Post-Tensioning System used to be designed in accordance with national regulations.

2.2 Tendons

Prestressing forces are specified in the respective national provisions.

The maximum force P_{max} shall not exceed the force P_{max}= 0.9 A_p $f_{p0,1k}$ laid down in Table B1.

The value of the initial prestressing force $P_{m0}(x)$ immediately after tensioning and anchoring shall not exceed the force $P_{m0}(x)$ = 0.85 A_p $f_{p0.1k}$ laid down in Table B1.

Table B1: Maximum prestressing forces[1] for tendons with A_p=150mm²

Tendon Designation	Number of strands	Cross sectional area A_p [mm²]	Prestressing force Y1770S7 $f_{p0,1k}$=1520N/mm²		Prestressing force Y1860S7 $f_{p0,1k}$=1600N/mm²	
			$P_{m0}(x)$ [kN]	P_{max} [kN]	$P_{m0}(x)$ [kN]	P_{max} [kN]
1-150	1	150	194	205	204	216
2-150	2	300	388	410	408	432
2x2-150 1x4-150	4	600	775	821	816	864
2x4-150	8	1200	1550	1642	1632	1728
3x4-150	12	1800	2326	2462	2448	2592
4x4-150	16	2400	3101	3283	3264	3456

[1] The forces stated in Tables B1 are maximum values referring on $f_{p0,1k}$=1520N/mm² or $f_{p0,1k}$=1600N/mm². The actual prestressing forces are to be found in national regulations valid on place of use. If admissible in the place of use, strands with higher characteristic yield stresses might be used, but not more $f_{p0,1k}$=1560N/mm² (Y1770 S7) or 1640 N/mm² (Y1860 S7). In this case the prestressing forces of Table B1 can be increased by multiplying them with the factor ($f_{p0,1k}$/1520) or ($f_{p0,1k}$/1600).
Compliance with the stabilisation and crack width criteria in the load transfer test was verified to a load level of 0.80 F_{pk}.

The number of strands in a tendon may be reduced by leaving out strands lying radialsymmetrically in the anchor block. The provisions for tendons with completely filled anchor blocks (basic type) also apply to tendons with only partly filled anchor blocks. Into the unfilled cones of the anchor blocks short pieces of strands with wedges have to be pressed to assure a sufficient bending stiffness of the anchor blocks.

The admissible prestressing force is reduced per strand left out as shown in Table B2:

Table B2: Reduction of the prestressing force when leaving out one strand

A_p	Y1770 S7		Y1860 S7	
	$\Delta P_{m0}(x)$ [kN]	ΔP_{max} [kN]	$\Delta P_{m0}(x)$ [kN]	ΔP_{max} [kN]
150 mm²	194	205	204	216

2.3 Radius of curvature of the tendons in the deviators

The smallest admissible radii of curvature are given in Annex B, section 4.3.2.1.

An analysis of the edge stresses in the strands can be omitted while following this curvature values.

2.4 Concrete strength

Concrete complying with EN 206-1:2021-06 shall be used.

At the time of transmission of the full prestressing force the mean concrete strength of the normal weight concrete in the anchorage zone shall be at least $f_{cmj,cube}$ or $f_{cmj,cyl}$ according to Table B3. The mean concrete strength ($f_{cmj,cube}$ or $f_{cmj,cyl}$) shall be verified by means of at least three specimens (cube with the edge length of 150 mm or cylinder with diameter of 150 mm and height of 300 mm), which shall be stored under the same conditions as the concrete member, with the individual values of specimens not differ no more than 5 %.

Table B3: Necessary mean concrete strength f_{cmj} of the specimens at time of prestressing

$f_{cmj,cube}$ [N/mm²]	$f_{cmj,cyl}$ [N/mm²]
34	27
42	34

For partial prestressing with 30 % of the full prestressing force the actual mean value of the concrete compressive strength to be proved is 0.5 $f_{cmj,cube}$ or 0.5 $f_{cmj,cyl}$; intermediate values may be interpolated linearly.

2.5 Centre and edge distances of the tendon anchorages, concrete cover

The centre and edge distances of the tendon anchorages shall not be less than the values given in the Annex A 12 depending on the actual mean concrete strength.

The values of the centre or edge distances of the anchorages given in the Annex A 12 may be reduced in one direction up to 15 %, however, not to a lesser value than the minimal distance between the additional reinforcing bars or the external diameter of the helix plus 2 cm. In this case the centre or edge distances of the anchorages in the other direction shall be increased for keeping the same concrete area in the anchorage zone. The dimensions of the additional reinforcement shall be adjusted accordingly.

All centre and edge distances have only been specified in conjunction with load transfer to the structure; therefore, the concrete cover given in national standards and provisions shall be taken into account additionally.

The concrete cover may under no circumstances be less than 20 mm nor smaller than the concrete cover of the reinforcement installed in the same cross section. The concrete cover of the anchorage should be at least 20 mm. Standards and regulations on concrete cover valid in place of use shall be considered.

2.6 Reinforcement in the anchorage zone

The anchorages (including reinforcement according to Annex A 12) for the transfer of the prestressing forces to the structural concrete are verified by means of tests. The resistance to the forces occurring in the structural concrete in the anchorage zones outside the helix and the additional reinforcement shall be verified. An adequate transverse reinforcement shall be provided here in particular for the occurring transverse tension forces (not shown in the attached drawings).

The steel grades and dimensions of the additional reinforcement (stirrups) shall follow the values given in Annex A.

This reinforcement shall not be taken into account as part of the statically required reinforcement. Existing reinforcement in a corresponding in excess to the reinforcement required by design may be taken into account for the additional reinforcement. The additional reinforcement shall consist of closed stirrups (stirrups closed by means of bends or hooks or an equivalent method) or of orthogonal reinforcement properly anchored. The stirrup locks (bends or hooks) shall be paced staggered.

In the anchorage zone vertically led gaps shall be provided for proper concreting and compacting.
Force transmission from the deviators into the structure must be statically verified.

2.7 Slip at the anchorages

The slip at the anchorages (see Annex B, section 3.1.4) shall be taken into account in the static calculation and the determination of the tendon elongation.

2.8 Inner sliding path on the deviation saddles

The inner sliding path (relative movement of the strands to sheath 1) on the deviation saddles (prestressing, restressing and possible releasing of the prestressing force) must not, in relation to the curvature radius, exceed the permissible values according to Annex B, section 4.3.2.1. The minimum radii must not fall below the specification in Annex B, section 4.3.2.1.

2.9 Resistance to fatigue

With the fatigue test for the anchors carried out in accordance with EAD 160004.00.0301, the stress range of 80 N/mm² of the strands at the maximum stress of 0,65 f_{pk} at 2×10^6 load cycles was verified.

In the areas of deviation of tendons a stress range of 35 N/mm² at 2×10^6 load cycles can be assumed as verified. Due to national provisions at the place of use, higher stress ranges up to 80 N/mm² might be assumed as verified in the areas of deviation.

2.10 Guidance of Tendons through Construction

Where tendons are guided through the construction an appropriate size of the opening in the construction part, taking the production tolerance into account, must be provided to make sure that the tendons do not touch the construction part. When used as prevention of cross oscillation of the tendons as described in Annex B, section 2.10, the guiding-through shall be carried out like a deviation saddle.

2.11 Prohibition of transversal oscillation of tendons

Critical transversal oscillations of the tendons caused by traffic, wind or others shall be avoided by constructive measures.

If at the place of the use no other regulation is valid for bridges of box sections a fixing distance of 35 m is recommended. Outside of box sections smaller fixing distance are necessary. The fixings shall be performed in such a manner that the tendon, especially sheath 2, shall not be damaged and the movement in longitudinal direction of the tendon is not limited.

2.12 Protection of the Tendons

The tendons may be protected against malfunction resulting from extraneous cause (e.g. vehicle impact, elevated temperature in case of fire, vandalism). The requirements must be individually investigated and rated according the project conditions. Tendons enclosed by a box girder are classified as sufficiently protected.

2.13 Lengths of Transitions Pipes and Overlapping of Protection Sheath 2

The required lengths of the transition pipes as well as the required overlapping of protection sheath 2 into the trumpets shall be specified under consideration of all possible influences, in particular temperature differences during construction, movements caused by prestressing and construction tolerances, in order to make sure that the minimum overlapping of both protection sheaths in the final state (see Specific Part of the European Technical Assessment, section 1.9 and Annexes A 4 and A 6) are reached. This decision must be made by the manufacturer or in consultation with them.

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3 Assumptions under which the fitness of the product for the intended use was favourably assessed

3.1 Installation

3.1.1 General

Assembly and installation of the tendons shall only be performed by qualified post-tensioning specialist companies which have the required technical skills and experiences with this VBT post-tensioning system. The company's site manager shall have a certificate of the Manufacturer certifying that he is instructed by the Manufacturer and has the required knowledge and experience with this post-tensioning system. National standards and regulations valid on site shall be considered.

The Manufacturer is responsible to inform anyone concerned about the use of this VBT post-tensioning system.

The tendons and the components shall be handled carefully.

3.1.2 Welding

Steel welding at the anchorages is only permitted at the following points:

a) Welding of the end of the helix to a closed ring

b) For ensuring the central position the helix may be attached to the bearing plate or anchor body by welding

c) Welding on additional reinforcement, e.g. to close the stirrups

After placing the tendons no more welding works shall be performed at the anchorages.

4.1.3 Installation of tendon

The central position of the helix or stirrups shall be ensured by tack-welding to the bearing plate or the anchor body or other appropriate mountings. The bearing plate or anchor body and the anchor head shall be in direction perpendicular to the axis of the tendon.

The determination according to sections 1.8 und 1.12 shall be observed.

3.1.4 Wedging force, slip at anchorages, wedge securing and corrosion protection compound

The wedges of all anchorages (fixed anchorages) which are no longer accessible during tensioning shall be secured by means of pre-wedging with 1.2 $P_{m0}(x)$ during installation. In the case of pre-wedging no slip shall be taken into account for the determination of elongation.

Pre-wedging is not necessary if wedges of fixed anchorages are secured by retainer discs. In this case a slip within the fixed anchorage of 6 mm shall be taken into account for the determination of elongation.

At stressing anchorage the slip of wedge is 6 mm and shall be taken into account for the determination of elongation. The slip is measured by the strand placed measuring marks behind the anchorage. The slip of the wedges is 1 mm smaller as the slip of the strand. During installation of wedges into the cones all relevant surfaces and clearances shall be protected against corrosion by grease. The material specifications of these greases are deposited at Deutsches Institut für Bautechnik.

VBT BE 1 to 16	Annex B 5
Intended Use Installation	

3.1.5 Tensioning and stressing records

3.1.5.1 Tensioning

At time of stressing the minimum mean concrete strength shall comply with the values given in Annex B, section 2.4.

Once 30 % of the prestressing force has been reached tendons at all deviation saddles shall be labelled, so that the movement of the protection sheath 2 on each band in respect to the deviation saddle can be clearly determined when the prestressing is being continued.

The inner sliding path is the difference between the calculated elongation of the tendon on the saddle and the measured movement of the protection sheath 2 at the deviator (outer sliding path). The amount of inner sliding (prestressing, restressing and possible releasing of the prestressing force) must not exceed 40 cm. The measured movement shall be recorded for each tendon and deviation saddle.

The strain of the protection sheath 2 shall be less then 1.5 % over the whole length of the tendon. Therefore it is sufficient to verify for every straight part of the tendon that the average strain does not exceed this value. As a function of the kind of limitation of the straight part of the tendon the average strain arises as follows:

1.) the straight part of the tendon is limited by two deviation saddles:

ratio between the difference of outer sliding at the two deviation saddles and the length of the straight part of the tendon

2.) the straight part of the tendon is limited by a deviation saddle and a stressing anchor:

ratio between the difference of outer sliding at the deviation saddle and the stressing anchor and the length of the straight part of the tendon

3.) the straight part of the tendon is limited by a deviation saddle and a fixed anchor:

ratio between the outer sliding at the deviation saddle and the length of the straight part of the tendon

The labelling and testing procedure can be renounced if the total elongation of the tendon at any deviation saddle does not exceed the maximum value of inner sliding given in Annex B, section 4.3.2.2 and in no straight part of the tendon the average strain of 1.5% is crossed. As a function of the kind of limitation of the straight part of the tendon the average strain arises as follows:

1.) the straight part of the tendon is limited by two deviation saddles:

ratio between the total elongation of the tendon at the deviation saddle which is closer to the stressing anchor and the length of the straight part of the tendon

2.) the straight part of the tendon is limited by a deviation saddle and a stressing anchor:

ratio between the total elongation of the tendon at the stressing anchor and the length of the straight part of the tendon

3.) the straight part of the tendon is limited by a deviation saddle and a fixed anchor:

ratio between the total elongation of the tendon at the deviation saddle and the length of the straight part of the tendon

The minimum straight length for tensioning behind the anchorages (strand protrusion see Annex A 7) depends on the jack which is used on site (appropriate information are available at the Manufacturer). All strands of a tendon should be stressed simultaneously. This can be done by centrally controlled individual jacks, single band jacks or by a bundle jack. If simultaneously stressing is not possible the inner sliding of any band shall not exceed the value given in Annex B, section 4.3.2.2 (appropriate information of special measures to fulfil this condition are available at the Manufacturer).

Local standards and national regulations valid in place of use shall be considered.

3.1.5.2Stressing record

All stressing operations shall be recorded for each tendon. In general, the required prestressing force shall be achieved. The elongation is measured and compared with the calculated value.

If during tensioning the difference between measured and calculated elongation or tensioning force is more than 5 % for the sum of all tendons at the cross or 10 % for a single tendon of the calculated value then the engineer shall be informed and the causes shall be found.

Local standards and national regulations valid in place of use shall be considered.

3.1.5.3Restressing

It is admissible to restress the tendons by releasing and re-using the wedges. After restressing and anchoring, wedge marks on strands resulting from first stressing shall be moved to the outside by at least 15 mm. For restressing a minimal overlength of the strands is necessary (see Annex A 7).

3.1.5.4Prestressing jacks and space requirements, safety-at-work

For stressing works hydraulic jacks are used. Information about the stressing equipment has been submitted to Deutsches Institut für Bautechnik.

To stress the tendons, minimal clearance behind the anchorages according to the information of the Manufacturer is necessary.

The safety-at-work and health protection regulations shall comply with.

3.1.6 Grouting of the wholes in the trumpet

After stressing either with grout for prestressing tendons according to EN 445:2007 or grease (see Annex A 13) can be used to grout the anchorages.

Grouting procedures with grout for prestressing tendons according to EN 445:2007 shall be carried out in accordance with EN 446:2007. The requirements of the quality management according to this standard shall be fulfilled. Local standards and national regulations valid in the place of use shall be considered.

3.1.7 Grouting of the cavities in the anchor blocks, between transition pipe and strand and in the protection cap

The cavities in the anchor block and between transition pipes and strands are filled with grease (see Annex A 13). Grouting occurs with a special fat press from the external side of the anchor blocks. It should be taken care to completely fill the remaining space. This shall be controlled afterwards by comparing of the volume, sound control by knocking or other adequate methods. After the fastening of the protection caps (see Annex A 7) these are also grouted with grease.

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4 Description of the prestressing system

4.1 Tendons

4.1.1 Description of tendons

The VBT-BE tendons are designed for external prestressing and consist either of a monostrand and a second sheath, or of bands of 2 to 4, side by side lying monostrands, which are factory protected against corrosion by a grease and sheath 1 of PE. The side by side lying monostrands are formed by a flat PE-pipe (sheath 2) with a rectangular section to stressing-bands.

4.1.2 Production of tendons

The side by side lying monostrands and the flat PE-pipe are put together in factory. The stressing-bands can be produced on drums in great single and multi lengths, or in length fitting for individual sites.

4.2 Anchorages

4.2.1 Stressing anchor and fixed anchor

Anchoring is being performed by anchor-plates, anchor-blocks with conical drillings parallel to the axis of tendon and ring-wedges, which consist of 3 equal parts. The transition area between the bands and the anchorage will be as follows: at the inner side of the anchor-plate a rectangular galvanized pipe of steel is welded to it. At this pipe the PE trumpet is fastened. In the area of the trumpet-box sheath 2 of the stressing-bands are to be removed, by use of a special knife. The strands with sheath 1 will be inserted through the transition pipes into the conical drillings of the anchor-block and anchored. Transition pipes are fixed to the anchor-blocks by strong hitting (see Annex A 6).

The ring gap between transition pipe and sheath 1 (monostrand) shall not exceed 1.75mm. If the ring gap is larger then special measures must be carried out in correspondence with the actual environmental situation. To secure, that sheath 1 can be inserted into the transition pipe without great resistance, the transition pipes can be widened at their ends.

When stressing is finished, the inner space of the trumpet will be grouted by grout for prestressing tendons according to EN 445:2007 or corrosion protection grease. Tightening at exit of trumpets between trumpet-box and bands will be done by tightening mass (e.g. PU foam).

At the non-restressable anchorages with short over-length a protection cap of PE or galvanized steel will be fastened by galvanized screws. The space inside the cap should be filled with corrosion protection grease (see Annex A 7 below).

At the restressable anchorages with long over-length (see Annex A 7 on top) a protection cap (minimum length in respect to the available stressing jack, e.g. 40 cm) will be fastened, made of PE or galvanized steel, by galvanized screws to the anchor-block. Anchor block and ring-wedges will be lubricated by corrosion protection grease. The strands (over-length) are covered by corrosion protection grease and additional transition pipes.

4.3 Deviations

4.3.1 Implementation of trumpets and deviation boxes

At the anchors and deviations the band tendons are guided in rectangular trumpets or deviation boxes. The surfaces of the trumpets and deviation boxes are adapted to geometry of cable layout. For avoiding any sharp bend of the tendons, the trumpets and deviation boxes are widened at their ends like a trumpet, so that the tendon path is to be without kink (see specific conditions of European technical assessment, sections 1.8 and 1.12).

Normally, material of the trumpets and deviation boxes is PE. Execution in corrosion protected steel is possible as well. The trumpets and deviation boxes of PE are fully embedded in concrete or grout in the deviator area. If steel saddle boxes are used they can also be supported by a steel structure according the project requirements, instead to or in combination with grouting or concrete support, provided that the conditions of this assessment are complied with and the static verifications are furnished.

PE: Thickness $\geq$ 8mm
Corrosion protected steel Thickness $\geq$ 3mm

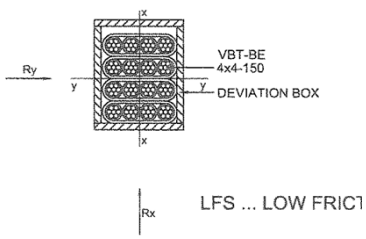
Table B4: Minimum section dimensions of deviation boxes

Number of bands	1x1	1x2	2x2	1x4	2x4	3x4	4x4
min. width (inside) X	33	52	52	95	95	95	95
min. height (inside) Y	33	38	67	38	67	96	125
Wall Thickness	PE $\geq$ 8 mm / Steel ≥ 3 mm						

If the trumpets and deviation boxes are made of steel the initial minimum wall thickness of the monostrand need to be 2 mm, or a PE-insert with a minimum thickness of 8 mm has to be placed between the contact surfaces of the trumpet or deviation box and the tendon. A kink-free path of the tendons shall be observed.
If trumpets and deviation boxes of steel with the above mentioned PE-insert or trumpets and deviation boxes of PE are used the initial wall thickness of the monostrands can be less than 2 mm according Annex B, section 4.3.2.1.

4.3.2 Radii of curvature and limits of inner sliding

4.3.2.1 Radii of curvature



The minimum radii of curvature $R_{x,min}$ for the curvature of the narrow side (bending around the y-axis) of four stacked bands are given in Table B5, line 4. In case of different stacking arrangements the minimum radius of curvature is calculated in the following approach (e.g. three stacked bands, n = 3):

$$R_{min}(d_{inside};n) \geq Max\left\{\begin{matrix} R_{x,,min}(d_{inside};4) * n/4 \\ 1.9\ m \end{matrix}\right\}$$

d_{inside} minimum initial wall thickness of the monostrand
n number of stacked band layers

Example - Band Type 3x4 (d_{inside} ≥2.00 mm; n = 3)

R_{min}(2,00;3) ≥ 5.0 m * 3 / 4 = 3,75 m (see Table B5, column 2, row 3)

Table B5: Minimum curvature radius $R_{x,min}$ using 40 cm or less inner sliding movement

number of band layers	Initial wall thickness of sheath 1 [mm]				
	2	1.75	1.5	1.25	1 (restressable)
	Minimum deviation radius [m]				
4	5.50	6.20	7.20	11.60	∞
3	4.20	4.70	5.40	8.70	∞
2	2.80	3.10	3.60	5.80	∞
1	1.90	1.90	1.90	2.90	∞

The minimum radius of curvature ($R_{y,min}$) for the curvature of the wide of the bands side (bending around the x-axis)is fixed to 10.00m for all type of bands and independent of R_x.

In order not to exceed the tested deviation angles of 2.9° of the strands at the exit from the anchor blocks the minimum length of the straight part of the trumpet $l_{straight}$ (see Annex A 4) in dependence to the used tendon given in Table B6 shall be kept.

Table B6: Minimum length of the straight part of the trumpet $l_{straight}$ at anchorages

	Minimum length of the straight part of the trumpet $l_{straight}$ [mm]						
System VBT-BE	1-150	2-150	2x2-150	1x4-150	2x4-150	3x4-150	4x4-150
Minimum length[1] $l_{straight}$ (mm)	600[2) 3)]	750[2) 3)]	750[2) 3)]	1000[2) 3)]	1190[2) 3)]	1310[2) 3)]	1440[2) 3)]

[1)] starting from the transition of the anchor plate to the welded on steel tin
[2)] the anchor block and anchor plate shall be positioned perpendicular and centrically to the axis of the tendon [3)] When planning the determinations according to the specific conditions of European technical assessment, sections 1.8 and 1.12 from the planning stage.

4.3.2.2 Permissible inner sliding on a deviation saddle

The resulting elongation can be separated into inner and outer sliding.

Inner sliding is the movement of the steel strand in the monostrand sheath.
Outer sliding is the movement of the complete tendon in the deviation saddle.

The maximum allowable value of inner sliding must not exceed 40 cm.

The maximum allowable value of outer sliding is infinite.

Outer sliding is allowed with no limitations. Typical values of outer sliding ratio are ranges from 50-90% without LFS (low friction saddle), and from 95-99% with LFS. The values with or without LFS can additional vary depending on cleanness of saddle surfaces and restriction to movements of the bands. The real behaviour of the sliding conditions will in most cases be a mixture of inner and outer sliding. The distribution will depend on e.g. the cleanness of the deviation surfaces, grease application and optional of a low friction system.

4.4 Corrosion Protection

4.4.1 Tendon in free length

The cables are protected against corrosion by the sheath 1 and sheath 2 as well as by a corrosion protection mass.
The minimum wall thickness of sheath 1 is related to the chosen deviation radius.
The initial minimum wall thickness of sheath 2 is $t \geq 3.00$ mm.

4.4.2 Anchorages

The inner space of the anchorage trumpet will be filled with grout or corrosion protection mass. The monostrands will be guided to the anchor block through PE transition pipes. The end of the trumpet to the free length of the bands will be tightened by sealing compound. The protection cap is made of PE or steel. All outside surfaces of steel elements must be protected against corrosion (see Annex A 6).

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Prestressing losses due to friction and wobble effects

The losses due to friction and unwanted deflection can be determined in the static calculation using the friction coefficient μ and the unintentional angular displacement k (wobble coefficient) specified in Table C 1.

Tabelle C1: Reibung und ungewollte Umlenkung

Anzahl der gestapelten Bandebenen	**Reibungsbeiwert μ**		**Ungewollte Umlenkung k**
	Ohne Gleitsattel (LFS "low frictional saddle") (siehe Anhang A 9)	Mit Gleitsattel (LFS "low frictional saddle") (siehe Anhang A 9)	
[-]	[rad^{-1}]	[rad^{-1}]	[°/m]
1	0,06	0,03	0
2	0,08		
3	0,10		
4	0,12		

MATERIALIEN

Benennung	Werkstoff Nr.*	Norm
Anchor Block	Unlegierter Stahl	DIN EN 10 083-2 (2006-10)
Ring wedge	Gehärteter Stahl	DIN EN 10 084 (2008-06)
Padding	Unlegierter Stahl	DIN EN 10 025 (2005-02)
Transition pipes	PE	DIN EN 16 776 (4.78)
Protection cap	PE	DIN EN 16 776 (4.78)
oder	Unlegierter Stahl	DIN EN 10 025 (2005-02)
Anchor plate	Unlegierter Stahl	DIN EN 10 025 (2005-02)
Trumpet	PE	DIN EN 16 776 (4.78)
oder	unlegierter Stahl	DIN EN 10 025 (2005-02)
Deviation box	PE	DIN EN 16 776 (4.78)
oder	unlegierter Stahl	DIN EN 10 025 (2005-02)
oder	Edelstahl	DIN EN 10 088-3 (2014-12)
Sliding tins	Edelstahl	DIN EN 10 088-3 (2014-12)
Sliding foil	PE	DIN EN 16 776 (4.78)
Corrosion protection mass (grease)	*	Hersteller
HDPE Monostand	PE	Hersteller
HDPE Strand	PE	Hersteller
Corrosion protection fort he outer surfaces, galvanized 80mm		DIN EN ISO 1461 (2022-12)

* exact material definitions deposited at DIBt

VBT BE 1 to 16

Materials and References
Materials

Annex D 1

Deutsches Institut für Bautechnik DIBt

Codes and References

prEN 10138-3:2009-08	Prestressing Steels – Part 3: Strand
EAD 160004-00-0301	Post-tensioning kits for prestressing of sructures
EN 10204:2005-01	Metallic products – Types of inspection documents
EN ISO 12944-4:2018-04	Paints and varnishes – Corrosion protection of steel structures by protective paint systems – Part 4: Types of surface and surface preparation (ISO 12944-4:2017)
EN ISO 12944-5:2020-03	Paints and varnishes –Corrosion protection of steel structures by protective paint systems – Part 5: Protective paint systems (ISO 12944-5:2019)
EN ISO 12944-7:2018-04	Paints and varnishes – Corrosion protection of steel structures by protective paint systems – Part 7: Execution and supervision of paint work (ISO 12944-7:2017)
EN 10025-2:2005-04	Hot rolled products of structural steels – Part 2: Technical delivery conditions for non-alloy structural steels
EN 10083-2:2006-10	Steels for quenching and tempering – Part 2: Technical delivery conditions for non-alloy steels