Deutsches Institut für Bautechnik DIBt

Approval body for construction products and types of construction

Bautechnisches Prüfamt

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European Technical Assessment

ETA-11/0123 of 18 April 2023

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General Part

Technical Assessment Body issuing the European Technical Assessment:	Deutsches Institut für Bautechnik
Trade name of the construction product	BBV External Post-Tensioning System Type E
Product family to which the construction product belongs	PAC 16, Post-tensioning kits (internal unbonded for strands)
Manufacturer	BBV Systems GmbH Industriestraße 98 67240 Bobenheim-Roxheim DEUTSCHLAND
Manufacturing plant	BBV Systems GmbH Industriestraße 98 67240 Bobenheim-Roxheim DEUTSCHLAND
This European Technical Assessment contains	49 pages including 4 annexes (with 40 pages) 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-11/0123 issued on 3 April 2019

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Specific Part

1 Technical description of the product

1.1 Definition of the construction product

The BBV External Post-Tensioning System Type E consists of 3 to 31 strands with a nominal tensile strength of 1770 MPa or 1860 MPa (Y1770S7 or Y1860S7 according to prEN 10138-3:2009-08, Table 4), a nominal diameter 15.3 mm (0.60" - 140 mm²) or 15.7 mm (0.62" - 150 mm²) which are used in normal-weight concrete with the following anchors (stressing and fixed anchors):

1. Stressing (active) anchor type S and fixed (passive) anchor type F with bearing plate and anchor head for tendons of 3, 4, 5, 7 and 9 strands,
2. Stressing (active) anchor type S and fixed (passive) anchor type F with cast-iron anchor body and anchor head for tendons of 12, 15, 19, 22 and 31 strands,
3. Stressing (active) anchor type S and fixed (passive) anchor type F with patched bearing plate and anchor head for tendons of 3, 4, 5, 7, 9, 12, 15, 19 and 22 strands,
4. Single strand coupling EÜK (movable) for tendons of 3, 4, 5, 7, 9, 12, 15, 19, 22, 27 and 31 strands, nominal diameter 15.7 mm (0.62" or 150 mm²).

Additional components are:

1. Bursting reinforcement (helixes and stirrups),
2. Sheathing (ducts),
3. Corrosion protection.

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

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

1.2 Strands

Only 7-wire strands shall be used in accordance with national provisions and 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	15.3	15.7
Nominal cross section	A_p	mm²	140	150
Nominal mass	M	g/m	1093	1172
Individual wires				
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

To avoid confusion, only strands with one nominal diameter shall be used on one site. If the use of strands with R_m = 1860 MPa is intended on site, these shall solely be used there.

Only strands stranded in the same direction shall be used in a tendon. For further characteristic values of the strands see Annex A19.

1.3 Wedges

Wedges type 30, smooth or knurled, (see Annex A2) are approved. The knurled wedges shall only to be used for pre-wedged (pre-locked) fixed anchors. The segments of the wedges for strands Ø 15.7 mm shall be marked with "0.62".

1.4 Anchor heads

Anchor heads type 2 are used. The conical boreholes of the anchor heads shall be clean, stainless and provided with corrosion protection agent.

1.5 Bearing plates

For tendons consisting of 3 to 9 strands, rectangular bearing plates according to Annexes A3 and A6 shall be used. The long side of the bearing plates shall be installed parallel to the largest centre or edge distance. For tendons consisting of 7 and 9 strands, round bearing plates according to Annexes A3 and A6 can be used alternatively.

The anchorage using patched, round bearing plates according to Annex A8 applies to tendons of 3 to 22 strands.

1.6 Cast-iron anchor bodies

For tendons of 12 to 31 strands multi-surfaced cast-iron anchor bodies shall be used (see Annex A6).

1.7 Helixes and stirrups

The steel grades and dimensions of the helixes and of the stirrups shall comply with the values given in the Annexes. The central position in the structural concrete member on site shall be ensured according to Annex B2, section 3.3.

1.8 Corrosion protection of the anchorage zone and of the free tendon length

Each tendon is fully encapsulated by a duct along its whole length.

On site, after tightening, but before stressing the tendon, the duct will be filled completely with hot vaseline acting as corrosion protection grease. The vaseline shall comply with EAD 1600027-00-0301, and with national provisions.

The connection duct provides the transition from the PE-duct to the free length of the tendon to the anchorage (see Annexes A10 to A12).

The connection duct overlaps with the trumpet, during concreting of the anchor it is swathed with PE-tape for leak tightness. After concreting this area is no longer accessible from the outside.

After cooling down of the wax and before tendon stressing, every high point is reinjected with "cold" corrosion protection mass (see Annexes A14 to A16 and B3).

With the use of certain types of ducts (according to Annex A9), the prestressed tendon may alternatively be grouted with a cementitious grout according to EN 447 or EAD 160027-00-0301. Grouting shall be carried out and monitored according to EN 446. The national standards and regulations applicable at the place of use must be taken into account also. The requirements according to EAD 160027 must be respected.

After prestressing, the tendons must be grouted with cementitious grout as soon as possible. If the tendons remain ungrouted for a longer period of time, suitable corrosion protection measures must be taken as specified by the ETA holder. Normally, the ducts must not be flushed with water. Grouting speed shall be between 3 m/min and 12 m/min. The maximum length of an injection section depends on the capacity of the injection equipment and must be determined on a project-specific basis prior to the injection process (taking into account the height difference at high and low points). It should not exceed 120 m (for BBV L27 the maximum length of an injection section must not exceed 95 m and for BBV L31 80 m). If these tendon lengths are exceeded, additional grouting openings must be provided.

If the tendon is placed over high points, suitable vents must be provided. If necessary, subsequent grouting must be carried out to avoid cavities. Grouting with cementitious grout in the area of high points at inaccessible deflections according to Annexes A13 to A15 shall be carried out in accordance with the procedure described in the control plan. The grouting speed in these areas shall not exceed 4.5 m/min. If grouting is carried out over more than one high point, the grouting speed shall not exceed 4.5 m/min in the entire tendon area. Particular care must be taken to ensure that timing specifications for the use of the grout according to EN 446 and EN 447 are observed. The PE ducts and deflection ducts to be used for this purpose can be found in Annexes A13 to A15.

After stressing, the protection measures for the anchorages shall be carried out according to the description in Annex B3 and as specified in the Annexes A3, A4 and A8.

1.9 Corrosion protection of exposed steel components

Exposed steel components which are not sufficiently covered by concrete (at least 5 cm) or which are not protected by corrosion protection material (e.g. wax) shall be protected against corrosion by one of the following protective paint systems according to EN ISO 12944-5:2008-01:

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

b) with zinc coating (galvanised): A7.10, A7.11, A7.12, A7.13

The surface preparation of the steel components shall be carried out according to EN ISO 12944-4:1998-07. For execution of the paint work EN ISO 12944-7:1998-07 shall be observed.

Local approved and recognised corrosion protection principles can be used instead, if admissible at the place of use.

1.10 Clearances at anchorages, minimum width of crossbeams

The anchorages are schematically shown in Annexes A3, A4 and A8 as well as A10 to A12. At the entrances of the crossbeams, trumpet-like widenings shall be provided, with a minimum of $\Delta\alpha = 3°$. The widenings shall allow for unscheduled deviations from the planned position of the tendon axis (tendon path) without any kinks up to the angle $\Delta\alpha$.

In the case of fixed anchors at the entrance of the structure/crossbeam, the admissible strand displacement due to stressing shall not exceed 10 cm (see Annex B2, sections 3.9 and 3.11). The minimum width of the crossbeam at both the stressing and the fixed anchors is given in Annexes A10 and A11, in the case of deviations behind the anchorage area in Annex A12. Over the length min. L1 the tendon path must be straight.

1.11 Ducts

Along their free length, the tendons shall be ensheathed with PE-ducts according to EN 12201 and Annex A2. The scheme of the duct installation and the duct connections are shown in Annex A16.

PE-ducts or PE-reducing sockets will be assembled by means of heated tool butt-welding or helical heating element welding. For the welding of PE-ducts the regulations at the place of use shall be observed. The welding shall be carried out by professional plastic welders with a certification valid at the place of use.

The trumpets at the active and passive anchors are manufactured from PE-material of at least 3.5 mm thickness. At their ends the trumpets overlap with the connection ducts.

The maximum admissible deviation angle of the strands at the anchors and at joints between ducts with different diameter is max. 2.6°.

The strand deflection due to single strand couplings (see Annex A1) is 2.2°. At the end of the wedge there is no deflection angle.

During construction work the connection duct is attached to the trumpet by adhesive tape winding or a heat shrinking sleeve.

At the fixed anchor, the duct is positioned inside the connection duct as far as approximately 16 cm before the trumpet, and behind (outside) the crossbeam the duct is attached to the connection duct with a tensile-proof connection.

At the stressing anchor, before tightening the tendon, the duct shall extend at least 10 cm into the deviated area of the crossbeam. The duct in the free tendon length at the stressing anchor glides into the connection duct during the stressing process.

At the stressing anchor, the tensile-proof connection between connection duct and duct is assembled after the prestressing has been completed with an electric welding sleeve.

At the bearing plates the trumpets and subsequently ducts are enclosed by a suitable cement mortar. This cement mortar must absorb the spreading forces by bundling the strands and the pressure of the anti-corrosions agent.

1.12 Points of Deviation

In the area of deviation, the minimum radius of curvature shall always be above the values given in Annex A2, depending on the grade of the prestressing steel, the tendon size and the diameter of the duct.

The minimum radius of curvature shall also be complied with in the area of the provided trumpet-shaped widenings.

The formation of the area of deviation is shown in the Annexes A13 to A15. At the ends of the areas of deviation (entrance of the crossbeam), there are trumpet-like widenings with at least $\Delta\alpha = 3°$, which permit tolerances from the planned position of the tendon axis (tendon path) without a kink up to the angle $\Delta\alpha$.

In the area of deviation the duct lies inside a deviation duct which is coated with grease on the inside and extends about 10 cm over the area of deviation. In the case of the deviation type S, the maximum admissible deviation length max L_{zul} shall be observed (see Annex A14).

At the active and the passive anchors in the distance min L1 from the anchor heads deviations may be planned (see Annex A12). At the stressing anchor, before the tightening of the tendon, the duct shall extend from the curved (deviation) zone into the crossbeam for at least 10 cm.

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 B1.

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	The acceptance criterion to EAD 160004-00-03-01 clause 2.2.7 is fulfilled
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 18 April 2023 by Deutsches Institut für Bautechnik

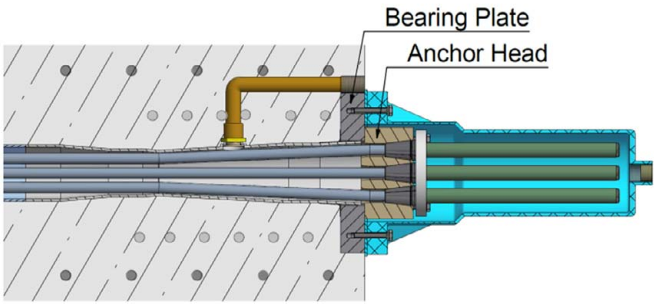
Dr.-Ing. Lars Eckfeldt
Head of Section

beglaubigt:
Knischewski

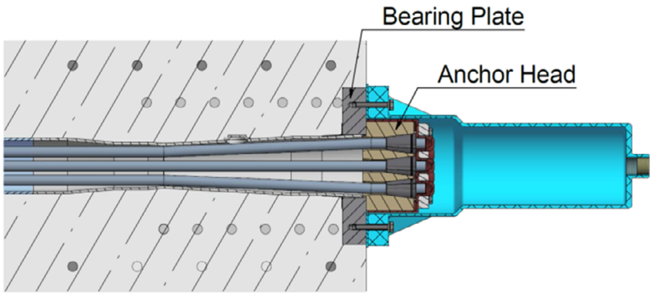
BBV External PT-System Type E

Overview Anchorages and Couplings

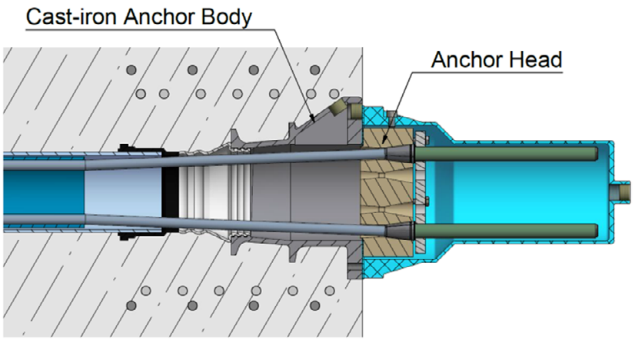
1. Active Anchor (S) BBV L3 E – BBV L9 E



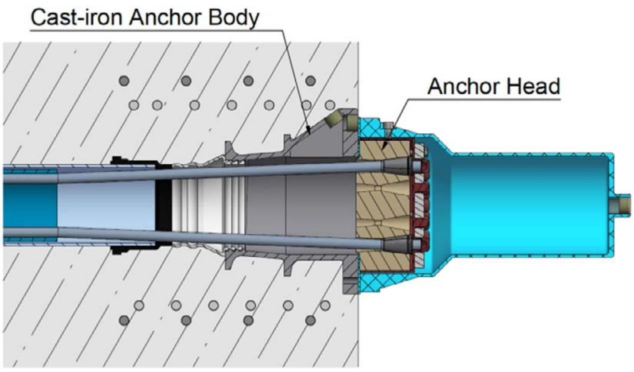
2. Passive Anchor (F) BBV L3 E – BBV L9 E



3. Active Anchor (S) BBV L12 E – BBV L31 E



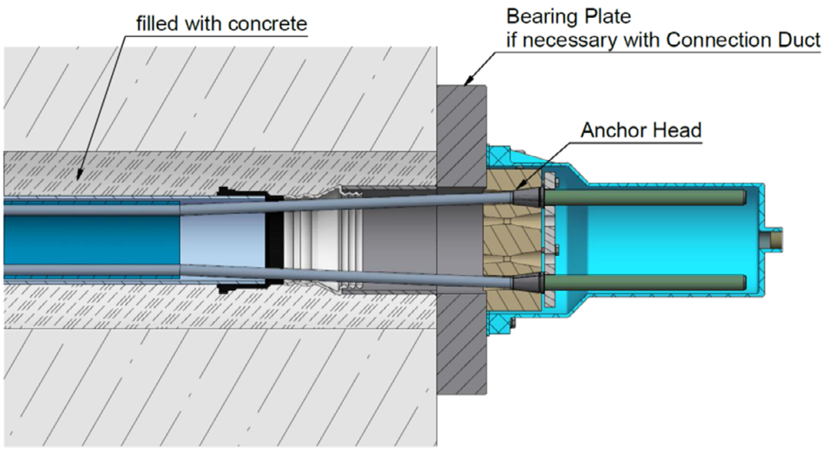
4. Passive Anchor (F) BBV L12 E – BBV L31 E



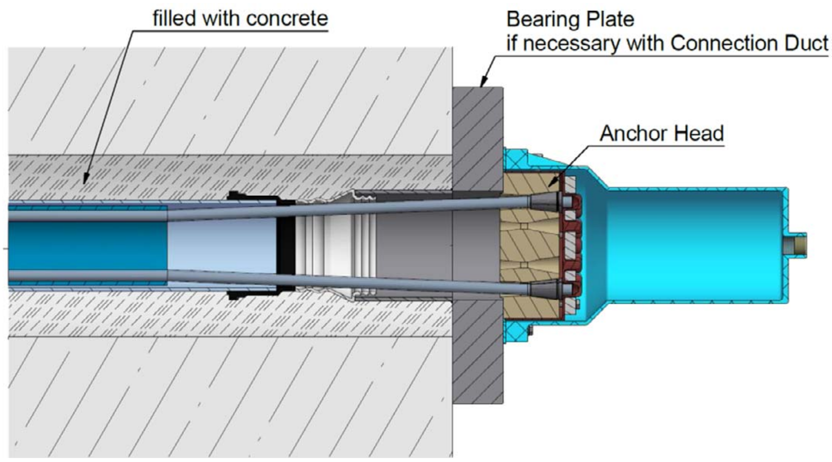
BBV External Post-Tensioning System Type E	Annex A1 Page 1 of 2
Product Description Overview Anchorages and Couplings	

BBV External PT-System Type E
Overview Anchorages and Couplings

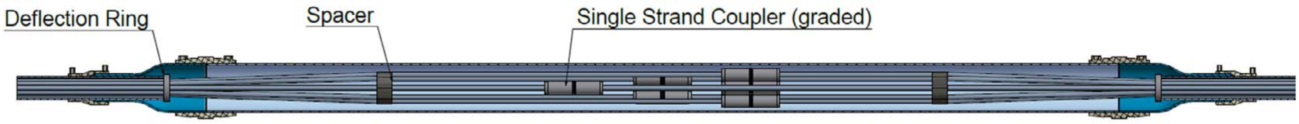
5. Active Anchor (S) for Patched Bearing Plates BBV L3 E – BBV L22 E



6. Passive Anchor (F) for Patched Bearing Plates BBV L3 E – BBV L22 E



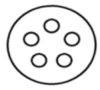
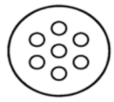
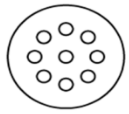
7. Single Strand Coupling (EÜK) BBV L3 E – BBV L31 E



BBV External Post-Tensioning System Type E	Annex A1 Page 2 of 2
Product Description Overview Anchorages and Couplings	

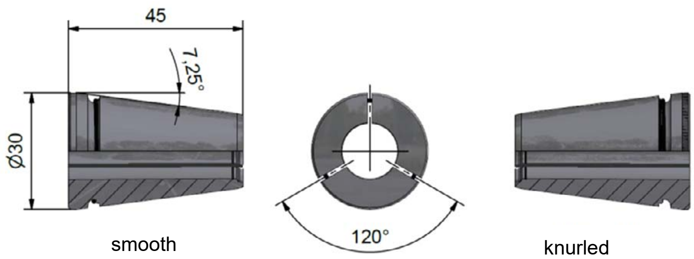
Technical Details BBV L3 E - BBV L9 E

Steel Grade Y1770S7 and Y1860S7

Tendon Type	Unit	**BBV L 3**	**BBV L 4**	**BBV L 5**	**BBV L 7**	**BBV L 9**
Strand Pattern						
Number of Strands	n	3	4	5	7	9
150mm² : Nom. Cross Section A_p	mm²	450	600	750	1050	1350
150mm² : Nom. Mass	kg/m	3.52	4.69	5.86	8.2	10.55
150mm² : F_{pk} (f_{pk}=1770N/mm²)	kN	797	1062	1328	1859	2390
150mm² : F_{pk} (f_{pk}=1860N/mm²)	kN	837	1116	1395	1953	2511
140mm² : Nom. Cross Section A_p	mm²	420	560	700	980	1260
140mm² : Nom. Mass	kg/m	3.28	4.37	5.47	7.65	9.84
140mm² : F_{pk} (f_{pk}=1770N/mm²)	kN	743	991	1239	1735	2230
140mm² : F_{pk} (f_{pk}=1860N/mm²)	kN	781	1042	1302	1823	2344
Friction Losses						
Active Anchor $\Delta P_{\mu S}$	%	1.2	1.2	1.2	1.1	1.0
Mean Friction Coefficient μ	-	0.08	0.08	0.08	0.08	0.08
PE-Duct						
Inner Diameter	mm	40.8	53.6	53.6	66.0	66.0
Wall Thickness	mm	4.6	4.7	4.7	4.5	4.5
Outer Diameter	mm	50	63	63	75	75
Min. Bending Radius (f_{pk}=1770N/mm²)	m	2.20	2.20	2.20	2.20	2.80
Min. Bending Radius (f_{pk}=1860N/mm²)	m	2.30	2.30	2.30	2.30	3.00
Strand Protrusion *	cm	21.5	21.5	70.0	71.0	82.0

* Distance from anchor head front face for placing of stressing jack, smaller distances are possible but only in consultation with BBV Systems GmbH.

Wedges Type 30



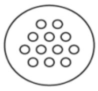
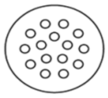
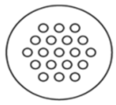
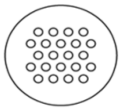
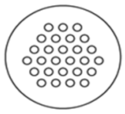
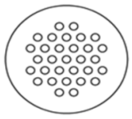
For pre-wedged passive anchors knurled wedges can be used optionally.

Wedges for strands of 150 mm² cross sectional area are marked "0.62" on the front face.

BBV External Post-Tensioning System Type E	Annex A2 Page 1 of 2
Product Description Technical Details BBV L3 E – BBV L9 E	

Technical Details BBV L12 E - BBV L31 E

Steel Grade Y1770S7 and Y1860S7

Tendon Type	Unit	**BBV L 12**	**BBV L 15**	**BBV L 19**	**BBV L 22**	**BBV L 27**	**BBV L31**
Strand Pattern							
Number of Strands	n	12	15	19	22	27	31
150mm² : Nom. Cross Section A_p	mm²	1800	2250	2850	3300	4050	4650
150mm² : Nom. Mass	kg/m	14.06	17.58	22.27	25.78	31.64	36.33
150mm² : F_{pk} (f_{pk}=1770N/mm²)	kN	3186	3983	5045	5841	7169	8231
150mm² : F_{pk} (f_{pk}=1860N/mm²)	kN	3348	4185	5301	6138	7533	8649
140mm² : Nom. Cross Section A_p	mm²	1680	2100	2660	3080	3780	4340
140mm² : Nom. Mas	kg/m	13.12	16.40	20.77	24.05	29.51	34.07
140mm² : F_{pk} (f_{pk}=1770N/mm²)	kN	2974	3717	4708	5452	6691	7682
140mm² : F_{pk} (f_{pk}=1860N/mm²)	kN	3125	3906	4948	5729	7031	8072
Friction Losses							
Active Anchor $\Delta P_{\mu S}$	%	0.8	0.8	0.8	0.6	0.8	0.8
Mean Friction Coefficient μ	-	0.08	0.08	0.08	0.08	0.08	0.08
PE-Duct (SDR17)							
Inner Diameter	mm	79.2	96.8	96.8	96.8 / 110.2	110.2	123.4
Wall Thickness	mm	5.4	6.6	6.6	6.6 / 7.4	7.4	8.3
Outer Diameter	mm	90	110	110	# 110 / 125	125	140
Min. Bending Radius (f_{pk}=1770N/mm²)	m	2.90	2.80	3.50	4.00 / 3.60	4.40	4.30
Min. Bending Radius (f_{pk}=1860N/mm²)	m	3.00	2.90	3.70	4.20 / 3.70	4.60	4.50
PE-Duct (SDR22) **							
Inner Diameter	mm	-	100	100	100 / 113.6	113.6	127.2
Wall Thickness	mm	-	5.0	5.0	5.0 / 5.7	5.7	6.4
Outer Diameter	mm	-	110	110	# 110 / 125	125	140
Min. Bending Radius (f_{pk}=1770N/mm²)	m	-	3.00	3.80	4.40 / 3.80	4.60	4.40
Min. Bending Radius (f_{pk}=1860N/mm²)	m	-	3.20	4.00	4.60 / 4.00	4.90	4.70
Strand Protrusion *	cm	80	80	110	110	120	120

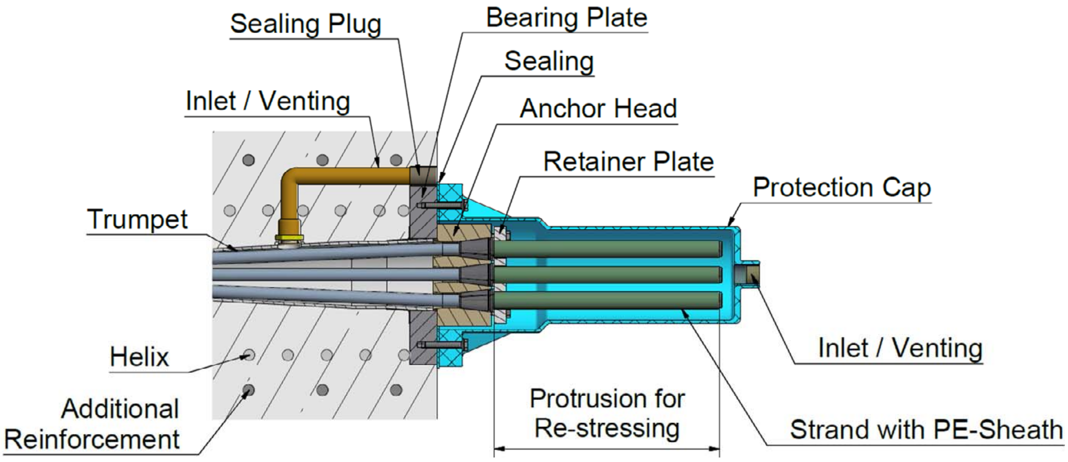
* Distance from anchor head front face for placing of stressing jack, smaller distances are possible but only in consultation with BBV Systems GmbH.

** Optional to be confirmed by BBV Systems GmbH

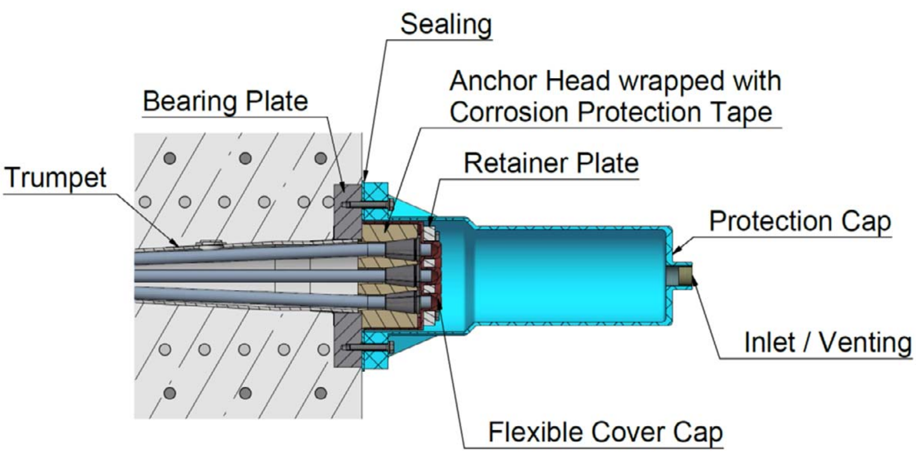
\# Use of smaller duct diameters to be confirmed by BBV Systems GmbH

Anchorage with Bearing Plate L3 E – L9 E

Active Anchor (S)



Passive Anchor (F)

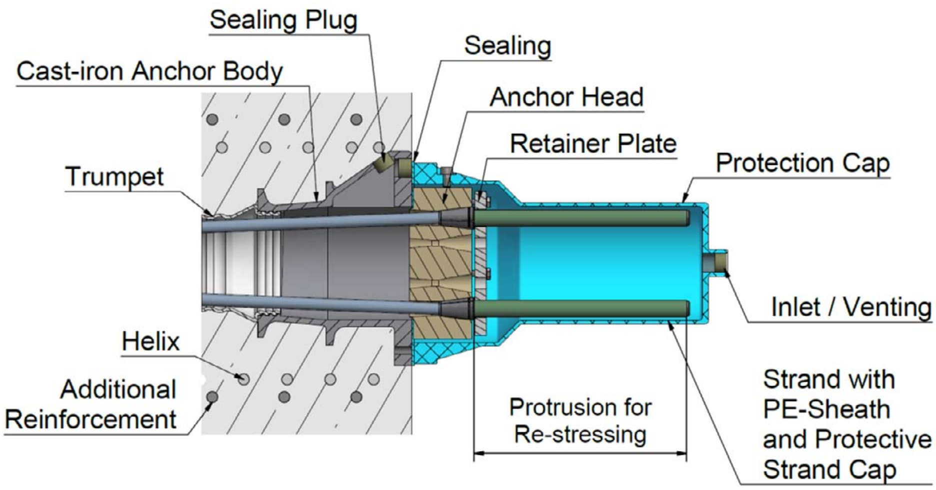


Alternatively:
If the flexible cover cap is omitted, the protection cap has to be filled with corrosion protection mass.

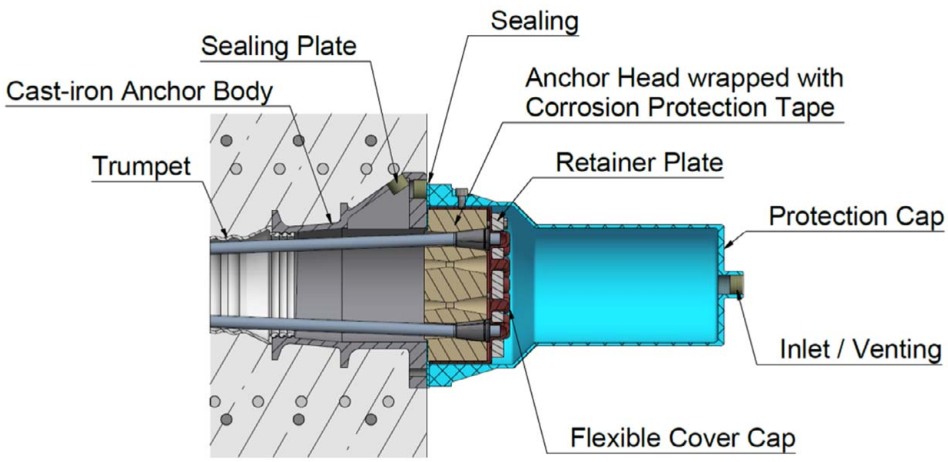
BBV External Post-Tensioning System Type E	Annex A3
Product Description Anchorages with Bearing Plate L3 E – L9 E	

Anchorage with Cast-iron Anchor Body L12 E – L31 E

Active Anchor (S)



Passive Anchor (F)



Alternatively:
If the flexible cover cap is omitted, the protection cap has to be filled with corrosion protection mass.

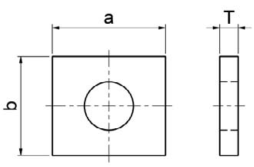
BBV External Post-Tensioning System Type E	Annex A4
Product Description Anchorages with Cast-iron Anchor Body L12 E – L31 E	

Dimensions of Anchor Components

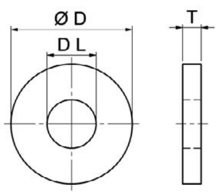
Tendon Type		Unit	L3	L4	L5	L 7	L 7R	L 9	L 9R	L 12	L 15	L 19	L 22	L 27	L31
Bearing Plate, rect.															
Side Length	a	mm	160	180	195	215		250							
Side Length	b	mm	140	160	170	190	-	220	-	-	-	-	-	-	-
Thickness	T	mm	25	25	30	35		35							
Hole Diameter		mm	72	81	83	93		113							
Bearing Plate, round															
Diameter	D	mm					230		265						
Thickness	T	mm	-	-	-	-	35	-	35	-	-	-	-	-	-
Hole Diameter	DL	mm					93		113						
Cast-iron Anchor Body															
Diameter	D	mm								240	270	300	327	360	382
Height	H	mm								182	203	227	248	272	294
Thickness 1st Plane	T	mm	-	-	-	-		-		22	23	27	28	32	34
Hole - ø, top	Lo	mm								131	150	163	183	199	208
Hole - ø, bottom	Lu	mm								123	139	148	165	176	182
Anchor Head															
Diameter (Type 2)	D	mm	104	114	120	133		160		180	194 1)	220	245	265	280
Thickness (Type 2)	T	mm	45	50	50	50		50		61	60	77	77	91	87
Diameter (Type 2)	A	mm	70	79	81	91		111		129	148	161	181	197	206
Hole Circle	e1	mm	45	54	56	66		86		2)	56	2)	2)	2)	2)
Hole Circle	e2	mm	-	-	-	-		-		-	120	-	-	-	-
Trumpet Min. Length		mm	≥ 450	≥ 439	≥ 439	≥ 485		≥ 645		≥ 200	≥ 205	≥ 305	≥ 765	≥ 895	≥ 355

1) optional 200mm 2) Grid

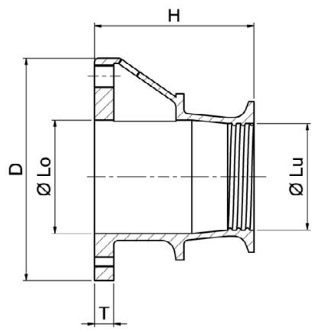
Bearing Plate, rectangular



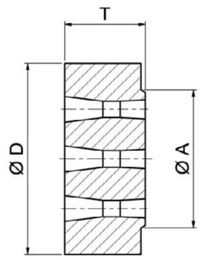
Bearing Plate, round



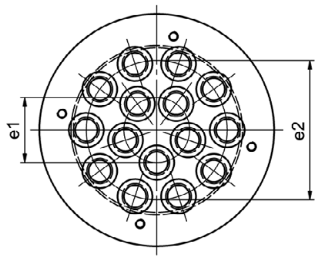
Cast-iron Anchor Body



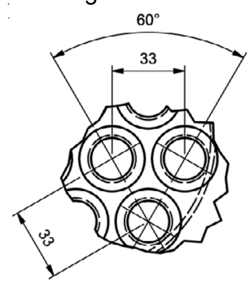
Anchor Head



<u>BBV L3; 4; 5; 7; 9 und 15</u>
All conical borings are aligned on one or two circles (e1 and e2). See table above



<u>BBV L12; 19; 22; 27 und 31</u>
Conical borings are in line, lines result in a grid.



Centre and Edge Distances

Tendon Type		**L3**	**L4**	**L5**	**L7**	**L7 R**	**L9**	**L9 R**
	Unit	Bearing Plate						
Min. Centre Distance *								
$f_{cmj,cube} \geq 30$ N/mm²	mm	215 x 190	245 x 220	275 x 245	325 x 285	305 x 305	370 x 325	350 x 350
$f_{cmj,cube} \geq 34$ N/mm²	mm	200 x 175	230 x 205	260 x 230	305 x 270	290 x 290	345 x 305	325 x 325
$f_{cmj,cube} \geq 40$ N/mm²	mm	185 x 160	215 x 185	235 x 210	280 x 245	265 x 265	320 x 275	300 x 300
$f_{cmj,cube} \geq 45$ N/mm²	mm	170 x 150	200 x 175	225 x 195	260 x 230	245 x 245	295 x 265	280 x 280
Min. Edge Distance **								
$f_{cmj,cube} \geq 30$ N/mm²	mm	130 x 115	145 x 130	160 x 145	185 x 165	175 x 175	205 x 185	195 x 195
$f_{cmj,cube} \geq 34$ N/mm²	mm	120 x 110	135 x 125	150 x 135	175 x 155	165 x 165	195 x 175	185 x 185
$f_{cmj,cube} \geq 40$ N/mm²	mm	115 x 100	130 x 115	140 x 125	160 x 145	155 x 155	180 x 160	170 x 170
$f_{cmj,cube} \geq 45$ N/mm²	mm	105 x 95	120 x 110	135 x 100	150 x 135	145 x 145	210 x 155	160 x 160

Tendon Type		**L12**	**L15**	**L19**	**L22**	**L27**	**L31**
	Unit	Cast-iron Anchor Body					
Min. Centre Distance *							
$f_{cmj,cube} \geq 28$ N/mm² (square)	mm	405	450	505	545	605	645
$f_{cmj,cube} \geq 34$ N/mm² (square)	mm	370	415	465	500	550	595
$f_{cmj,cube} \geq 40$ N/mm² (square)	mm	340	380	430	460	510	545
$f_{cmj,cube} \geq 45$ N/mm² (square)	mm	325	360	405	435	485	520
Min. Edge Distance **							
$f_{cmj,cube} \geq 28$ N/mm² (square)	mm	225	245	275	295	325	345
$f_{cmj,cube} \geq 34$ N/mm² (square)	mm	205	230	255	270	295	320
$f_{cmj,cube} \geq 40$ N/mm² (square)	mm	190	210	235	250	275	295
$f_{cmj,cube} \geq 45$ N/mm² (square)	mm	185	200	225	240	265	280

* Distances can be reduced to 85% of the given values in one direction, if increased correspondingly in the other direction.

** Minimum edge distance: min. centre distance/2 + 20mm (rounding up at 5 mm intervals)

Helix and Additional Reinforcement

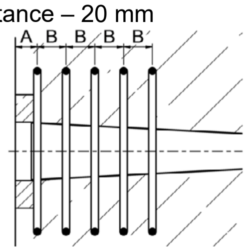
Tendon Type	Unit	L3	L4	L5	L 7	L 9	L 12	L 15	L 19	L 22	L 27	L31
		Bearing Plate					Cast-iron Anchor Body					
Helix *												
Bar Diameter												
$f_{cmj,cube}$ ≥ 28/30 N/mm² **	mm	14	14	14	14	14	14	14	16	16	16	16
$f_{cmj,cube}$ ≥ 34 N/mm²	mm	14	14	14	14	14	14	16	16	16	16	16
$f_{cmj,cube}$ ≥ 40 N/mm²	mm	14	14	14	14	14	14	14	16	16	16	16
$f_{cmj,cube}$ ≥ 45 N/mm²	mm	14	14	14	14	14	14	14	16	16	16	16
Outer Diameter *												
$f_{cmj,cube}$ ≥ 28/30 N/mm² **	mm	140	160	180	200	240	300	345	390	430	490	520
$f_{cmj,cube}$ ≥ 34 N/mm²	mm	135	150	170	190	230	300	340	380	410	450	480
$f_{cmj,cube}$ ≥ 40 N/mm²	mm	130	135	160	190	225	285	320	360	380	430	460
$f_{cmj,cube}$ ≥ 45 N/mm²	mm	120	120	140	180	220	270	315	340	365	410	430
min. Length *												
$f_{cmj,cube}$ ≥ 28/30 N/mm² **	mm	200	230	250	300	350	350	400	450	450	550	550
$f_{cmj,cube}$ ≥ 34 N/mm²	mm	180	210	240	270	310	300	350	400	450	470	470
$f_{cmj,cube}$ ≥ 40 N/mm²	mm	170	200	220	250	290	300	300	350	350	450	450
$f_{cmj,cube}$ ≥ 45 N/mm²	mm	160	180	200	250	275	250	250	300	300	350	350
min. Pitch *												
$f_{cmj,cube}$ ≥ 28/30 N/mm² **	mm	40	40	40	50	50	50	50	50	50	50	50
$f_{cmj,cube}$ ≥ 34 N/mm²	mm	40	40	40	50	50	50	50	50	50	50	50
$f_{cmj,cube}$ ≥ 40 N/mm²	mm	40	40	40	50	50	50	50	50	50	50	50
$f_{cmj,cube}$ ≥ 45 N/mm²	mm	40	40	40	50	50	50	50	50	50	50	50
Helix Turns *												
$f_{cmj,cube}$ ≥ 28/30 N/mm² **	n	6	7	7.5	7	8	8	9	10	10	12	12
$f_{cmj,cube}$ ≥ 34 N/mm²	n	5.5	6.5	7	6.5	7	7	8	9	10	10.5	10.5
$f_{cmj,cube}$ ≥ 40 N/mm²	n	5.5	6	6.5	6	7	7	7	8	8	10	10
$f_{cmj,cube}$ ≥ 45 N/mm²	n	5	5.5	7	6	6.5	6	6	7	7	8	8
Stirrup Reinforcement ***												
$f_{cmj,cube}$ ≥ 28/30 N/mm² **	Qty. x Ø	4 x ø10	4 x ø12	4 x ø14	4 x ø14	5 x ø14	6 x ø12	5 x ø14	6 x ø16	7 x ø16	11 x ø16	12 x ø16
$f_{cmj,cube}$ ≥ 34 N/mm²	Qty. x Ø	4 x ø10	5 x ø10	5 x ø12	5 x ø12	5 x ø14	6 x ø14	8 x ø14	7 x ø16	8 x ø16	9 x ø20	10 x ø20
$f_{cmj,cube}$ ≥ 40 N/mm²	Qty. x Ø	4 x ø8	4 x ø12	5 x ø12	5 x ø12	5 x ø14	5 x ø16	6 x ø16	7 x ø16	6 x ø20	8 x ø20	10 x ø20
$f_{cmj,cube}$ ≥ 45 N/mm²	Qty. x Ø	4 x ø8	4 x ø10	4 x ø12	4 x ø12	6 x ø12	5 x ø16	6 x ø16	8 x ø16	8 x ø16	8 x ø20	9 x ø20
Position behind Bearing Plate / Cast-iron Anchor Body		A / B	A / B	A / B	A / B	A / B	A / B	A / B	A / B	A / B	A / B	A / B
$f_{cmj,cube}$ ≥ 28/30 N/mm² **	mm	45 / 60	45 / 70	50 / 75	55 / 95	55 / 80	50 / 70	50 / 95	50 / 90	50 / 80	60 / 60	60 / 55
$f_{cmj,cube}$ ≥ 34 N/mm²	mm	45 / 55	45 / 50	50 / 55	55 / 65	55 / 75	50 / 65	50 / 55	50 / 70	50 / 65	60 / 65	60 / 55
$f_{cmj,cube}$ ≥ 40 N/mm²	mm	45 / 55	45 / 60	50 / 50	55 / 60	55 / 70	50 / 70	50 / 65	50 / 60	50 / 75	60 / 65	60 / 55
$f_{cmj,cube}$ ≥ 45 N/mm²	mm	45 / 50	45 / 55	50 / 60	55 / 75	55 / 50	50 / 65	50 / 60	50 / 55	50 / 50	60 / 60	60 / 55

* Nominal Dimensions, Tolerances deposited at DIBt

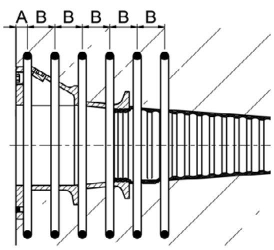
** $f_{cmj,cube}$ ≥ 30 N/mm² apply to BBV L3 - L9 / $f_{cmj,cube}$ ≥ 28 N/mm² apply to BBV L12 - L31

*** Side Length Stirrup ≥ Min. Centre Distance – 20 mm

<u>Sketches:</u> **L3 E – L9 E**



L12 E – L 31 E



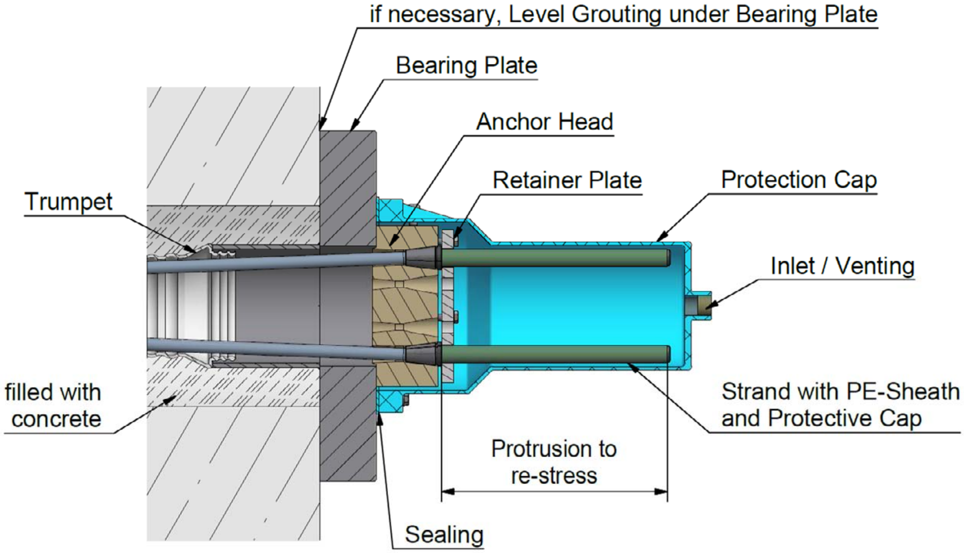
BBV External Post-Tensioning System Type E

Product Description
Helix and Additional Reinforcement

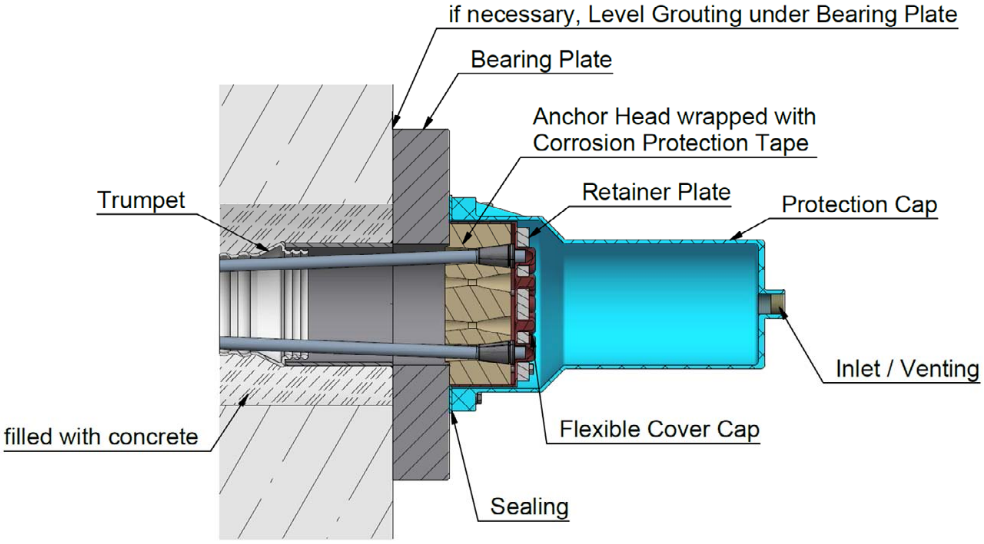
Annex A7

Anchorage with Patched Bearing Plates L3 E – L22 E

Active Anchor (S)



Passive Anchor (F)

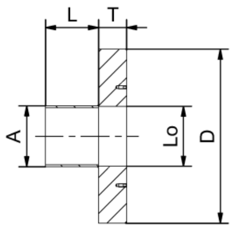


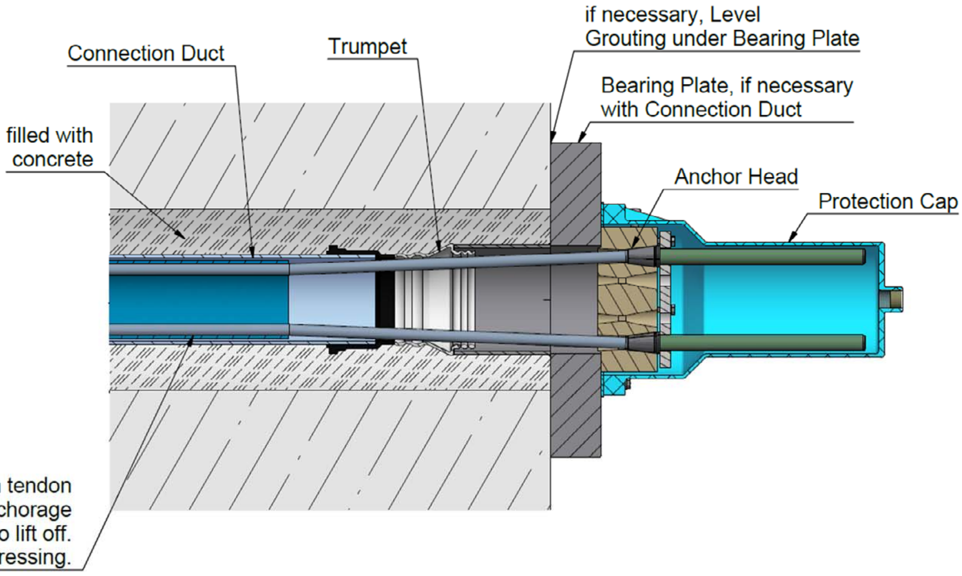
<u>Alternatively:</u>
If the flexible cover cap is omitted, the protection cap has to be filled with corrosion protection mass.

BBV External Post-Tensioning System Type E	Annex A8 Page 1 of 2
Product Description Anchorage with Patched Bearing Plate L3 E – L22 E	

Anchorage with Patched Bearing Plate L3 E – L22 E

Patched Bearing Plate





Tendon Type		Unit	**L3 E**	**L4 E**	**L5 E**	**L7 E**	**L9 E**	**L12 E**	**L15 E**	**L19 E**	**L22 E**
Bearing Plate											
Outer Diameter	D	mm	240	255	275	310	345	390	435	485	515
Thickness	T	mm	50	50	50	55	60	65	70	75	80
Hole Diameter	Lo	mm	72	81	83	93	113	131	150	163	183
Connection Duct											
Outer Diameter	A	mm	No Connection Duct Required					139.7	152	168.3	193.7
Length	L	mm						117	133	152	168
Penetration Pipe or Core Drilling											
max. Diameter	K	mm	160	160	160	170	190	200	225	230	250
Min. Strength of Concrete or Level Grouting for Stressing											
$f_{cmj,cube}$		MPa	38								
min. Center / Edge Distance *		mm	285 / 165	320 / 180	350 / 195	400 / 220	450 / 245	520 / 280	580 / 310	640 / 340	690 / 365

* Edge distance: Centre distance/2 + 20mm (rounding up at 5mm intervals)
The Centre / Edge distances can be converted to the similar area from square to rectangular; the shorter side has to be min. 85% of the square side length. The anchorage distances in one direction can be reduced to 85% of the table values, if the distances correspondingly increased in the other direction.

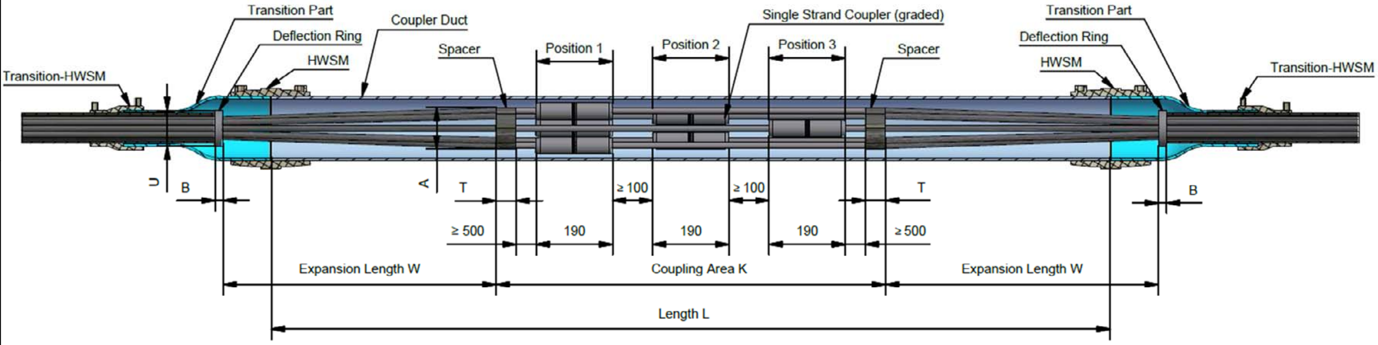
<u>Note:</u>
Regarding the additional reinforcement Annex B1 section 2.6 must be considered

BBV External Post-Tensioning System Type E

Product Description
Anchorage with Patched Bearing Plate L3 E – L22 E

Annex A8
Page 2 of 2

Single Strand Coupling (EÜK)



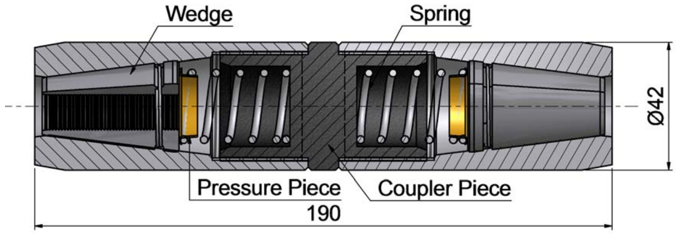
Dimensions of Components

All measures are minimal dimensions!

Tendon Type		Unit	L3 E	L4 E	L5 E	L7 E	L9 E	L12 E	L15 E	L19 E	L22 E	L27 E	L31 E
Spacer													
Outer Diameter	A	mm	62	71	73	83	103	118	127	139	158	173	177
Thickness	T_A	mm	30	30	30	50	50	40	50	70	70	70	70
Hole Diameter	e1	mm	45	54	56	66	86	*Grid	56	*Grid	*Grid	*Grid	*Grid
Hole Diameter	e2	mm							120				
Deflection Ring													
Outer Diameter	U	mm	60.3	73	73	88.9	88.9	101.6	127	133	133 / 152.4	152.4	168.3
Wall Thickness	T_U	mm	5	5	5	6.3	6.3	5	8	11	11 / 12.5	12.5	14.2
Width	B	mm	20	20	20	20	20	20	20	25	25 / 30	30	30
Coupler Duct													
Length, min.	L	mm	2500	2330	2550	2730	2990	3050	3710	3720	3980	4000	4370
Expansion Length	W	mm	450	520	480	550	680	680	1030	1010	1140	1130	1300
Coupling Area, min.	K	mm	1830	1540	1830	1870	1870	1850	1870	1910	1910	1910	1910
Inner Diameter		mm	96.8	110.2	110.2	147.6	147.6	184.6	184.6	184.6	184.6 / 230.8	230.8	230.8
Wall Thickness		mm	6.6	7.4	7.4	6.2	6.2	7.7	7.7	7.7	7.7 / 9.6	9.6	9.6
Outer Diameter		mm	110	125	125	160	160	200	200	200	200 / 250	250	250
PE Duct; PE; SDR 17													
Inner Diameter		mm	40.8	53.6	53.6	66	66	79.2	96.8	96.8	96.8 / 110.2	110.2	123.4
Wall Thickness		mm	4.6	4.7	4.7	4.5	4.5	5.4	6.6	6.6	6.6 / 7.4	7.4	8.3
Outer Diameter		mm	50	63	63	75	75	90	110	110	#110 /125	125	140
PE Duct; PE; SDR 22													
Inner Diameter		mm							100	100	100 / 113.6	113.6	127.2
Wall Thickness		mm							5	5	5.0 / 5.7	5.7	6.4
Outer Diameter		mm							110	110	#110 /125	125	140

* grouting of all SDR 22 ducts as well as SDR17 ducts with an outside diameter of 110 mm for tendon L22 has to be carried out with non-cementitious corrosion protection compounds specified in Annex D1.

Dimensions of a Single Strand Coupler

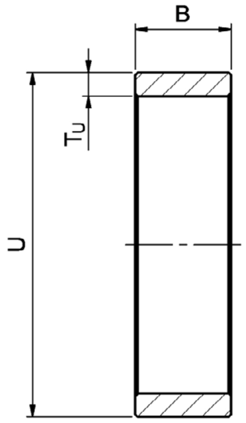


Note:
During installation please pay attention to the wedge marking. Wedges for anchoring strands with 150 mm² (0.62“) cross section are marked with "0.62" on the front face.

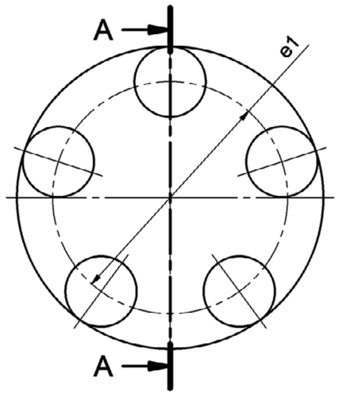
BBV External Post-Tensioning System Type E	Annex A9 Page 1 of 2
Product Description Single Strand Coupling EÜK	

Single Strand Coupling (EÜK)

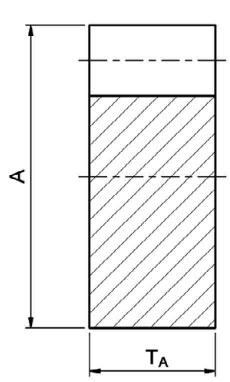
Deflection Ring



Spacer (L5 shown)

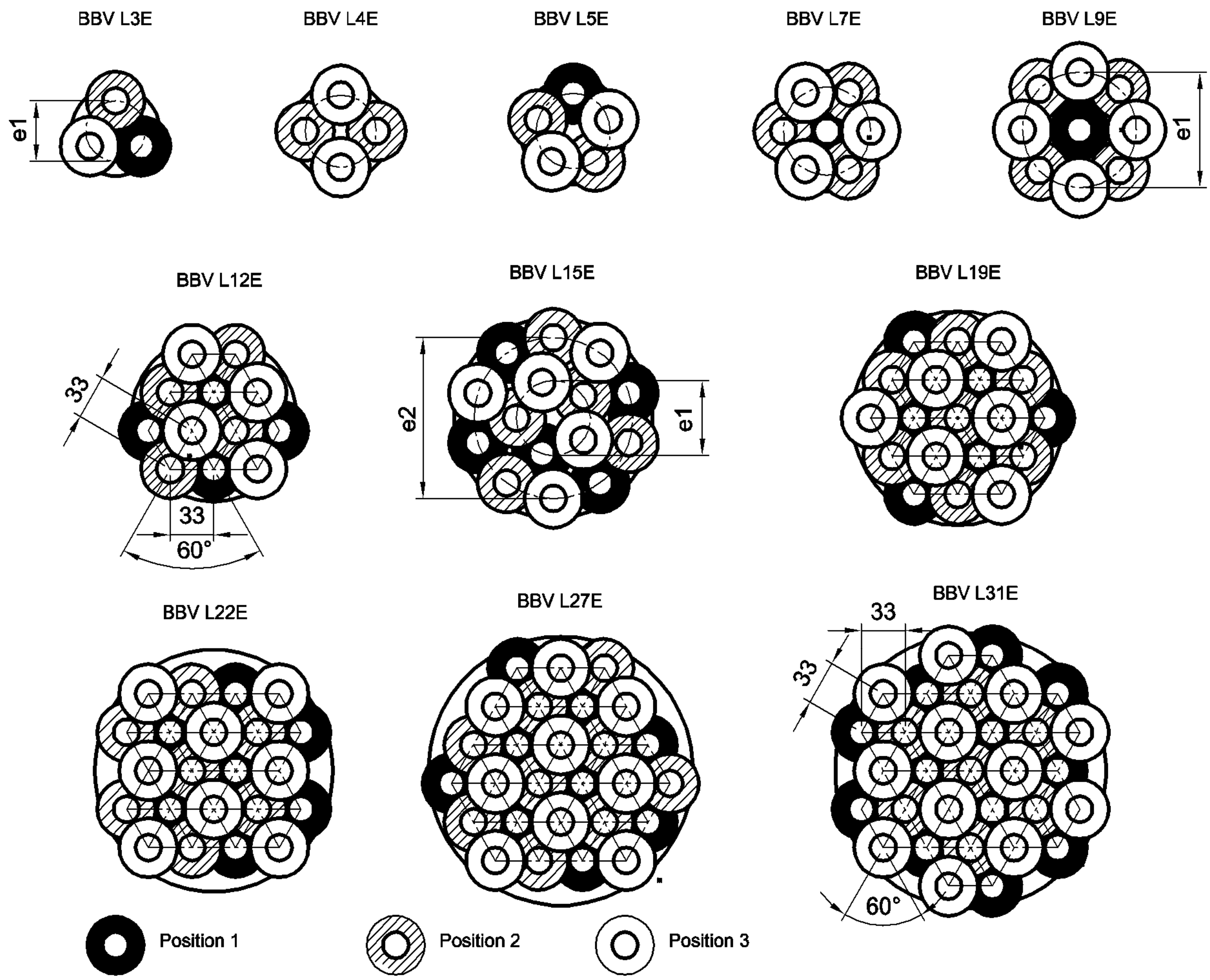


A-A



Information to circle or grid pattern see positions of single strands

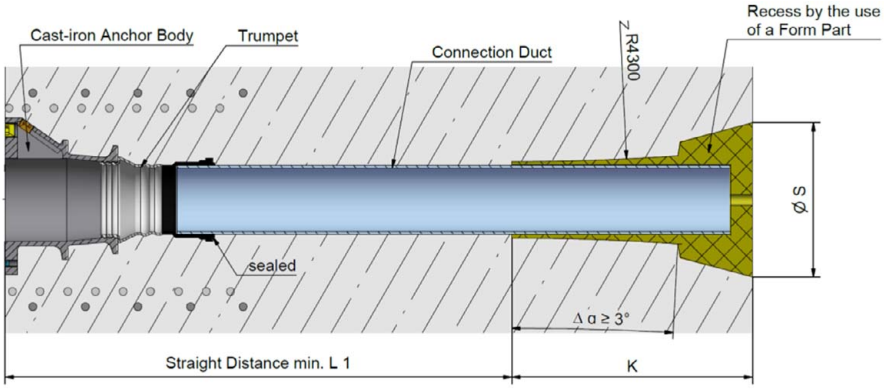
Positions of Single Strands



BBV External Post-Tensioning System Type E	Annex A9 Page 2 of 2
Product Description Single Strand Coupling EÜK	

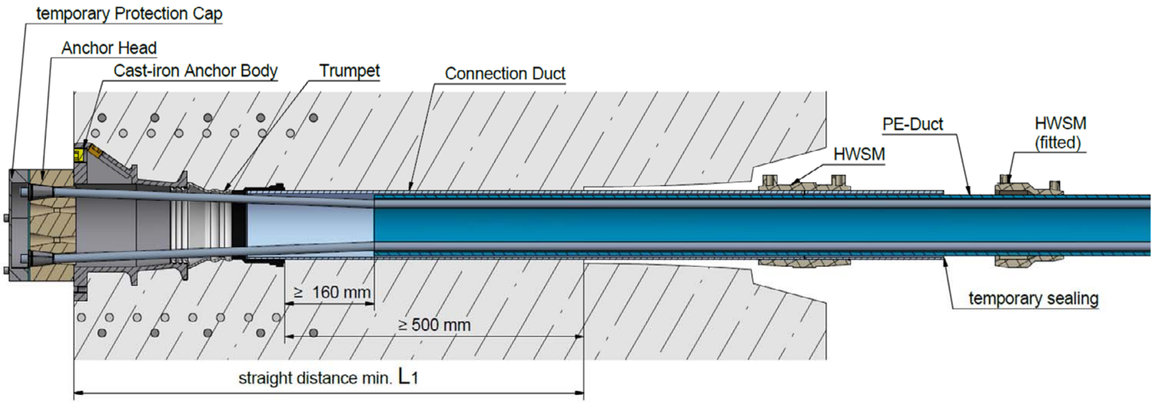
Connection Passive Anchor (F) - Duct

1. State of Construction with Form Parts, straight Connection Duct

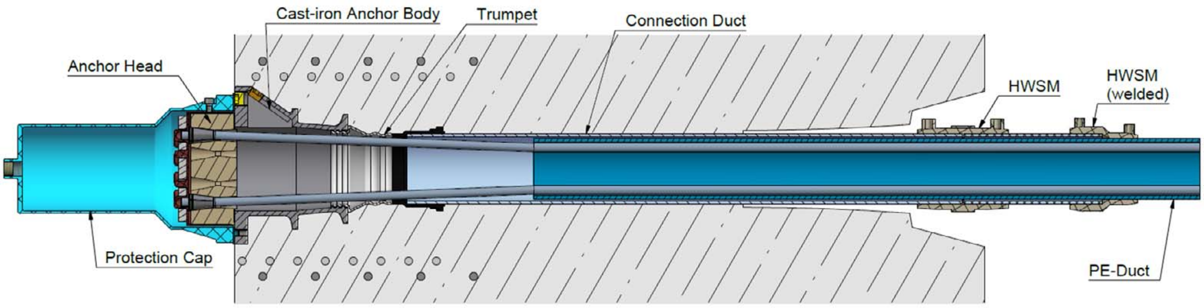


Note for the Recess Form Part ØS and Length K: Depending on the chosen electro welding sleeve (HWSM) and after consultation with BBV Systems smaller recesses are possible (analogous in Annex A11).

2. Situation before Stressing Process, Connection with the Duct



3. Final State, Connection with the Duct

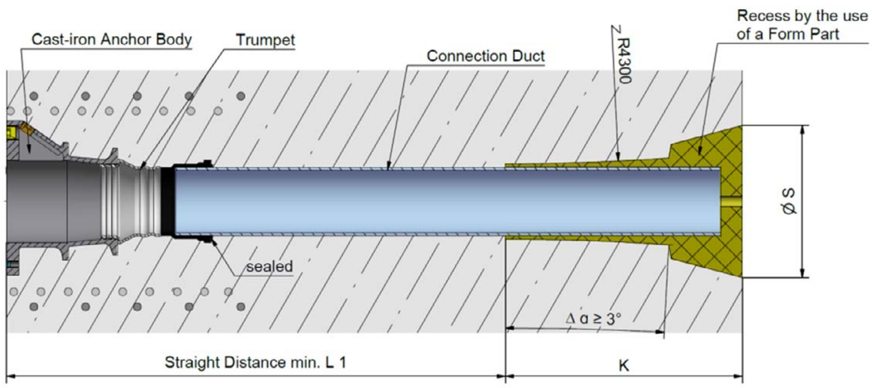


HWSM = Electro Welding Sleeve

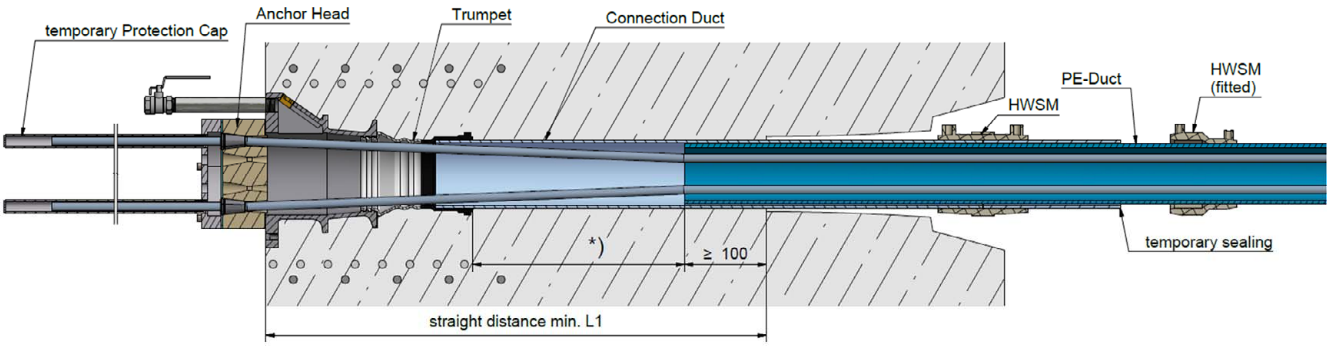
BBV External Post-Tensioning System Type E	Annex A10
Product Description Connection Passive Anchor (F) - Duct	

Connection Active Anchor (S) – Duct

1. State of Construction with Form Parts, straight Connection Duct

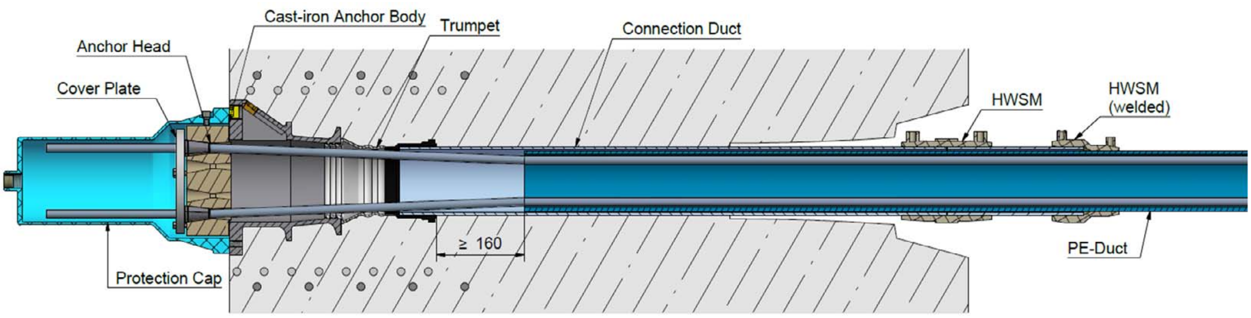


2. Situation before Stressing Process, Connection with the Duct



*) ≥ Tendon Elongation + 160mm + if applicable re-stressing elongation ≥ 500mm (the higher value is decisive!)

3. Final State, Connection with the Duct



Tendon Type	Unit	L3 E	L4 E	L5 E	L7 E	L9 E	L12 E	L15 E	L19 E	L22 E	L27 E	L31 E
Outer Diameter Plastic Duct	mm	50	63	63	75	75	90	110	110	110/125	125	140
Connection Duct												
Outer Diameter	mm	63	75	75	90	90	110	125	125	140	140	160
Min. Wall Thickness	mm	4.3	4.3	4.3	5.1	5.1	6.3	4.8	4.8	4.3	4.3	6.2
Recess Form Part ØS	mm	201	213	213	233	238	263	279	285	288/285	311	330
Length Form Part K	mm	338	331	331	348	411	421	435	519	575/512	613	592
Straigth Distance min. L1												
Smooth Plastic Duct PE SDR 17	mm	660	780	860	870	1100	1270	1530	1440	1420/1710	1870	2370
Smooth Plastic Duct PE SDR 22	mm	-	-	-	-	-	-	1580	1500	1480/1760	2020	2430

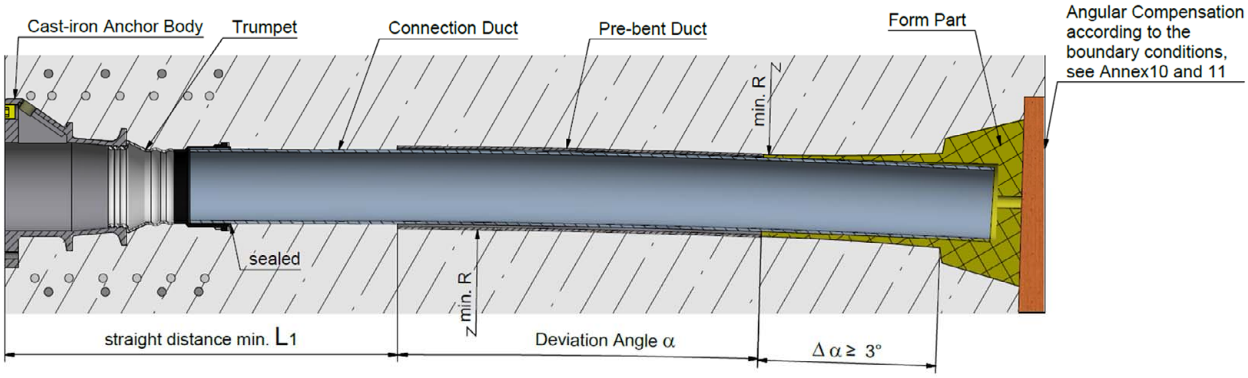
BBV External Post-Tensioning System Type E

Product Description
Connection Active Anchor (S) - Duct

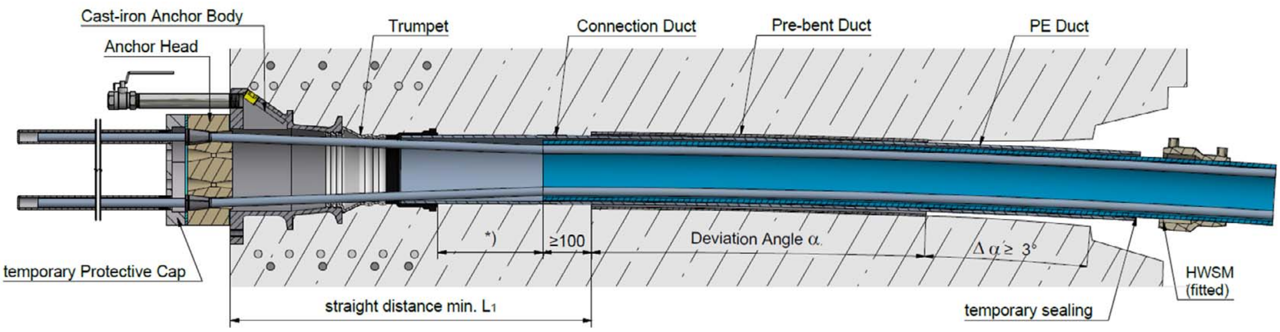
Annex A11

Connection Anchor Close Deviation – Active Anchor

1. State of Construction with Form Part, Connection Duct, Pre-Bent Steel Pipe

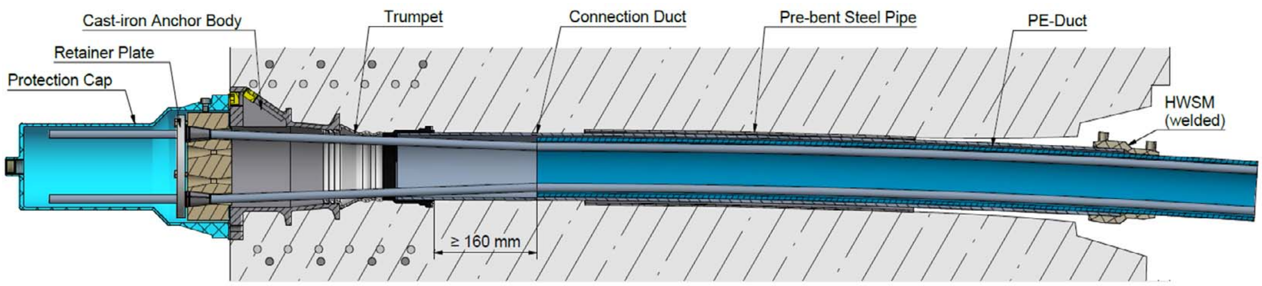


2. Situation before the Stressing Process, Connection with the Duct



*) ≥ Tendon Elongation + 160mm + if applicable re-stressing Elongation ≥ 500mm (the higher value is decisive!)

3. Final State, Connection with the Duct



Tendon Type	Unit	L3 E	L4 E	L5 E	L7 E	L9 E	L12 E	L15 E	L19 E	L22 E	L27 E	L31 E
Outer Diameter Plastic Duct	mm	50	63	63	75	75	90	110	110	110/125	125	140
Connection Duct												
Recess Form Part ØS		Dimensions see Annex 11										
Length Form Part K												
Straight Distance min. L1												
Smooth Plastic Duct PE SDR 17	mm	910	1150	910	1270	1300	1410	1940	1650	1660/1940	2080	2360
Smooth Plastic Duct PE SDR 22	mm	-	-	-	-	-	-	1940	1650	1670/1940	2080	2420
Pre-bent Steel Pipe												
Outer Diameter d_s	mm	76.1	88.9	88.9	101.6	101.6	127.0	139.7	139.7	159.0	159.0	177.8
Wall Thickness	mm	2.9	3.2	3.2	3.6	3.6	4.0	4.0	4.0	4.5	4.5	5.0

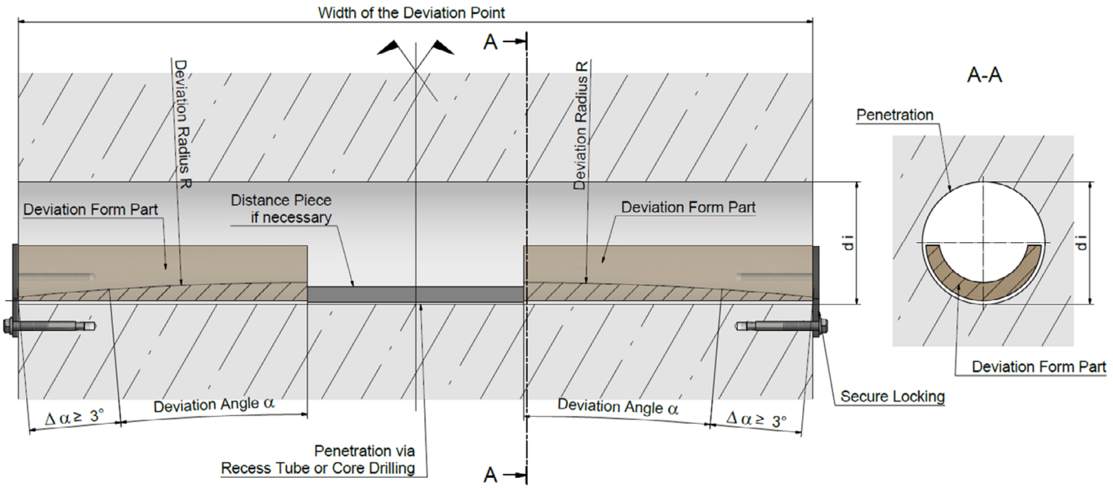
BBV External Post-Tensioning System Type E

Product Description
Connection Anchor Close Deviation (F) - Duct

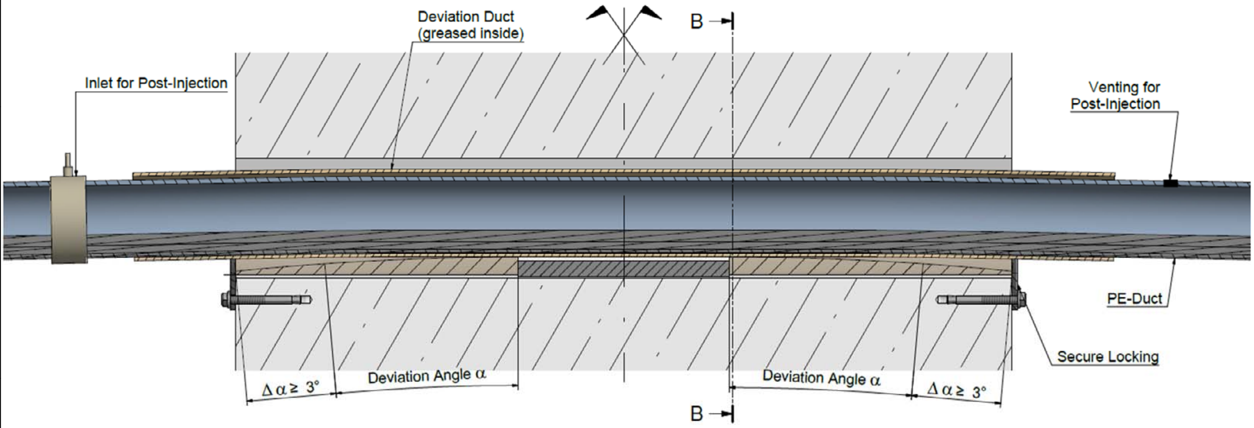
Annex A12

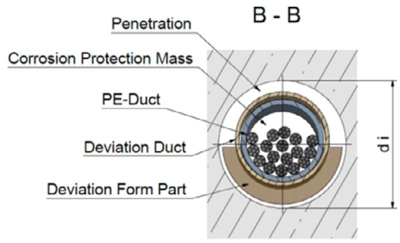
Deviation Type F: Penetration with Inserted Deviation Form Parts

State of Construction



Final State





During construction, misalignment of the penetration tubes must be avoided.
The deviation form parts are made of plastic and steel.

The penetration consists of galvanized steel-, PVC- or PE-tube or can be made by core drilling.

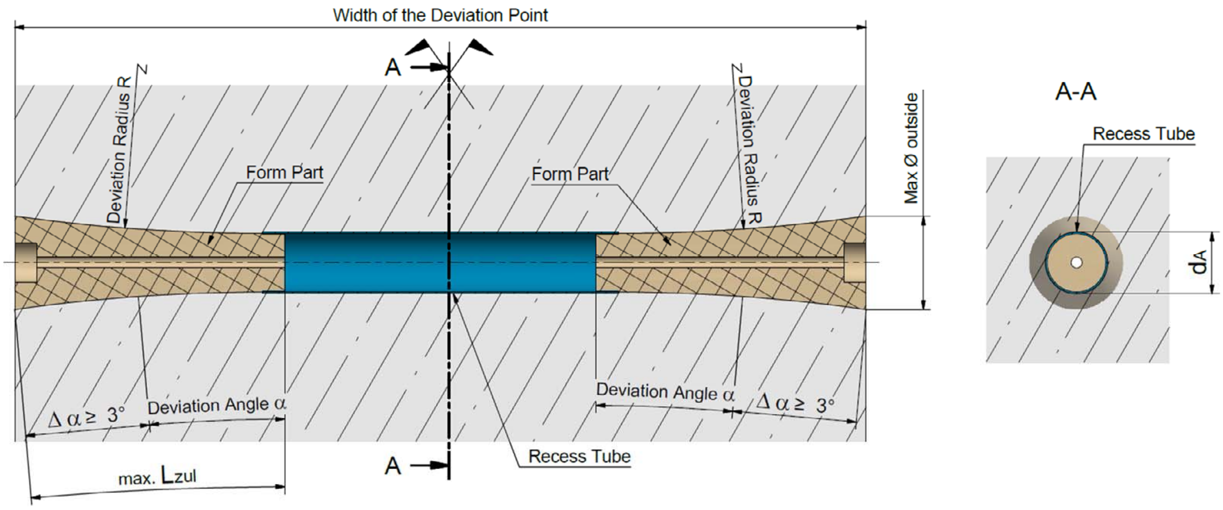
Tendon Type	Unit	**L3 E**	**L4 E**	**L5 E**	**L7 E**	**L9 E**	**L12 E**	**L15 E**	**L19 E**	**L22 E**	**L27 E**	**L31 E**
Outer Diameter Plastic Duct	mm	50	63	63	75	75	90	110	110	110/125	125	140
Additional Deviation Angle Δα	°	≥ 3										
Deviation Duct												
Outer Diameter	mm	63	75	75	90	90	110	125	125	125/140	140	160
Wall Thickness	mm	4.3	4.3	4.3	5.1	5.1	6.3	4.8	4.8	4.8/4.3	4.3	6.2
Penetration d_i	mm	to be confirmed by BBV Systems GmbH										

For tendon size L22 it is stated, that tendons with an outer diameter of the PE sheathing pipes of 110 mm in accordance with the associated deflection ducts, recess ducts and bent steel ducts may only be grouted with non-cementitious corrosion protection compounds according to Annex D1.

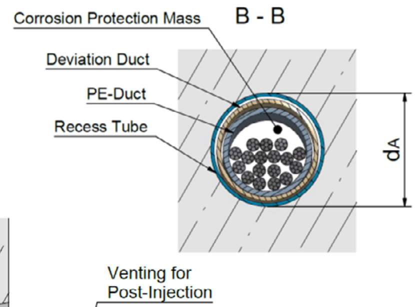
BBV External Post-Tensioning System Type E	Annex A13
Product Description Deviation Type F	

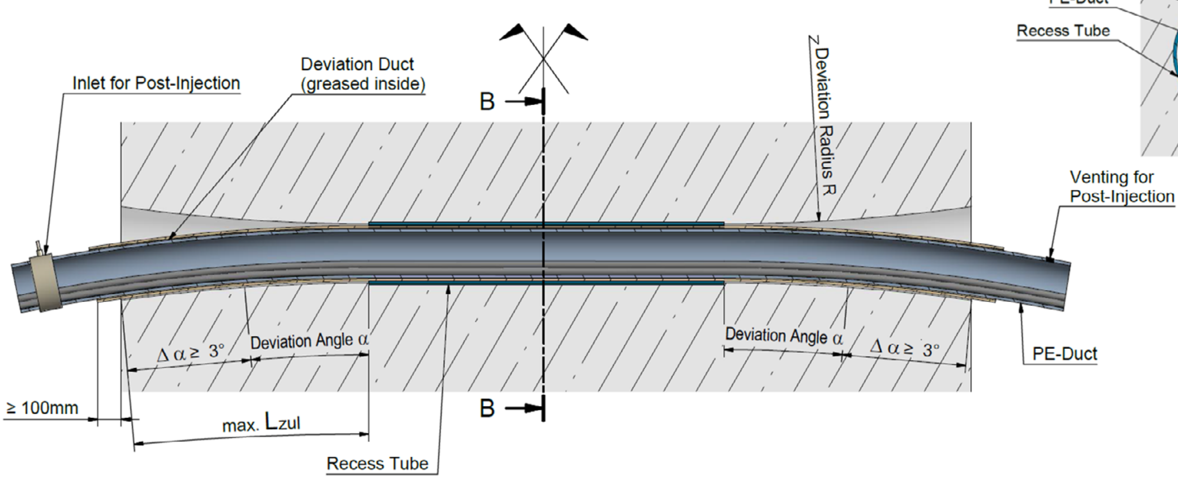
Deviation Type S: Penetration with placed Form Parts

State of Construction



Installation Deviation Duct and Duct





During construction, misalignment of the form parts and the recess tube is to be avoided.
The recess tube can be made of galvanized steel, PVC or PE or can be made by core drilling.

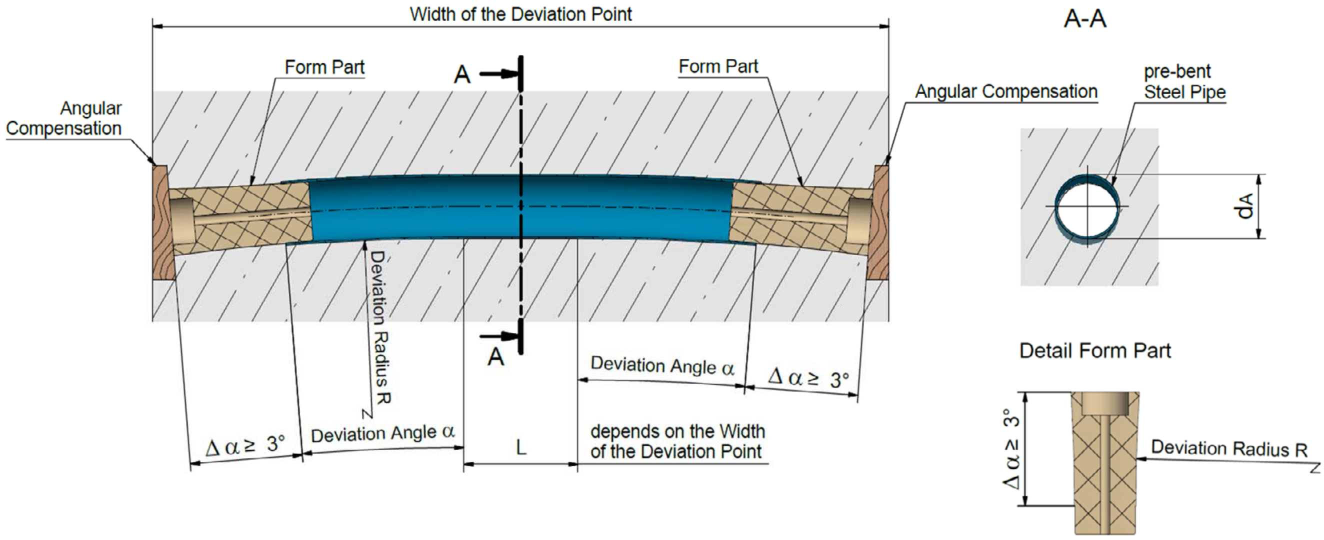
Tendon Type	Unit	L3 E	L4 E	L5 E	L7 E	L9 E	L12 E	L15 E	L19 E	L22 E	L27 E	L31 E
Outer Diameter Plastic Duct	mm	50	63	63	75	75	90	110	110	110/125	125	140
Deviation Angle α	°	≤ 5										
Additional Deviation Angle Δα	°	≥ 3										
Max. Deviation Length L_{zul}	mm	100	170	170	240	240	410	750	750	750/1100	1100	1500
Deviation Duct												
Outer Diameter	mm	63	75	75	90	90	110	125	125	125/140	140	160
Wall Thickness	mm	4.3	4.3	4.3	5.1	5.1	6.3	4.8	4.8	4.8/4.3	4.3	6.2
Recess Tube												
Outer Diameter d_A	mm	75	90	90	110	110	125	140	140	140/160	160	180
Wall Thickness	mm	3.6	4.3	4.3	5.3	5.3	6.0	4.1	4.1	4.1/4.7	7.7	8.6
Form Parts maxØ outside	mm	Depending on Tendon Size and Chosen Deviation Angle α										

For tendon size L22 it is stated, that tendons with an outer diameter of the PE sheathing pipes of 110 mm in accordance with the associated deflection ducts, recess ducts and bent steel ducts may only be grouted with non-cementitious corrosion protection compounds according to Annex D1.

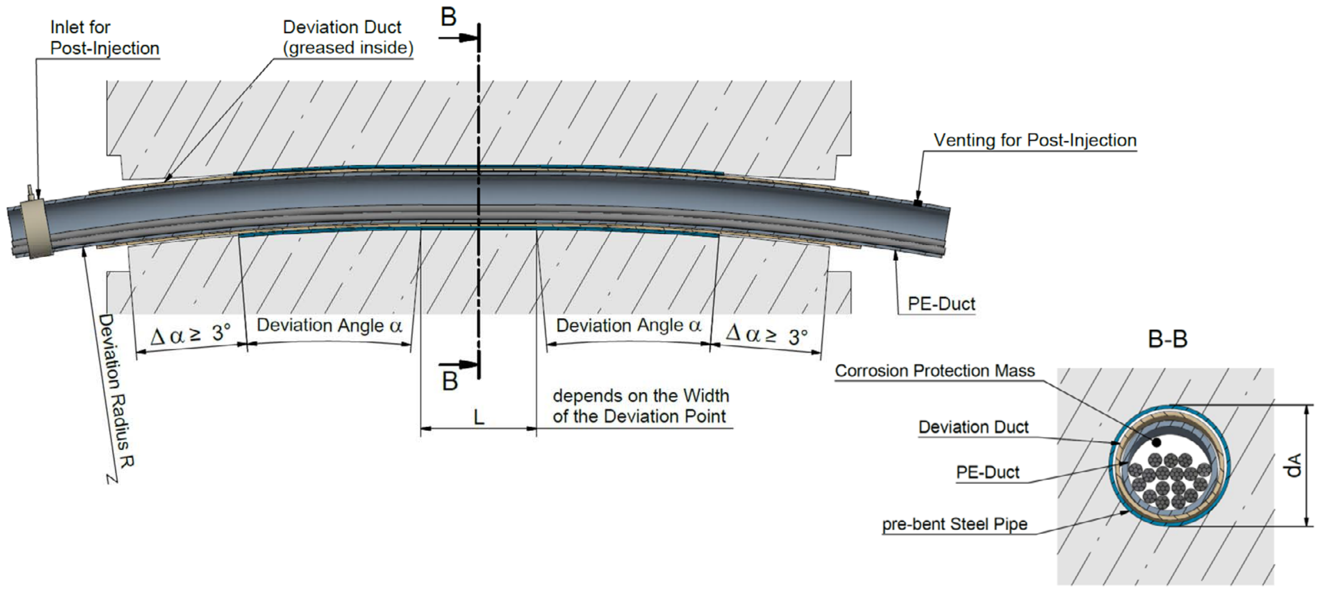
BBV External Post-Tensioning System Type E	Annex A14
Product Description Deviation Type S	

Deviation Type R: Penetration with a (pre-bent) Pipe

State of Construction



Installation Deviation Duct and Duct

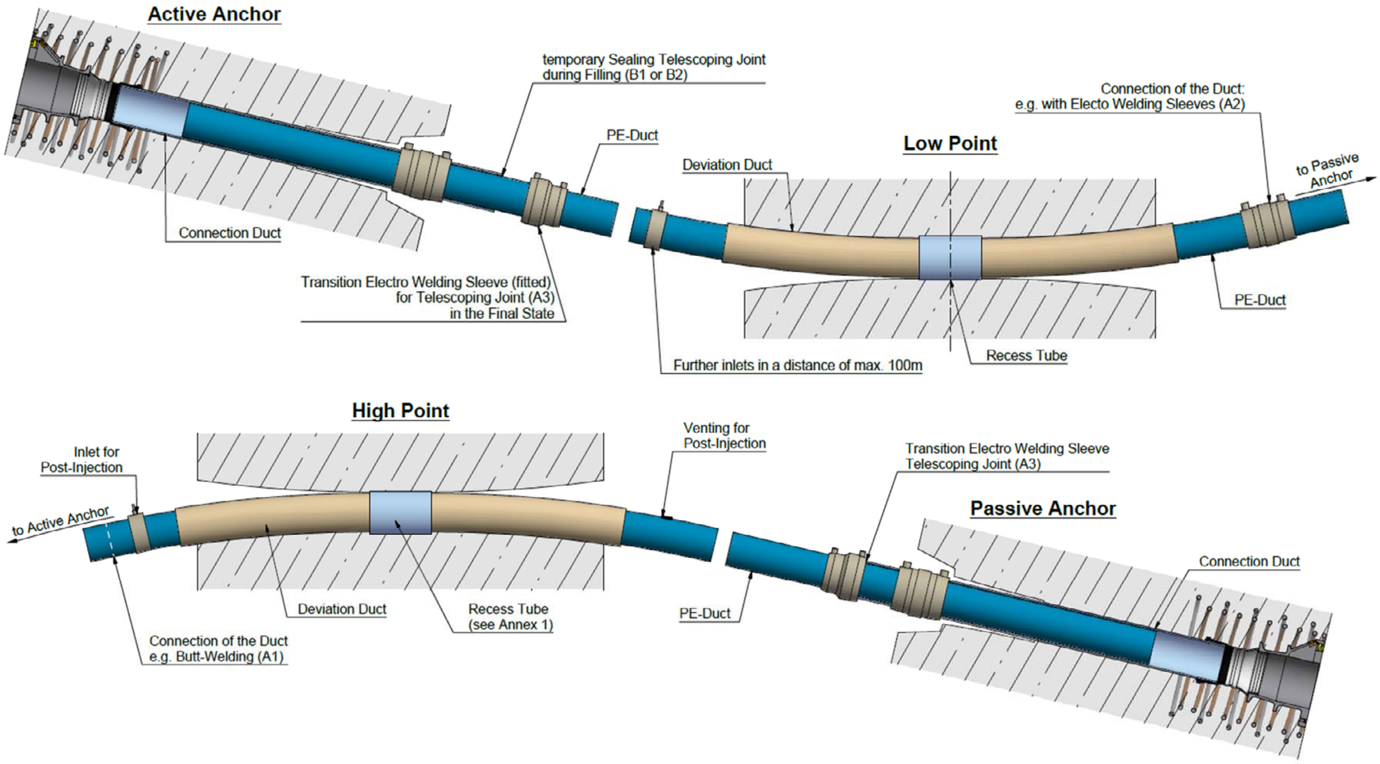


The form parts (see Deviation Type S) will be connected to both ends of the penetration tube (steel, galvanised) and allow an unintentional deviation of $\Delta\alpha$.

Tendon Type	Unit	L3 E	L4 E	L5 E	L7 E	L9 E	L12 E	L15 E	L19 E	L22 E	L27 E	L31 E
Outer Diameter Duct	mm	50	63	63	75	75	90	110	110	110/125	125	140
Additional Deviation Angle $\Delta\alpha$	°	≥ 3										
Deviation Duct												
Outer Diameter	mm	63	75	75	90	90	110	125	125	125/140	140	160
Wall Thickness	mm	4.3	4.3	4.3	5.1	5.1	6.3	4.8	4.8	4.8/1.3	4.3	6.2
Pre-bent Steel Pipe												
Outer Diameter d_A	mm	76.1	88.9	88.9	101.6	101.6	127	139.7	139.7	139.7/159	159	177.8
Wall Thickness	mm	2.9	3.2	3.2	3.6	3.6	4.0	4.0	4.0	4.0/4.5	4.5	5.0

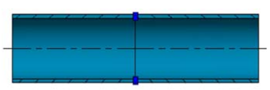
For tendon size L22 it is stated, that tendons with an outer diameter of the PE sheathing pipes of 110 mm in accordance with the associated deflection ducts, recess ducts and bent steel ducts may only be grouted with non-cementitious corrosion protection compounds according to Annex D1.

Duct Scheme with Connections and Joints

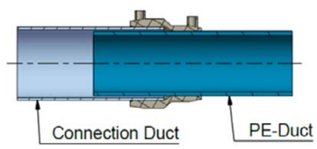


A) Tension Resistant Connections and Joints

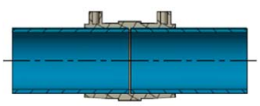
A1) Heated Tool Butt-Welding (HS)



A3) Transition Electro Welding Sleeve (Telescoping Joint)

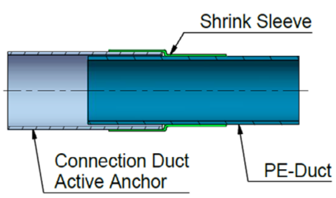


A2) Electro Welding Sleeves (HM)

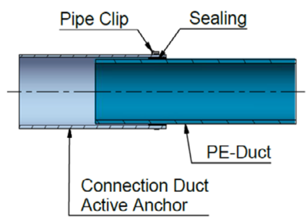


B) Temporary Sealing of the Telescoping Joint

B1) Shrink Sleeve



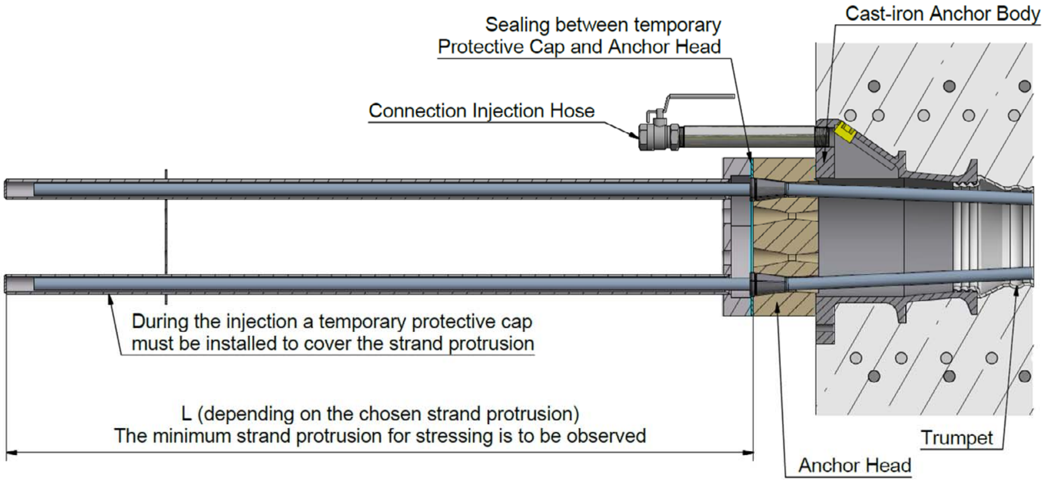
B2) Sealing O-Ring / Pipe Clip



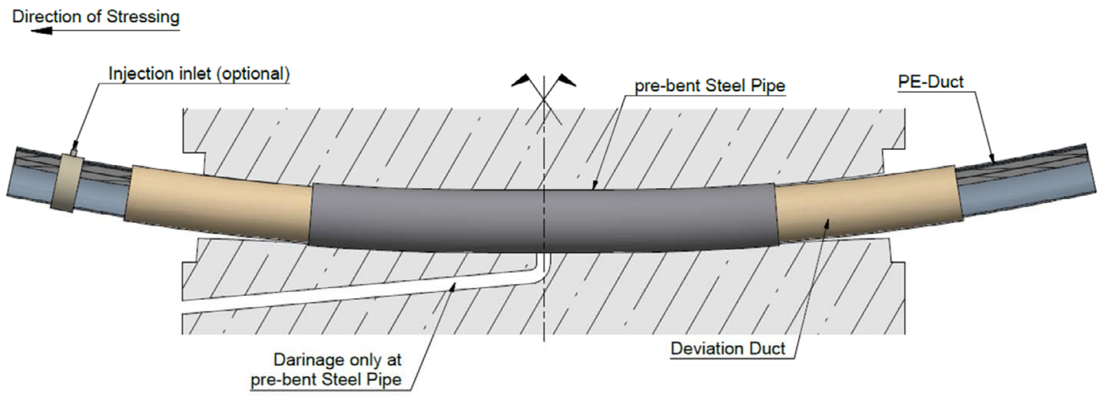
BBV External Post-Tensioning System Type E	Annex A16
Product Description Duct Scheme with Connections and Joints	

Injection of the Duct and Connection Points

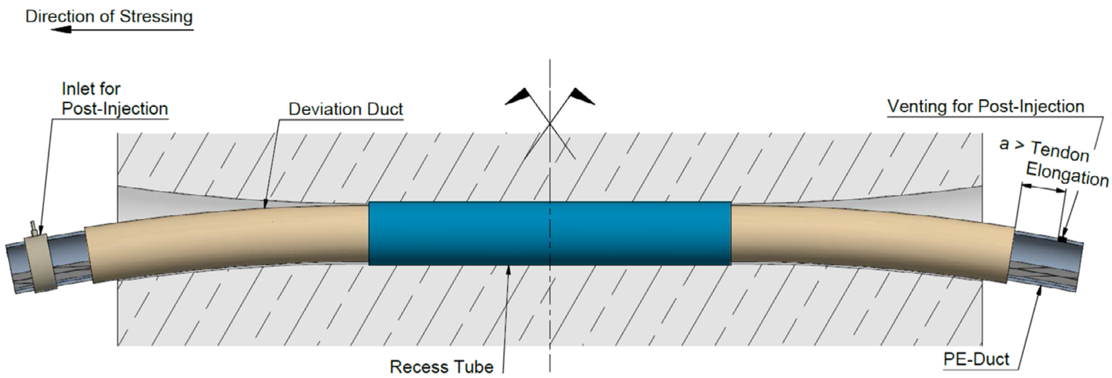
Anchorage (in case of Active Anchor)



Low Point (optional additional Injection Opening)



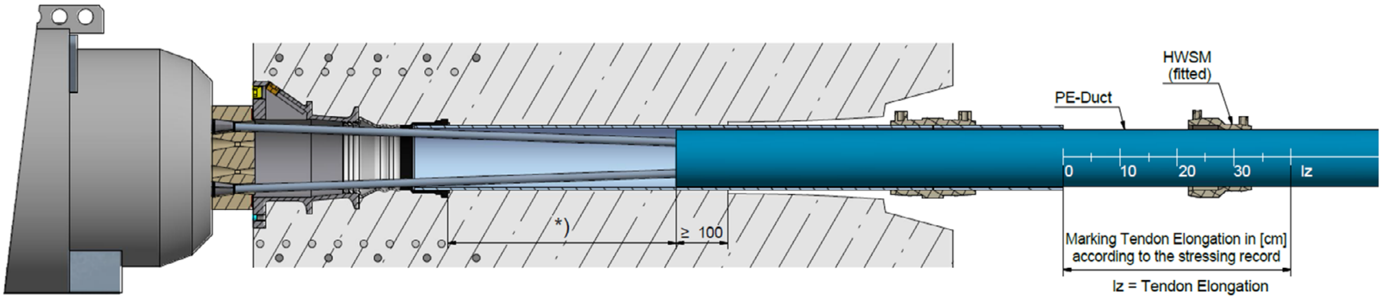
High Point (Post-Injection)



BBV External Post-Tensioning System Type E	Annex A17
Product Description Injection of the Duct and Connecting Points	

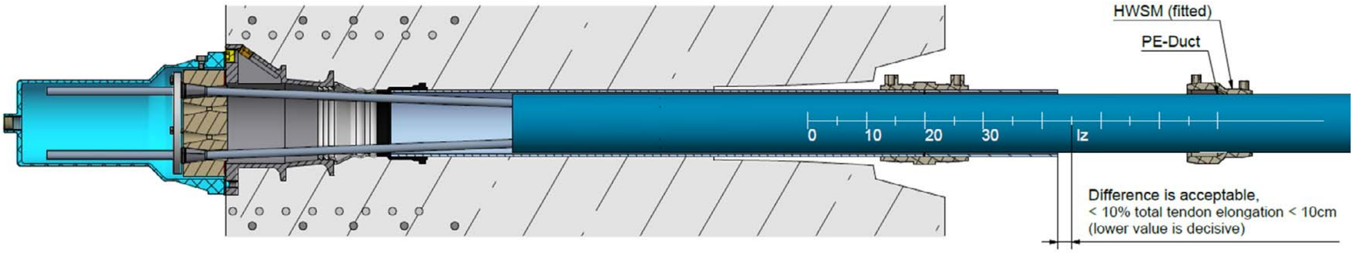
Marking of the Tendon Elongation on the Smooth Plastic Duct

Active Anchor (S) before stressing
(Reference measurement for determination of internal slip after tightening)

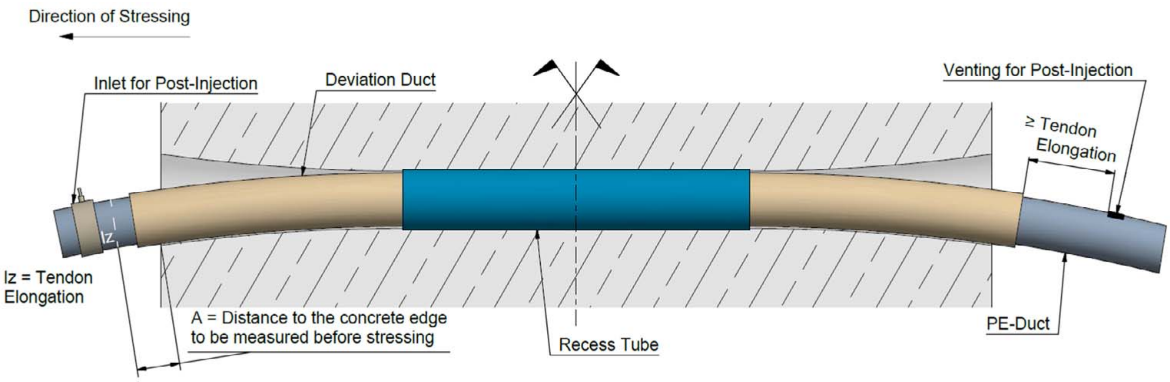


*) ≥ Tendon Elongation + 160mm + if applicable re-stressing Elongation ≥ 500mm (the higher value is decisive!)

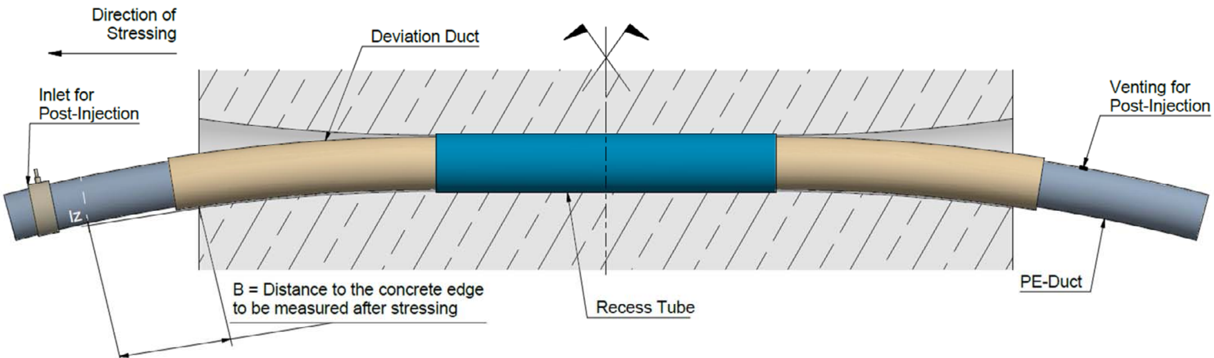
Active Anchor (S) after stressing



Deviation Point before stressing (reference measurement after tightening)



Deviation Point after stressing



Note: The difference of B-A must be < 10 % of total tendon elongation or < 10 cm (lower value is decisive!)

BBV External Post-Tensioning System Type E	Annex A18
Product Description Marking of the Tendon elongation on the Smooth Plastic Duct	

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.

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 component hight. The structural members are to be designed in accordance with national regulations.

Optional use categories:

- Resstressable tendon
- Exchangeable tendon
- Tendon for use in composite structures

2 Methods of verification

2.1 General

The structural members which are prestressed by means of the BBV External Strand Post-Tensioning System Type E have to be designed in accordance with national regulations.

2.2 Tendons

Prestressing and overtensioning forces are specified in the respective national provisions.

The maximum force P_{max} applied to a tendon shall not exceed the force $P_{max} \geq 0.9\ A_p\ f_{p0,1k}$ listed in Table B1 (140 mm²) or in Table B2 (150 mm²). The value of the initial prestressing force $P_{m0}(x)$ applied to the concrete after tensioning and anchoring shall not exceed the force $P_{m0}(x) \geq 0.85\ A_p\ f_{p0,1k}$ listed in Table B1 (140 mm²) or in Table B2 (150 mm²).

Table B1: Maximum prestressing forces [1)] for tendons with A_p = 140 mm²

Tendon Designation	Number of strands	Cross section A_p [mm²]	Prestressing force Y1770S7 $f_{p0,1k}$ = 1560 MPa		Prestressing force Y1860S7 $f_{p0,1k}$ = 1640 MPa	
			$P_{m0}(x)$ [kN]	P_{max} [kN]	$P_{m0}(x)$ [kN]	P_{max} [kN]
BBV L3 E	3	420	557	590	585	620
BBV L4 E	4	560	743	786	781	827
BBV L5 E	5	700	928	983	976	1033
BBV L7 E	7	980	1299	1376	1366	1446
BBV L9 E	9	1260	1671	1769	1756	1860
BBV L12 E	12	1680	2228	2359	2342	2480
BBV L15 E	15	2100	2785	2948	2927	3100
BBV L19 E	19	2660	3527	3735	3708	3926
BBV L22 E	22	3080	4084	4324	4294	4546
BBV L27 E	27	3780	5012	5307	5269	5579
BBV L31 E	31	4340	5755	6093	6050	6406

[1)] The indicated values are maximum values. The actual values are at the place of use applicable standards and regulations. Compliance with the stabilisation and crack width criteria in the load transfer test was verified to a load level of 0,80*F_{pk}. Over-tensioning is allowed according to EN 1992-1-1, if the force of the clamping press can be measured with an accuracy of ± 5% of the final value of the prestressing force and this is allowed according to the national requirements.

Table B2: Maximum prestressing force 1) for tendons with A_p = 150 mm²

Tendon Designation	Number of strands	Cross section A_p [mm²]	Prestressing force Y1770S7 $f_{p0,1k}$ = 1560 MPa		Prestressing force Y1860S7 $f_{p0,1k}$ = 1640 MPa	
			$P_{m0}(x)$ [kN]	P_{max} [kN]	$P_{m0}(x)$ [kN]	P_{max} [kN]
BBV L3 E	3	450	597	632	627	664
BBV L4 E	4	600	796	842	836	886
BBV L5 E	5	750	995	1053	1046	1107
BBV L7 E	7	1050	1392	1474	1464	1550
BBV L9 E	9	1350	1790	1895	1882	1993
BBV L12 E	12	1800	2387	2527	2509	2657
BBV L15 E	15	2250	2984	3159	3137	3321
BBV L19 E	19	2850	3779	4001	3973	4207
BBV L22 E	22	3300	4376	4633	4600	4871
BBV L27 E	27	4050	5370	5686	5646	5978
BBV L31 E	31	4650	6166	6529	6482	6863

The number of strands in a tendon may be reduced by leaving out strands lying radial-symmetrically in the anchor head (not more than four strands). The provisions for tendons with completely filled anchor heads (basic types) apply also to tendons with only partly filled anchor heads. Into the free drills in the anchor head short pieces of strands with wedges have to be pressed to prevent slipping out. The admissible prestressing force is reduced per left-out strand as shown in Table B3.

Table B3: Reduction of the prestressing force1) when leaving out a strand

A_p	Y1770S7		Y1860S7	
	$\Delta P_{m0}(x)$ [kN]	ΔP_{max} [kN]	$\Delta P_{m0}(x)$ [kN]	ΔP_{max} [kN]
140 mm²	186	197	195	207
150 mm²	199	211	209	221

For further characteristic values of the tendons (mass per meter, ultimate stressing force F_{pk}) see Annex A2.

2.3 Radius of curvature of the tendons in the structure

The smallest admissible radii of curvature (minimum bending radii) are given in Annex A2. An analysis of the edge stresses in the strands can be omitted while following these radii of curvature. The acceptance of the forces due to the deviation of the tendon in the structure shall be verified.

2.4 Concrete strength

At the time of transmission of the full prestressing force the mean concrete strength of the normal weight concrete $f_{cmj,cube}$ or $f_{cmj,cyl}$ in the anchor zone shall be at least according to Table B4 and Annexes A5 to A8. The mean concrete strength 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 specimen not differ more than 5 %.

Table B4: Necessary mean concrete strength f_{cmj} of the specimens at time of prestressing

$f_{cmj,cube}$ [N/mm²]	$f_{cmj,cyl}$ [N/mm²]
28*)/30**)	23*)/25**)
34	28
38	31
40	32
45	35

*) 12 to 31 strands

**) 3 to 9 strands

For partial prestressing with 30 % of the full prestressing force it has to be proven a minimum value of the concrete compressive strength of 0.5 $f_{cmj,cube}$ or 0.5 $f_{cmj,cyl}$; intermediate values can be interpolated linearly.

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

The centre and edge distances of the tendon anchorages must not be shorter than the values given in the Annexes A6 and A8 depending on the minimum concrete strength. In case of anchorages BBV L3 to BBV L9 the large side of the bearing plate (side length a according to Annex A5) shall be installed parallel to the large concrete side (maximum value of minimum centre distance).

The values of the centre or edge distances of the anchors given in Annex A6 and A8 may be reduced in one direction up to 15 %, however, not to a smaller value than the external dimensions of the stirrup reinforcement or the outer diameter of the helix. In this case the centre and the edge distances in the other direction shall be increased to ensure the same size of concrete area in the anchor zone.

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

2.6 Load transfer in the structural concrete, Reinforcement in the anchorage zone

The anchorages (including reinforcement) are verified by tests for the transfer of the prestressing forces to the structural concrete.

The resistance to the forces occurring in the structural concrete in the anchorage zone outside (behind) the helix 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 the Annexes D1 and A7. This reinforcement must not be taken into account as part of the statically required reinforcement. However, existing reinforcement in a corresponding position exceeding the statically required reinforcement may be taken into account for the additional reinforcement. The given reinforcement consists of closed stirrups (stirrups closed by means of bends or hooks or an equivalent method). The stirrup locks (bends or hooks) shall be placed mutually offset.

Vertical gaps shall be provided in the anchorage zone to ensure proper concreting.

If in exceptional cases[2)] – due to an increased amount of reinforcement – the helix or the concrete cannot be properly placed, the helix can be replaced by other equivalent reinforcement.

For the patched bearing plates without scheduled additional reinforcement, the tensile forces that will occur due to the concentrated force, usually be detected by means of a framework model. Special care should be given to the evidence and structural penetration in the load transfer areas. This is especially true for the balance of component edges and edge regions of tendon groups. Verification shall be carried out in accordance with EN 1992-1-1 and applicable standards and regulations at the place of use. Load transfer tests were carried out according to EAD 160004-0301-00 containing reinforcement amounts below 50kg/m³. This reinforcement is according to EAD 160004-0301-00 not reported in this ETA.

For adjacent bearing plates, the unfavourable influence of the superposition of concrete stresses due to the load transfer has to be taken into account. The bearing plates have to rest evenly on the entire surface (outside of the core drilling holes). The strength of the existing concrete with subsequently patched anchors has to be verified by structural inspection if necessary.

2.7 Slip at the anchorages

The slip at the anchorages (see Annex B2, section 3.7) shall be taken into account in the static calculation and the determination of the tendon elongation.

2.8 Fatigue resistance

With the fatigue tests for the anchors and couplers 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 $2x10^6$ 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.

2.9 Guidance of tendons through construction members

Where tendons are guided through a straight penetration of a construction member, an appropriate size of their opening, taking into account the construction tolerances, shall be provided to ensure that the tendons have no contact with the construction member.

2.10 Protection of the tendons

The tendons shall be protected against failure resulting from extraneous cause (e.g. vehicle impact, elevated temperatures in case of fire, vandalism). The requirements shall be investigated on a case by case basis and rated according to the specific project conditions. Tendons enclosed by a box girder are classified as sufficiently protected.

Tendons enclosed by a box girder are supposed to be sufficiently protected against corrosion. For tendons placed outside a box girder, especially in corrosion enhancing conditions, the applicability of the tendons shall be verified.

2.11 Single strand couplings

The coupling shall only be used if the calculated stressing force at the coupler is at least 0.7 $P_{m0}(x)$ according to EN 1992-1-1, section 5.10.3 (2), Eq. (5.43).

The single strand couplings shall be positioned in straight tendon sections with straight length of at least 1.0 m on each side. The position and length of the coupler duct shall ensure a movement over the length of at least 1.2 Δl + 50 mm, where Δl is the maximum elongation length at the time of prestressing.

[2)] This requires the approval for individual case according to the national regulations and administrative provisions.

3 Installation

3.1 General

The assembly of the tendons has to be carried out at building site. 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 the BBV External Post-Tensioning System Type E. The company's site manager shall have a certificate of the manufacturer certifying that he was instructed by the manufacturer and has the required knowledge and experience with this post-tensioning system. Standards and regulations valid on site shall be considered.

The manufacturer is responsible to inform anyone concerned about the use of the BBV-External Post-tensioning System Type E. Additional information as listed in EAD 160004-00-0301 shall be held available by the manufacturer and distributed as needed.

The tendons and the components shall be handled carefully.

3.2 Welding

Welding at the anchorages is only permitted at the following parts:

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

b) For ensuring the central positioning, the helix may be attached to the bearing plate by tack-welding.

After placing the strands in the ducts no further welding shall be performed at the anchorages.

3.3 Installation of the anchorages, the helix and the additional reinforcement

The conical boreholes of the anchor heads shall be clean, stainless and coated with corrosion protection mass. The central position of the helix and the stirrups shall be ensured by tack-welding to the bearing plate or the cast-iron anchor body or attaching by mounting brackets. The bearing plate or cast-iron anchor body and the anchor head shall be positioned perpendicular to the axis of the tendon.

Behind the anchor head the tendon shall be placed straight over the length min. L1 (see Annexes A10 to A12). Distinction shall be drawn between anchorages where the tendon is placed straight forward and anchorages with deviation close to the anchor.

The joint between trumpet and connection duct shall be sealed carefully with PE-tape, first to avoid the penetration of concrete and later to avoid leakage of corrosion protection material.

The minimum width of the crossbeam at both the active and passive anchorages is shown in Annexes A10 to A12.

3.4 Installation of the strands and the ducts

All recess ducts (in the area of anchorages and deviations) shall be fastened in such a way that they cannot be moved during concreting.

At all locations where the tendons exit from the construction member trumpet-like widenings $\Delta\alpha$ shall be provided, which allow for unscheduled deviation from the planned position of the tendon axis without kink up to a minimum of 3°. The installation of the ducts and the strands shall be carried out according to the description in Annex B3. The duct scheme with connections and joints is shown in Annex A16. At both the stressing and fixed anchors, connection ducts are installed (see Annexes A10 to A12).

At the fixed anchors, the duct ends about 16 cm in front of the trumpet and is permanently connected with the duct of the free tendon length. At the stressing anchors the duct is shifted into the crossbeam until it reaches beyond the deviation zone by at least 10 cm.

The required insertion length of the duct at stressing and fixed anchors shall be measured and marked in advance. Before tightening the right position of the tendon at the stressing anchor shall be checked once more and it shall be recorded in writing how far the tendon reaches into the crossbeam.

Recess clearances, deviation form parts and deviation ducts at the deviation points shall be clean and smooth. Before pulling in the ducts, the deviation ducts shall be greased inside.

3.5 Prohibition of transversal oscillation of tendons

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

If at the place of use no other regulation is valid for bridges of box girders, a fixing distance for the tendons of about 35 m is recommended. Transversal oscillations which occur nevertheless usually do not have any harmful effects.

Outside of box girders smaller fixing distances are required.

The fixings shall be performed in such a way that the duct will not be damaged and the movement in longitudinal direction of the tendon is not obstructed.

3.6 Unscheduled contact of the tendon and free lift-off at outlets of the building/crossbeams

Unscheduled contact of the tendon with the building structure is inadmissible.

At the outlets of anchorages or deviation points the tendon shall lift-off freely (the tendon shall have no unscheduled contact (no kink), see also Annex B2, section 3.9). After the tightening of the tendon and before filling in hot corrosion protection mass the free lift-off should be checked at all entrances.

3.7 Wedging force, slip, wedge securing and corrosion protection mass in the wedge-seating area

The wedges of fixed anchors shall be pre-wedged with 1.1 $P_{m0}(x)$ (see Annex B1, section 2.2), if knurled wedges "type 30" are used.

Without pre-wedging the slip has to be taken into account for the determination of the elongations/movements of the strands is 4 mm at fixed anchorages. In the case of hydraulic pre-wedging with 1.1 $P_{m0}(x)$, except for movable single strand couplings, no slip shall be taken into account for the determination of the elongations/ movements of the strands.

The wedges of stressing anchors shall be pre-wedged after tensioning with the minimum force of 0.1 $P_{m0}(x)$. In this case the slip is 3 mm. If the wedges are not compressed, the slip shall be about 6 mm (a reset plate shall be used to fix the wedges).

The wedges shall be secured by a retaining plate.

3.8 Tightening and filling with corrosion protection mass

At the stressing anchor, the displacement of the duct shall already be documented during the tightening (see also Annex B2, section 3.4).

Before the stressing and the filling with hot corrosion protection mass the tendon shall be tightened with a minimum of 5 % and a maximum of 10 % F_{pk}.

After the temporary sealing of the duct at the stressing anchor, the duct shall be injected from one anchor with hot corrosion protection mass with a maximum temperature of 100 °C (usually from one point close to an anchor and in proximity to the next low point).

Hot corrosion protection mass must be pressed into the PE ducts of the tendons until hot, still liquid corrosion protection mass emerges at the exit point. If the flowability of the corrosion protection mass is lost due to cooling, intermediate openings alongthe tendon strand must be provided, e.g. at low points. As soon as corrosion protection mass is present at an intermediate opening, further pressing of the next section continuous from there. For this purpose, containers with hot corrosion protection mass or their supply lines must be provided.

Without further intermediate openings, a maximum length of 250 m may be grouted. For an injection length (without intermediate openings) of more than 120 m, the outside temperature must not be below 5° C and it must be demonstrated on a test tendon at the construction site that complete injection is ensured.

Before further work is carried out, the corrosion protection material shall have cooled down to the ambient air temperature (about 30 °C). For that, usually one day is sufficient.

After the corrosion protection mass cooled down, all high points shall be post-injected with cold corrosion protection mass (see Annex A16 and A17 and B3). After the drilling of the necessary inlets and vents, the temperature of the corrosion protection mass in the duct shall be measured, in order to check whether it has cooled down sufficiently.All voids shall be filled completely with corrosion protection material. Complete filling with corrosion protection material shall be checked by tapping along the tendon over its full length.

Possible defects shall be post-injected. When setting the inlets and ventings care must be taken to ensure that their distance to the deviation zone is sufficient so that they will not have been pulled into the deviation zone during stressing or re-stressing.

3.9 Prestressing and admissible elongation way/prestressing path

All strands of a tendon shall be stressed simultaneously. In the case of straight tendons it is permitted to stress strand by strand. The order of the strands to be stressed shall be determined in such a way that the anchor carries only the eccentricity of the prestressing force of one stand at a time, in order to keep the eccentric load of the anchor head at a minimum.

At the fixed anchor the elongation/ movement of the strands resulting from stressing and restressing at the entrance from the structure/crossbeam shall not exceed 10 cm.

During stressing at every deviation point and at the stressing anchor the amount of inner gliding (difference of the movement of the strand and the movement of the duct at the marking) and outer gliding (movement of the duct) shall be documented by the company carrying out the work.

At the stressing anchor, the movement of the duct shall already be documented during the tightening. At the stressing anchor, during stressing or re-stressing the duct in the free length of the tendon glides into the connection duct.

To determine of the displacement with inner gliding the measured values between 10 % F_{pk} and 100 % of the prestressing force (target load) shall be taken into account. The movement of the strands shall be recorded in the stressing manual for each deviation point and for the stressing anchor.

After the tightening and the cooling of the corrosion protection mass, markings shall be placed at the stressing anchorage and at all deviators the duct. The initial positions of the markings shall be measured (see Annex A18).

At the stressing anchor the temporary sealing of the telescoping joint shall be opened again and a clamp for fastening of a chain hoist at the duct shall be installed.

If necessary, for achieving outer gliding of the duct at the stressing anchor as well, simultaneous pulling of the chain hoist and the duct together with the movement (stressing) of the strands is possible. In the case of tendons deviated in proximity behind the stressing anchor (see Annex A12) pulling of the duct is usually not necessary.

The movements of the ducts shall be measured and compared to the calculated elongations/movements of the strands (each deviation point and stressing anchor). The amount of inner gliding (difference of the movement of the strands and the movement of the duct at the marking) during stressing (after tightening) must not exceed 10 % of the total elongation or 10 cm (the lower of the two values is decisive). The amount of outer gliding of the duct (movement of the duct) shall be at least 90 % of the total elongation. When fulfilling this requirement no limitation of the prestressing displacement (elongation) is necessary. This requirement is not relevant for straight tendons without scheduled or unscheduled deviations.

The duct shall not be compressed near the stressing anchor. The initial position and the full movement of the duct shall be additionally measured and documented, in order to verify that in the final state the position of the duct is according to annexes A10 or A12, figure 3, respectively.

It is admissible to re-stress the tendons by releasing and re-using the wedges. After re-stressing and setting of the wedges, wedge marks on the strands resulting from first stressing shall be moved to the outside by at least 15 mm. Re-stressing paths < 15 mm are not admissible.

Not later than after the stressing to the full target load at the entrances of anchors and deviators it shall be checked whether the tendons lift-off freely. In cases where the tendon does not lift-off freely, the tendon shall be dismantled and the corresponding place in the concrete member shall be repaired. Whether the same ten-don may be re-installed, shall be decided after consultation with the client

3.10 Corrosion protection with cementitious grout

When using certain types of ducts (see Annex A9), the prestressed tendon may alternatively be grouted with a cementitious grout according to EN 447 or EAD 160027-00-0301. Grouting shall be carried out and monitored according to EN 446. The national standards and regulations applicable at the place of use must be considered also.

After prestressing, the tendons must be grouted as soon as possible. If the tendons remain ungrouted for a longer period of time, suitable corrosion protection measures must be taken as specified by the ETA holder. The ducts must not be flushed with water. The grouting speed must be between 3 m/min and 12 m/min. The maximum length of an injection section depends on the capacity of the injection equipment, shall be determined prior to the injection process and shall not exceed 120 m (for BBV L27 the maximum length of an injection section shall not exceed 95 m and for BBV L31 80 m). If these tendon lengths are exceeded, additional grouting openings must be provided. The grouting speed in this area must not exceed 4.5 m/min. If grouting is carried out over more than one high point, the grouting speed must not exceed 4.5 m/min in the entire tendon area. Particular care must be taken to ensure that the timing specifications for the use of the grout according to EN 446 and EN 447 are observed.

If the tendon is passed over high points, suitable vents shall be provided. Grouting with cementitious grout in the area of high points at inaccessible deflections according to Annex A13 to A15 shall be carried out according to the innovative BBV method for complete venting or void-free filling of the ducts in the area of high points of deflected tendons. The procedure description is deposited with the control plan at approval office. The drill holes and drill hole diameters required for this in the cladding tube at the high point can be found in the procedure description. The distances between the boreholes are 100 ± 5 mm. The PE ducts and deflection ducts to be used are listed in Table B5 and in the process description.

Tabelle B5:

Tendon size n	PE-duct			PE-deflection duct			drill hole diameter (in PE-duct at hight point) ΔA
	outside diameter	Wall thickness	inner diameter	outside diameter	Wall thickness	inner diameter	
[-]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]
3	50	4,6	40,8	63	4,3	54,4	5
4	63	4,7	53,6	75	4,3	66,4	5
5	63	4,7	53,6	75	4,3	66,4	5
7	75	4,5	66,0	90	5,1	79,8	5
9	75	4,5	66,0	90	5,1	79,8	5
12	90	5,4	79,2	110	6,3	97,4	6
15	110	6,6	96,8	125	4,8	115,4	6
19	110	6,6	96,8	125	4,8	115,4	6
22	125	7,4	110,2	140	4,3	131,4	8
27	125	7,4	110,2	140	4,3	131,4	8
31	140	8,3	123,4	160	6,2	147,6	8

The position of the drilled holes in relation to the longitudinal direction of the tendon and the orientation of the drilled holes in relation to the top apex shall be marked on the PE casing pipes in such a way that it can be corrected after application of the prestressing and before welding so that the target position of the drilled holes is safely achieved.

The fluidity determined by the funneling method according to EN 445:2007 shall satisfy the following conditions: $t0 \leq 20s$; $16s \leq t30 \leq 24s$

3.11 Corrosion protection measures after prestressing

Anchors shall be protected against corrosion with protection caps and a system consisting of retainer plates and flexible cover caps or tubes (see Annexes A3 and A4 and B3, section 4.2.3).

At the stressing anchor, the joint between the connection duct and the duct shall be closed permanently with a transition electro welding sleeve (see Annexes A10 and A11 and B3, section 4.3).

Voids in the ducts shall be filled completely with corrosion protection mass (see Annex B2, section 3.8 and Annex B3, section 4.5.6).

3.12 Re-stressing

Re-stressing of the tendons by releasing and re-using of the wedges is admissible (see Annex B2, section 3.9).

Preparatory works are: removing the protection caps and the joints between the connection duct and the duct at the stressing anchorage. In the same way as for prestressing, the duct shall be provided with markings and their initial positions shall be measured.

The movements of the duct shall be measured and compared with the calculated elongations/movement of the strands (each deviation point and stressing anchorage). The amount of inner gliding (difference of the movements of the strands and the movement of the duct at the marking) during stressing shall not exceed 10 % of the total elongation or 10 cm (the lower of the two values is decisive).

The movements achieved during prestressing shall be taken into account. When fulfilling this requirement, limitation of the re-stressing elongation is not necessary. If the value of 10 cm for inner gliding is reached at one point of the structure, further re-stressing of the tendon is not allowed. If the value of 10 cm has already been reached during prestressing, re-stressing is not admissible.

At the stressing anchor the duct shall not be compressed (see Annex B2, section 3.9). After re-stressing corrosion protection measures according to Annex B2, section 3.10 shall be carried out.

3.13 Exchange of tendons

The dismounting of tendons and the following installation of new tendons is possible (see Annex B3, section 4.10). The conditions for future displacement of tendons, the number of tendons that can be dismounted at the same time and the on-site provisions, which already shall be planned during the design of the building, shall be determined for each single case.

For every case of cutting of the tendons the relevant working instructions and the safety provisions for workers shall be determined by the operating company and agreed upon by the client.

3.14 Single strand couplings

The single strand couplings must be staggered arranged in accordance with Annex A9. In order to ensure the insertion depth the strands have to be highlighted by colour markings.

3.15 Packaging, transport and storage

The components and the tendons shall be protected against moisture and staining.

The tendons shall be kept away from areas where welding procedures are performed.

For transport and handling of the strands, the provisions of the strand manufacturer shall be observed.

The PE-ducts are to be delivered as straight.

4 Description of the Post-Tensioning System

4.1 Tendons

For the tendons 7-wire strands with a nominal diameter of 15.3 mm (nominal cross-section 140 mm²) or with a nominal diameter of 15.7 mm (nominal cross-section 150 mm²) are used. Steel grades Y1770S7 or Y1860S7 are allowed. The stressing system covers tendons from 3 to 31 strands. The anchors are identical for both prestressing steel grades.

The number of strands in the tendons may be reduced by omitting strands in such a way that the pattern maintains radially symmetric in the anchorage (not more than four strands). Into the free drills in the anchor head short pieces of strands with wedges have to be pressed to prevent slipping out. The strands of the tendons are combined in a duct without spacers. Strands are stressed simultaneously and then anchored individually with round wedges. PE-tubes in accordance with EN 12201-1:2011-11 and EN 12201-2:2011-02 are used. The scheme of the duct installation is shown in Annex A16. The tendons may be re-stressed and replaced since the ducts are filled with non-hardening corrosion protection mass. The length of the tendons is unlimited.

4.2 Anchorages

4.2.1 Wedge anchorages

The anchorage with anchor plate or cast-iron anchor body and anchor head usually is used as an active anchor (S) or a passive anchor (F). In the anchorage zone, the duct is replaced by a trumpet, in which the strands are deflected by a maximum of 2.6°. For anchorages with 150 mm² strands, wedges with markings "0.62" on the front face shall be installed. The bursting forces caused by the load transfer to the concrete member shall be carried by a helix made of ribbed reinforcing steel. Additional reinforcement is also installed. The forces outside from the helix due to stressing force transfer shall be verified with the structural design.

4.2.2 Strand protrusion for stressing and re-stressing

The strand protrusion beyond the anchor head serves the purpose of fitting the stressing jack for initial stressing and re-stressing. Annex A2 specifies the strand protrusion generally required for initial stressing. The required strand protrusion and the required space for the stressing jack could be adapted to specific project requirements after consulting BBV Systems.

4.2.3 Corrosion protection of the anchor

The corrosion protection system of the anchors is shown in Annexes A3 and A4. Strand protrusion and anchor head at the passive anchor shall be protected with flexible cover cap. The anchor head for the passive anchor shall be additionally wrapped with DENSO tape. Retainer plate has to be placed on flexible cover cap. A PE protective cap is set over the anchor head, cover cap and wedge protection disc and is screwed together with front side of the anchor plate / cast iron anchor body. Between them a NBR-sealing is arranged.

The contact area between retainer plate and the anchor head is coated with corrosion protection mass on active anchor side. The anchor head is wrapped with DENSO tape. Greased strand protrusions are covered with covering tubes. Every covering tube is placed in the wedge protection disc and closed with a plug. A PE protective cap is set on the anchor head, wedge protection disc and strand protrusions and is screwed together with front side of the anchor plate / cast iron anchor body. Between them is a NBR-sealing arranged.

4.3 Ducts

PE tubes in accordance with EN 12201-1:2011-11 und EN 12201-2:2011-02 are used as ducts. The trumpet is connected to the connection duct in area of the active and passive anchor. The transition is sealed with adhesive PE tape (during concreting) or equivalent (e.g. pipe sleeve). During the stressing operations the duct moves into the larger connection duct at the active anchor.

The connection at the active anchor between the connection duct and the duct shall be temporarily closed during the filling with corrosion protection mass, to prevent the escape of corrosion protection mass. The temporary seal is removed after the corrosion protection mass has cooled down. Then the transition is finally closed permanently and sealed with an electric welding sleeve after completion of the stressing works.

4.4 Deviations

4.4.1 General

The transition of deviation to the free length of tendon features a trumpet-shaped widening. In addition to the designed deviation angle α the widening permits an unintended deviation angle free of kinks with at least $\Delta\alpha \geq 3°$ in all directions. The minimal deviation radius of curvature R is specified in Annex A2. It refers to the tendon's plane of curvature (which may also be inclined with respect to the vertical). The mini-mum permitted radius of curvature R shall also be complied with on the trumpet-shaped opening.

Three types of deviation points are available:

- Deviation type F: Penetration with inserted deviation form parts
- Deviation type S: Creation of the deviation contour with form parts
- Deflection type R: Penetration with a (pre-bent) pipe

In all types of deviations the duct is guided through a greased deviation duct. A minimum protrusion of the deviation duct of at least 10 cm beyond the cross-beam dimensions is required on both sides. The prestressed tendon must lift off free of kinks at the end of the deviation area.

4.4.2 Deviation type F: Penetration with inserted form parts

For this, a tubular penetration is made, generally by installing a recess pipe. The penetration can also be made by core drilling or equivalent. The tendon is deflected only with the aid of form parts made of plastic or steel, inserted into the penetration. The form parts have the required geometry for guiding the tendon and must be adequately secured to the building structure so that the duct and form parts are not misaligned when stressing. The form parts can be modified by addition of a spacer to match the cross beam dimensions.

4.4.3 Deviation type S: Creation of the deviation contour with form parts

The deviation is produced by rotationally symmetric form parts which helps to form the deviation geometry in the structural concrete or in the precast element. A recess pipe can be installed centrally for adapting the deviation point to various lengths of crossbeams.

The intended deviation is limited to a maximum permitted angle per rotationally symmetric form part. In addition, the intended and unintended deflections are limited to a maximum permitted length max. L_{zul} (see Annex A14).

4.4.4 Deviation Type R: Penetration with a pre-bent pipe

The deviation arrangement is produced by a pre-bent steel pipe (corrosion-protected). Rotationally symmetric form parts which allow for an unintended deviation of $\Delta\alpha \geq 3°$ on all sides are attached to the ends of the pipe, free of knicks. One option of deviation type R is that a deviation exceeding the unintended deviation can be provided with form parts.

Deviation Type R can be formed at the active anchor (anchor close deviation), whereby the requirements regarding the slip conditions shall be observed. Deflection Type R can be formed at the passive anchor if the elongation (stressing and, possibly, restressing) at the exit point of the building structure does not exceed 10 cm.

4.4.5 Unintended contact

Unintended contact of the tendon with the structure is not permitted. Additional unintended deviations of $\Delta\alpha \geq 3°$ shall be arranged at the ends of the areas of deviation and the exit of the tendon from the concrete member at the active and passive anchors. The minimum radius of curvature shall also be complied with in the area of unintended deviations. The tendon shall lift off freely at the exit of the structure.

4.4.6 Corrosion protection of exposed steel components

See section 1.9 of the Specific Part of the European Technical Assessment

4.5 Assembly of the tendons

4.5.1 Components for casting

On site, bearing plates, cast-iron anchor bodies, trumpets connection ducts, form parts of the anchor zones, helixes and additional reinforcement are cast in concrete. According to the design, penetration tubes (straight or curved) and, if necessary, form parts are cast in concrete at the deviation points. Deviation points can be made also only with form parts and if necessary with recess tubes depending on the length of the cross-beam. At existing structures, recesses can also be produced e.g. by core drilling.

4.5.2 Installation of the ducts

Initially, ducts are pulled into the structure. A transition electro welding sleeve shall be used for providing a strain resistant connection between the duct and the connection duct at the active anchor.

The duct is slid into the connection duct at the passive anchor so that the duct lays at least 16cm before the trumpet. The connection of the duct and the connection duct shall be created strain resistant.

The duct is then slid into the connection duct at the active anchor to such an extent that the duct lays approx. 10 cm beyond the intended and unintended deviation area (deviation α or $\Delta\alpha$) in the direction of the active anchor before tightening. The length of the connection duct from the trumpet to the duct at the active anchor shall permit movements with complete outer gliding of the duct while tightening, stressing and possibly re-stressing process. The connection of the duct to the connection duct and duct joints on the free length shall be created strain resistant connection by butt welding with heat elements or by electro welding sleeves.

4.5.3 Installation of the strands

The strands shall be inserted into the ducts either by means of a strand pushing machine or a cable winch.

4.5.4 Tightening of the strands

If tendons have deviation points, they are tightened to a pre-load after strand insertion. Deviated tendons shall have a pre-load of at least 5% and a maximum of 10 % of F_{pk}. The joint between duct and connection duct at the active anchor is temporarily sealed before filling with corrosion protection mass.

In case of straight tendons (without intended or unintended deviation), the strands can be stressed completely up to the required load. No shifting of the duct occurs during tightening and subsequent stressing. No chain hoist in accordance to Annex B3, section 4.6 is used. No measures are required for influencing the gliding conditions.

4.5.5 Filling of the ducts with corrosion protection mass

See Annex B2, section 3.8 and Annex A16 and A17

4.5.6 Post-Injection at high points

After the filled tendon has cooled down, all high points shall be post-injected with cold corrosion protection mass. In order to do this, an inlet or a venting opening must be drilled in front of and behind each deviation point. A thermometer is used to measure the temperature of the corrosion protection mass. In case of temperatures ≤ 30 °C, the high point can be post-injected.

A pressure-tight inlet connecting branch is fixed at the inlet to which the supply hose is connected to. The distance between venting openings of the tendon and the deviation points must be selected in each case so that the definite filling of the tendons high point is ensured.

The distance between the inlet or venting openings and the deviation points must be selected adequately large so that the inlet or venting openings do not move into the deviation area during stressing and re-stressing.

Post-injection is finished as soon as corrosion protection mass emerges from the venting opening. Continuous escape of the corrosion protection mass from the venting opening ensures that the high point is reliably permanently protected against corrosion. Subsequently, the openings are sealed professionally with press-fit or sealing-lip closure plugs. By knocking on the duct, it is checked that the duct has been filled completely. Any not filled points shall be post-injected (see Annex A16 and A17).

4.6 Initial stressing/stressing

Before initial stressing, the ducts are marked at all deviation points in the direction of the active anchor and at the active anchor itself. The distance between these markings and the deviation point (e.g. edge of the cross beam) shall be measured and recorded before stressing. The mobility of the telescoping joint at the active anchor must be ensured before starting to stress removal of the temporary seal). On tendons with deviation point(s), mainly outer gliding is required when stressing. Suitable measures must be taken to ensure that the elongation / movement of the strands and the movement of the duct are parallel. This can be done by means of a chain hoist or an equivalent (see Annex B2, section 3.9).

A hydraulic pump unit and a stressing jack are used to stress the tendons. All strands of a tendon are gripped and stressed simultaneously. In case of straight tendons, a single-strand stressing jack can be used. Step-by-step stressing and re-setting of the jack is possible. When stressing, it must be ensured that the duct moves continuously in accordance with the elongation / movement of the strands (for instance by using a chain hoist for assistance). The duct shall be marked in order to confirm its movement (see Annex A18).

The strands are stressed to the required load. The duct is moved in parallel in accordance with the elongation by frictional connection between strand and duct at the deviation points (outer gliding). The movement of the ducts during stressing at the deviation points and in front of the active anchor is determined by measuring the change in spacing between the markings made beforehand and the reference point. These movements are compared with the theoretical elongation of the strands.

The relative movement (difference between the movements) between strands and duct (inner gliding) must not exceed 10 % of the elongation of the strands or 10 cm respectively (the lower of the two values is the decisive value). The duct may not be compressed at the active anchor.

After stressing, the wedges will be pressed into the wedge seat using a wedge seating device. A wedge slip of approx. 3 mm occurs when the stressing force is released. In case of not pressed wedges, the slip amount is 6 mm. The slip has to be considered in statically calculations.

4.7 Final works

After completion of the stressing works, the joint between the duct and the connection duct is closed by a transitional electro welding sleeve or an equivalent. Active and passive anchor are protected against corrosion with a protective cap (see Annex B3, section 4.2.3).

4.8 Re-stressing

A strand protrusion can be planned at the active anchor / passive anchor for future re-stressing of the tendon after removal of the protective cap. Based on gliding conditions recorded in the stressing record, it will be decided whether the connection between the duct and connection duct at the active anchor shall be opened. If openings are necessary, the connection has to be suitably reclosed after re-stressing. Corrosion protection of the anchorage shall be reinstalled correctly. During re-stressing, it must be ensured that the relative movement between strands and duct (inner gliding) does not exceed 10% of the total elongation / movement of the strands or 10 cm respectively (the lower of the two values is the decisive value). The movements already achieved when stressing have to be considered additionally, regardless of the stressing direction). The duct may be pulled in longitudinal direction at the active anchor in order to assist outer gliding, e.g. with a chain hoist. If using a chain hoist, use an accurately fitting steel clamp to connect to the duct (drawing submitted to DIBt).

4.9 Check of stressing force

The stressing force may be checked by lifting off the anchor head approximately 1-2 mm of the bearing plate / cast-iron anchor body by means of a stressing jack. The required stressing force for lifting off is considered to be the current stressing force. The stressing jack is positioned on a stressing chair in order to transfer the force directly onto the bearing plate / cast-iron anchor body. The wedges are not released during this operation.

4.10 Replacing a tendon

If it becomes necessary to replace a tendon, the tendon must be cut close to an anchor or deviation point (safety aspects are to be considered). Subsequently, all movable anchorage and deviation components are removed. The bearing plate / cast-iron anchor body, trumpet, connection duct and other cast-in parts remain in the building structure. The new tendon can then be installed in the same way as the original tendon. Before inserting the strands, the transitional area between trumpet and the connection duct at the stressing anchorage shall be examined for any signs of damage and if necessary replaced / repaired. All previously described installation steps shall be followed.

Prestressing losses due to friction and wobble effects

The losses due to friction may be determined in the calculation by using the friction coefficient μ = 0,08 given in the Annex A2 and the unintentional angular displacement k = 0 (wobble coefficient).

For the determination of the elongation/movement and the forces of prestressing steel, friction losses $\Delta P_{\mu S}$ in the stressing anchor zone (see Annex A2) shall be taken into account.

Material of Components

Designation	Material	Number	Standard
Anchorage			
Bearing Plate	deposited at DIBt		EN 10025-2:2005-04
Cast-iron Anchor Body	deposited at DIBt		
Wedges	deposited at DIBt		
Anchor Head	deposited at DIBt		EN 10083-2:2006-10
Helix and Additional Reinforcement	ripped reinforcing steel $R_e \geq 500$ MPa		valid provisions at the place of use
Trumpet	PE, deposited at DIBt		
Retainer Plate	PE, deposited at DIBt		
Protection Cap	PE or steel, deposited at DIBt		
Connection Duct	PE		EN 12201-1:2011-11 EN 12201-2:2013-12
Duct			
Duct	PE		EN 12201-1:2011-11 EN 12201-2:2013-12
PE- Electro Welding Sleeve / Transition Welding Sleeve	PE		DIN 16963-7:1989-10
Shrink Sleeve	deposited at DIBt		DIN 30672-1:1991-09
Corrosion Protection Mass			
Vaseline FC 284 *)	deposited at DIBt		
Unigel 128F-1 *)	deposited at DIBt		
Deviation			
Deviation Duct	PE		EN 12201-1:2011-11 EN 12201-2:2013-12
Deviation form parts (Type F) Steel (coated or galvanized)	minimum S235JR or EN GJS-400-15 or EN GJS-400-15U		EN 10025:2005-04 EN 1563: 2012-03 EN 1563: 2012-03
Deviation form parts (Type F) Plastic Material	PE (deposited at DIBt)		EN ISO 1872-1:1999-10
Penetration Pipe (Type F) and Recess Tube (Type S)	steel S235JR (galvanized) PVC-U PE		EN 10025-2:2005-04 DIN 8061: 2009-10 DIN 8062: 2009-10 EN 12201-1:2011-11 EN 12201-2:2013-12
Pre-bent Pipe (Deviation Type R)	steel S235JR (galvanized)		EN 10025-2:2005-04
Form Parts (Deviation Type R and S)	PE or PA, deposited at DIBt		
Grease	deposited at DIBt		

Further details (e.g. minimum strength) of the components in deposited delivery conditions

*) according to the supplier's material composition deposited at the Deutsches Institut für Bautechnik, the material properties shall comply with EAD 160027-00-0301

BBV External Post-Tensioning System Type E

Materials and References
Used Materials

Annex D1

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 12201-1:2011-11	Plastics piping systems for water supply and for drainage and sewerage under pressure - Polyethylene (PE) – Part 1: General
EN 12201-2:2013-12	Plastics piping systems for water supply and for drainage and sewerage under pressure – Polyethylene (PE) – Part 2: Pipes
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
EN 1563:2012-03	Founding – Spheroidal graphite cast irons