Deutsches Institut für Bautechnik

Approval body for construction products and types of construction

Bautechnisches Prüfamt

An institution established by the Federal and Laender Governments

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European Technical Assessment

ETA-17/0775 of 8 May 2018

English translation prepared by DIBt - Original version in German language

General Part

Technical Assessment Body issuing the European Technical Assessment:	Deutsches Institut für Bautechnik
Trade name of the construction product	ENERCON - Post-tensioning System, type i
Product family to which the construction product belongs	PAC 16, Post-Tensioning kits (internal bonded for strands)
Manufacturer	ENERCON GmbH Dreekamp 5 26605 Aurich DEUTSCHLAND
Manufacturing plant	Werk 1, D Werk 2, D Werk 3, TR
This European Technical Assessment contains	26 pages including 19 annexes which form an integral part of this assessment
This European Technical Assessment is issued in accordance with Regulation (EU) No 305/2011, on the basis of	EAD 160004-00-0301

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Specific Part

1 Technical description of the product

1.1 Definition of the construction product

The European Technical Assessment applies to the post-tensioning kit for prestressing of structures with the trade name:

ENERCON-Post-Tensioning System, type i

consisting of 7 to 15 strands with a nominal tensile strength 1770 N/mm² or 1860 N/mm² (Y1770 S7 or Y1860 S7 in according with prEN 10138-3, table 4), nominal diameter 15.3 mm (0.6" - 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 and Fe with bearing plate and anchor head for tendons of 7 and 9 strands,
2. Stressing (active) anchor type S and fixed (passive) anchor type F and Fe with cast-iron anchor body and anchor head for tendons of 12 and 15 strands,

Additional components of the present Post-tensioning system are:

3. Bursting reinforcement (helixes and stirrups),
4. Sheathing (ducts),
5. Corrosion protection.

The anchorage of the strands in anchor heads is done by means of 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 with the characteristics given in Table 1:

Table 1: Dimensions and properties of 7-wire strands

Designation	**Symbol**	**Unit**	**Value**	
Tensile strength	Rm	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

Only strands stranded in the same direction shall be used in a tendon. Further characteristic values of the strands see Annex A6.

1.3 Wedges

To wedging the prestressing steel strands shall be used Wedges type 30, smooth or knurled, (see Annex A3). The knurled wedges shall only be used for pre-wedged (pre-locked) ones at fixed anchors. The segments of the wedges for strands Ø 15.7 mm shall be marked with "0.62".

1.4 Anchor heads

The dimension of the anchor heads shall be in accordance with Annex A2. The conical drills of the anchor heads shall be clean and free of rust and provided with a corrosion protection agent.

1.5 Bearing plates

For tendons of 7 and 9 strands rectangular bearing plates shall be used. The long side of the bearing plates shall be installed parallel to the biggest centre or edge distance (see Annex A2 and Annex A4).

1.6 Cast-iron anchor bodies

For tendons 12 and 15 strands multi-surfaced cast-iron anchor bodies shall be used (see Annex A4).

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 Ducts

Ducts shall be used according to EN 523:2003. The dimensions of the ducts shall comply with the values given in Annex A2. The trumpets at stressing and fixed anchors are manufactured from steel for tendons L7 and L9. The trumpets for tendons L12 and L15 are manufactured from 3.5 mm thick PE material (see Annexes A3 and A4). In the area of possible contact between strands and steel trumpet (point of deviation) PE pipes of at least 4 mm thickness and a length of 120 mm shall be provided for avoiding any contact between strands and steel. The PE pipes shall be fixed in the right position. When using trumpets made of plastic with a minimum thickness of 3.5 mm, it is not necessary to install a PE pipe. It shall be made sure that at anchors the maximum deflection angle of the strand is 2.6° (at the end of the wedge and at the deviation point between trumpet and duct).

1.9 Grout

Grout shall be used according to EN 447:1996.

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 Annexes B1 and B2.

2.2 Useful life

The test and assessment methods underlying this ETA lead to the assumption of a useful life of least 100 years. This useful life information cannot be construed as a warranty of the manufacturer, but it is an aid in selecting the right products for the expected economically reasonably life of the work.

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

No.	Essential characteristic	Performance (NPA = No Performance Assessed)
BWR 1: Mechanical restistance and stability		
1	Resistance to static load	The acceptance criterion to EAD 160004-00-03-01 clause 2.2.1 is fulfilled, see Annex B
2	Resistance to fatigue	The acceptance criterion to EAD 160004-00-03-01 clause 2.2.2 is fulfilled, see Annex B
3	Load transfer to structure	The acceptance criterion to EAD 160004-00-03-01 clause 2.2.3 is fulfilled, see Annex B
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	The acceptance criterion to EAD 160004-00-03-01 clause 2.2.5 is fulfilled, see Annex B
6	Deviation/ deflection (limits) for external tendon	NPA
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	NPA
9	Resistance to static load under cryogenic conditions for applications with anchorage/coupling inside the possible cryogenic zone	NPA
10	Material properties, component performance, system performance of plastic duct	NPA

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

11	Material properties, component performance, system performance of plastic duct to provide an encapsulated tendon	NPA
12	Material properties, component performance, system performance of plastic duct to provide an electrically isolated tendon	NPA
13	Corrosion protection	NPA
Monostrand, sheating base material		
14	Melt index	NPA
15	Density	NPA
16	Carbon black	NPA
17	Tensile strenght	NPA
18	Elongation	NPA
19	Thermal stability	NPA
Monostrand, manufactured sheating		
20	Tensile strenght	NPA
21	Elongation	NPA
22	Surface of sheating	NPA
23	Environtal stress cracking	NPA
24	Temperatur resistance	NPA
25	Resistance to externally applied agents (mineral oil, acid, base, solvents and salt water)	NPA
26	Sheating minimum thickness	NPA
Monostrand, manufactured monostrand		
27	External diameter of sheating	NPA
28	Mass of sheating per metre	NPA
29	Mass of filling material per metre	NPA
30	Alteration of dropping point caused by monostrand manufacturing	NPA

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

31	Alteration of oil separation caused by monostrand facturing	NPA
32	Impact resistance	NPA
33	Reibung zwischen Ummantelung und Litze	NPA
34	Leak tightness	NPA
BWR 2: Safety in case of fire		
35	Reaction to fire	NPA
BWR 3: Hygiene, health and the environment		
36	Content, emmission and/or release of dangerous substances	NPA

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.

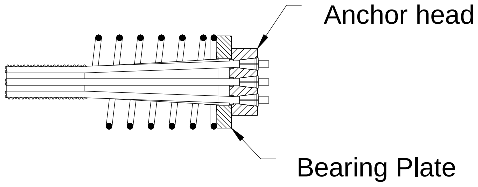
Issued in Berlin on 8 May 2018 by Deutsches Institut für Bautechnik

BD Dipl.-Ing. Andreas Kummerow
Head of Department

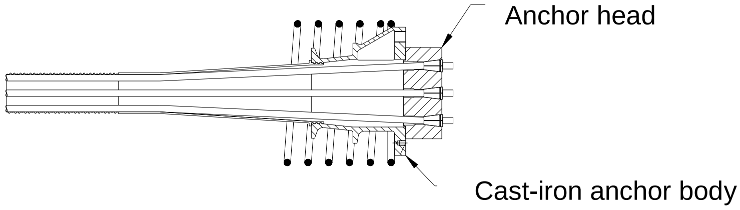
beglaubigt:
Sultani

OVERVIEW ANCHORAGES

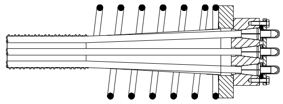
1. Active Anchor (S) and Passive Anchor (F) L7, L9



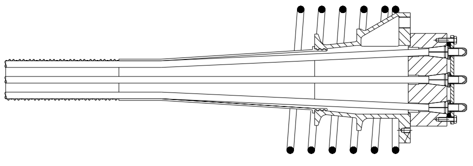
2. Active Anchor (S) and Passive Anchor (F) L12, L15



3. Embedded Passive Anchor (Fe) L7, L9



4. Embedded Passive Anchor (Fe) L12, L15



ENERCON - Post-tensioning System, type i	Annex A1
Description of the product Overview Anchorages	

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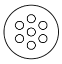
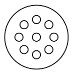
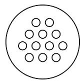
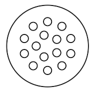
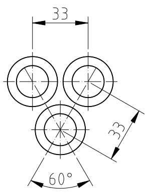
TECHNICAL DETAILS
Steel Grade Y1770
Anchors (S), (F), (Fe)

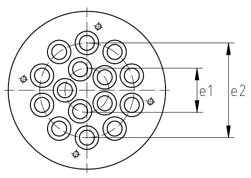
Tendon Type		**L 7**	**L 9**	**L 12**	**L 15**
Strand Pattern					
Number of strands	n	7	9	12	15
150mm² : Nominal Cross Section A_p	mm²	1050	1350	1800	2250
150mm² : Nominal mass M	kg/m	8.20	10.55	14.06	17.58
150mm² : Ultimate Force F_{pk}	kN	1859	2390	3186	3983
150mm² : $P_{0max} = 0.90 \cdot f_{p0.1k} \cdot A_p$ *	kN	1436	1847	2462	3078
150mm² : $P_{m0}(x) = 0.85 \cdot f_{p0.1k} \cdot A_p$ *	kN	1357	1744	2326	2907
140mm² : Nominal Cross Section A_p	mm²	980	1260	1680	2100
140mm² : Nominal mass M	kg/m	7.65	9.84	13,12	16,40
140mm² : Ultimate Force F_{pk}	kN	1735	2230	2974	3717
140mm² : $P_{0max} = 0.90 \cdot f_{p0.1k} \cdot A_p$ *	kN	1341	1724	2298	2873
140mm² : $P_{m0}(x) = 0.85 \cdot f_{p0.1k} \cdot A_p$ *	kN	1266	1628	2171	2713
Wobble Coefficient k	°/m	0.3	0.3	0.3	0.3
at max. Support Distance	m	1.80	1.80	1.80	1.80
Friction Coefficient μ	-	0.20 / 0.20 / 0.19	0.20 / 0.20 / 0.19	0.19/0.19/0.19	0.20/0.20 / 0.19
Friction Losses					
Active Anchor $\Delta P_{\mu}S$	%	1.1	1.0	0.8	0.8
Ducts					
Inner Diameter	mm	55/60/65	65/70/75	75/80/90	80/85/90
Outer Diameter	mm	61/67/72	72/77/82	82/87/97	87/92/97
Eccentricity, 150mm²	mm	5.7/9.0/12.1	8.4/12.1/15.4	10.3/13.9/20,2	9.0/12.4/15.8
Eccentricity, 140mm²	mm	7.2/10.4/14.2	10.5/13.9/17.1	11.7/14.9/21.1	10.1/14.0/17.7
Strand Protrusion **	cm	71	82	80	80
Anchors (S), (F), (Fe)					
Min. Centre / Edge Distance*,'****					
$f_{cmj,cube}$ = 28/30 N/mm² *	mm	325 x 285	370 x 325	405/225	450/245
$f_{cmj,cube}$ = 34 N/mm²	mm	305 x 270	345 x 305	370/205	415/230
$f_{cmj,cube}$ = 40 N/mm²	mm	280 x 245	320 x 275	340/190	380/210
$f_{cmj,cube}$ = 45 N/mm²	mm	260 x 230	295 x 265	325/185	360/200

* Based on $f_{p0,1k}$ = 1520 N/mm² (Grade Y1770S7)
** Distance from anchor head for placing of jack
*** Distances can be reduced to 85 % of the given values in one direction, if increased correspondingly in the other direction
**** Min. edge distance : min. centre distance/2+20 mm
**** $f_{cmj,cube}$ = 30 N/mm² apply to L7 and L9 / $f_{cmj,cube}$ = 28 N/mm² apply to L12 and L15

Strand Pattern L 12
Conical borings are in line, lines result in a grid



L 7; 9; 15
All conical borings are aligned on one or two circles e1 and e 2).



Example: L15

ENERCON - Post-tensioning System, type i

Description of the product
Technical Details L7 – L15
Steel Grade Y1770S7

Annex A2
Page 1 of 2

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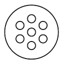
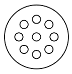
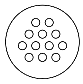
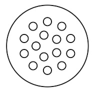
TECHNICAL DETAILS
Steel Grade Y1860
Anchors (S), (F), (Fe)

Tendon Type	Unit	**L 7**	**L 9**	**L 12**	**L 15**
Strand Pattern					
Number of Strands	n	7	9	12	15
150mm² : Nominal Cross Section Ap	mm²	1050	1350	1800	2250
150mm² : Nominal Mass M	kg/m	8.20	10.55	14.06	17.58
150mm² : Ultimate Force F_{pk}	kN	1953	2511	3348	4185
150mm² : $P_{0max} = 0.90 * f_{p0.1k} * A_p$ *	kN	1512	1944	2592	3240
150mm² : $P_{m0}(x) = 0.85 * f_{p0.1k} * A_p$ *	kN	1428	1836	2448	3060
140mm² : Nominal Cross Section Ap	mm²	980	1260	1680	2100
140mm² : Nominal Mass M	kg/m	7.65	9.84	13.12	16.40
140mm² : Ultimate Force F_{pk}	kN	1823	2344	3125	3906
140mm² : $P_{0max} = 0.90 * f_{p0.1k} * A_p$ *	kN	1411	1814	2419	3024
140mm² : $P_{m0}(x) = 0.85 * f_{p0.1k} * A_p$ *	kN	1333	1714	2285	2856
Wobble Coefficient k	°/m	0.3	0.3	0.3	0.3
at max. Support Distance	m	1.80	1.80	1.80	1.80
Friction Coefficient µ	-	0.20 / 0.20 / 0.19	0.20 / 0.20 / 0.19	0.19/ 0.19 / 0.19	0.20/0.20 / 0.19
Friction Losses					
Active Anchor $\Delta P_\mu S$	%	1.1	1.0	0.8	0.8
Ducts					
Inner Diameter	mm	55/60/65	65/70/75	75/80/90	80/85/90
Outer Diameter	mm	61/67/72	72/77/82	82/87/97	87/92/97
Eccentricity, 150mm²	mm	5.7/9.0/12.1	8.4/12.1/15.4	10.3/13.9/20,2	9,0/12.4/15.8
Eccentricity, 140mm²	mm	7.2/10.4/14.2	10.5/13.9/17.1	11.7/14.9/21,1	10,1/14.0/17.7
Strand Protrusion **	cm	71	82	80	80
Anchors (S), (F), (Fe)					
Min. Centre / Edge Distance* ********					
$f_{cmj,cube}$ = 28/30 N/mm² *****	mm	325 x 285	370 x 325	405/225	450/245
$f_{cmj,cube}$ = 34 N/mm²	mm	305 x 270	345 x 305	370/205	415 /230
$f_{cmj,cube}$ = 40 N/mm²	mm	280 x 245	320 x 275	340/190	380/210
$f_{cmj,cube}$ = 45 N/mm²	mm	260 x 230	295 x 265	325/185	360/200

* Based on $f_{p0,1k}$ = 1520 N/mm² (Grade Y1770S7)

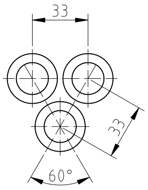
** Distance from anchor head for placing of jack

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

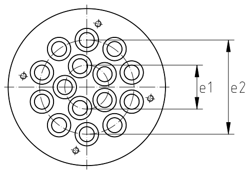
**** Min. edge distance : min. centre distance/2+20 mm

***** $f_{cmj,cube}$ = 30 N/mm² apply to L7 and L9 / $f_{cmj,cube}$ = 28 N/mm² apply to L12 and L15

Strand Pattern L12
Conical borings are in line, lines result in a grid.



L7; 9; 15
All conical borings are aligned on one or two circles (e1 and e2).



Example: L15

ENERCON - Post-tensioning System, type i	Annex A2 Page 2 of 2
Description of the product Technical Details L7 – L15 Steel Grade Y1860S7	

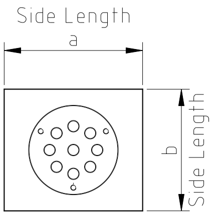
Description of Wedge Anchorages

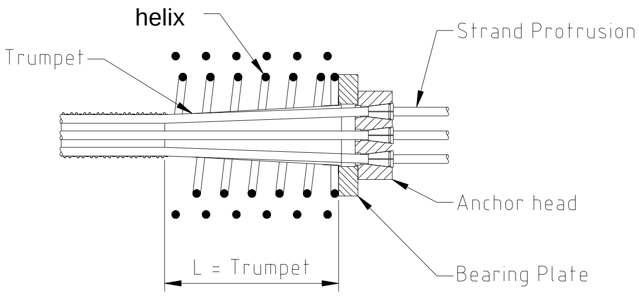
Active Anchors (S)
Passive Anchors (F), (Fe)

Active anchors (S) with bearing plate and anchor head
Accessible passive anchor (F) with bearing plate and anchor head

For embedded Passive Anchor (Fe) the anchor head is installed to the bearing plate, the wedges are sealed and secured in their cones by a retainer plate. The area around the wedges of embedded passive anchors is to be filled with corrosion protection mass and filled sealing caps are to be applied.

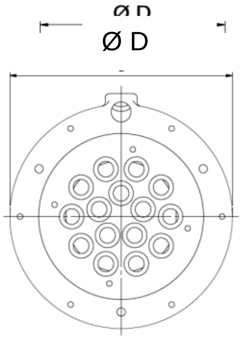
L 7, L 9

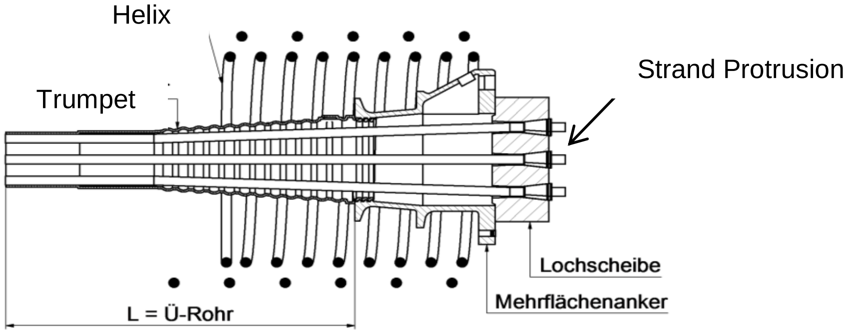




active anchor and passive anchor with rectangular bearing plate *a x b* and anchor head.

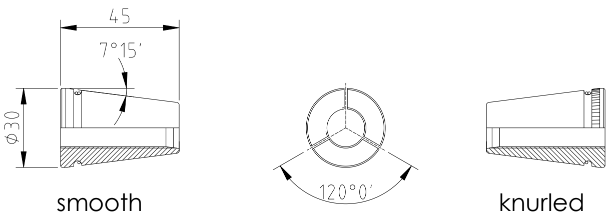
L12, L15





active anchor with cast-iron anchor body of diameter *d* and anchor head.

Wedges Type 30



Optional knurled wedges for pre-wedged passive anchors

Wedges for 150 mm² strands are marked with "0.62” on the front face.

ENERCON - Post-tensioning System, type i	Annex A3
Description of the product Wedge Anchorages	

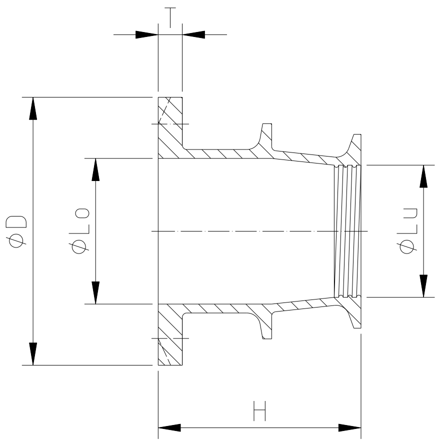
Dimension of Anchor Components

Tendon Type		L7	L9	L12	L15
Bearing Plate					
Side length a	mm	215	250		
Side length b	mm	190	220		
Thickness	mm	35	35		
Hole diameter	mm	93	113		
Cast-iron Anchor					
Diameter D	mm			240	270
Height H	mm			182	203
Thickness 1st plane T	mm			22	23
Hole - dia. top Lo	mm			131	150
Hole - dia. bottom Lu	mm			123	139
Anchor Head					
Diameter D	mm	132	160	180	200
Thickness T	mm	75	75	80	82
Diameter A	mm	89	109	127	146
Diameter circle e1	mm	66	86	*grid	56
Diameter circle e2	mm				120
Trumpet					
Max. outer diameter	mm	91	111	131	147
Length	mm	≥247	≥417	≥500	≥553

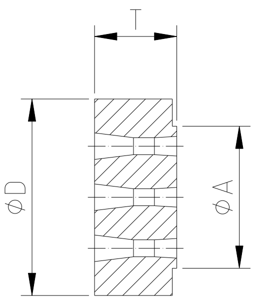
* Grid according to Annex A2

Bearing Plate see Annex A3

Cast iron Anchor Body



Anchor Head



ENERCON - Post-tensioning System, type i

Description of the product
Dimensions of Anchor Components

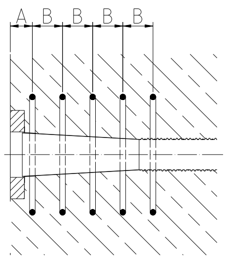
Annex A4

Helix and Additional Reinforcement

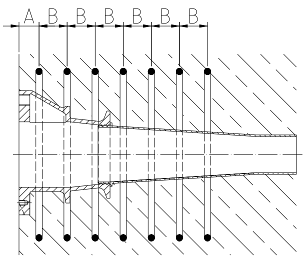
Tendon Type	Unit	**L7**	**L9**	**L12**	**L15**
Helix*					
Bar Diameter					
$f_{cmj,cube} \geq 28/30$ N/mm²**	mm	14	14	14	14
$f_{cmj,cube} \geq 34$ N/mm²	mm	14	14	14	16
$f_{cmj,cube} \geq 40$ N/mm²	mm	14	14	14	14
$f_{cmj,cube} \geq 45$ N/mm²	mm	14	14	14	14
Outer Diameter					
$f_{cmj,cube} \geq 28/30$ N/mm²**	mm	200	240	300	345
$f_{cmj,cube} \geq 34$ N/mm²	mm	190	230	300	340
$f_{cmj,cube} \geq 40$ N/mm²	mm	190	225	285	320
$f_{cmj,cube} \geq 45$ N/mm²	mm	180	220	270	315
Min. Length					
$f_{cmj,cube} \geq 28/30$ N/mm²**	mm	300	350	350	400
$f_{cmj,cube} \geq 34$ N/mm²	mm	270	310	300	350
$f_{cmj,cube} \geq 40$ N/mm²	mm	250	290	300	300
$f_{cmj,cube} \geq 45$ N/mm²	mm	250	275	250	250
Pitch					
$f_{cmj,cube} \geq 28/30$ N/mm²**	mm	50	50	50	50
$f_{cmj,cube} \geq 34$ N/mm²	mm	50	50	50	50
$f_{cmj,cube} \geq 40$ N/mm²	mm	50	50	50	50
$f_{cmj,cube} \geq 45$ N/mm²	mm	50	50	50	50
Helix Turns					
$f_{cmj,cube} \geq 28/30$ N/mm²**	n	7	8	8	9
$f_{cmj,cube} \geq 34$ N/mm²	n	6.5	7	7	8
$f_{cmj,cube} \geq 40$ N/mm²	n	6	7	7	7
$f_{cmj,cube} \geq 45$ N/mm²	n	6	6.5	6	6
Stirrup Reinforcement		Nos x dia.	Nos x dia.	Nos x dia.	Nos x dia.
$f_{cmj,cube} \geq 28/30$ N/mm²**	mm	4 ∅14	5 ∅14	6 ∅12	5 ∅14
$f_{cmj,cube} \geq 34$ N/mm²	mm	5 ∅12	5 ∅14	6 ∅14	8 ∅14
$f_{cmj,cube} \geq 40$ N/mm²	mm	5 ∅12	5 ∅14	5 ∅16	6 ∅16
$f_{cmj,cube} \geq 45$ N/mm²	mm	4 ∅12	6 ∅12	5 ∅16	6 ∅16
Position behind bearing plate/cast-iron anchor body		A/B	A/B	A/B	A/B
$f_{cmj,cube} \geq 28/30$ N/mm²**	mm	55 / 95	55 / 80	50 / 70	50 / 95
$f_{cmj,cube} \geq 34$ N/mm²	mm	55 / 65	55 / 75	50 / 65	50 / 55
$f_{cmj,cube} \geq 40$ N/mm²	mm	55 / 60	55 / 70	50 / 70	50 / 65
$f_{cmj,cube} \geq 45$ N/mm²	mm	55 / 75	55 / 50	50 / 65	50 / 60

* nominal dimensions, tolerances deposited at DIBt

** $f_{cmj,cube}$ = 30 N/mm² apply to L7 and L9 / $f_{cmj,cube}$ = 28 N/mm² apply to L12 and L15



L 7, L 9



L12, L15

ENERCON - Post-tensioning System, type i

Description of the product
Helix and Additional Reinforcement

Annex A5

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	1520 or 1600*****	
Strength at 0,2%	$f_{p0.2}$	MPa	1570 or 1660	
Modulus of elasticity	E	MPa	≈ 195,000	
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

* If admissible in the place of use, strands with higher characteristic yield stresses might be used, but not more than $f_{p0,1k} \geq 1560$ MPa (Y1770S7) or 1640 MPa (Y1860S7).

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

ENERCON - Post-tensioning System, type i	Annex A6
Description of the product Dimensions and Properties of 7-wire Strands	

1 Intended use

The Post-Tensioning System is assumed to be used for internal bonded tendons for normal-weight concrete structures or elements.

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

No optional use category is intended. The structural members used to be designed in accordance with national regulations.

2 Methods of verification

2.1 General

The structural members prestressed by means of the ENERCON-Internal Bonded Strand Post-Tensioning System 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 $P_{max} = 0.9\ A_p\ f_{p0,1k}$ (see Table B 1 (140 mm²) or Table B 2 (150 mm²) for $f_{p0,1k}$ = 1520 N/mm² or 1600 N/mm²). The value of the prestressing initial prestress force $P_{m0}(x)$ applied to the concrete after tensioning and anchoring shall not exceed the force $P_{m0}(x) = 0.85\ A_p\ f_{p0,1k}$ (see Table B 1 (140 mm²) or Table B 2 (150 mm²) for $f_{p0,1k}$ = 1520 N/mm² or 1600 N/mm²).

Table B 1: Maximal prestressing forces[1] for tendons with A_p = 140 mm²

Tendon Designation	Number of strands	Cross section A_p [mm²]	Prestressing force Y1770 S7 $f_{p0,1k}$ = 1520 N/mm²		Prestressing force Y1860 S7 $f_{p0,1k}$ = 1600 N/mm²	
			$P_{m0}(x)$ [kN]	P_{max} [kN]	$P_{m0}(x)$ [kN]	P_{max} [kN]
L7	7	980	1266	1341	1333	1411
L9	9	1260	1628	1724	1714	1814
L12	12	1680	2171	2298	2285	2419
L15	15	2100	2713	2873	2856	3024

Table B 2: Maximal prestressing forces[1] for tendons with A_p = 150 mm²

Tendon Designation	Number of strands	Cross section A_p [mm²]	Prestressing force Y1770 S7 $f_{p0,1k}$ = 1520 N/mm²		Prestressing force Y1860 S7 $f_{p0,1k}$ = 1600 N/mm²	
			$P_{m0}(x)$ [kN]	P_{max} [kN]	$P_{m0}(x)$ [kN]	P_{max} [kN]
L7	7	1050	1357	1436	1428	1512
L9	9	1350	1744	1847	1836	1944
L12	12	1800	2326	2462	2448	2592
L15	15	2250	2907	3078	3060	3240

[1] The forces stated in Tables B 1 to B 3 are maximum values referring on $f_{p0,1k}$ = 1520 N/mm² or 1600 N/mm². The actual prestressing forces are to be found in national regulations valid in the place of use. If admissible in the place of use, strands with higher characteristic yield stresses might be used, but not more than $f_{p0,1k}$ = 1560 N/mm² (Y1770S7) or 1640 N/mm² (Y1860S7). In this case the prestressing forces of Tables B 1 to B 3 can be linearly increased by multiplying them with the factor ($f_{p0,1k}$/ 1520) or ($f_{p0,1k}$/1600).

Compliance with the stabilisation and crack width criteria in the load transfer test was verified to a load level of 0,80*F_{pk}.

The number of strands in a tendon may be reduced by leaving out strands lying 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 the short pieces of strands with wedges have to be pressed to prevent slipping out. The admissible prestressing force is reduced per strand left out as shown in Table B 3.

Table B 3: Reduction of the prestressing force[1] when leaving out a strand

A_p	Y1770 S7		Y1860 S7	
	$\Delta P_{m0}(x)$ [kN]	ΔP_{max} [kN]	$\Delta P_{m0}(x)$ [kN]	ΔP_{max} [kN]
140 mm²	181	192	190	201
150 mm²	194	205	204	216

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 are given in Annex B3, section 4.2.

2.4 Concrete strength

Concrete complying with EN 206-1:2000, EN 206-1/A1:2004 and EN 206-1/A2:2005 shall be used.
At the time of transmission of the full prestressing force the mean concrete strength of the normal weight concrete in the anchor zone shall be at least $f_{cmj,cube}$ or $f_{cmj,cyl}$ according to Table B 4. The mean concrete strength shall be verified by means of tests at least three specimens (cylinder or cube with the edge length of 150 mm), which shall to 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
40	32
45	35

*) 12 to 15 strands

**) 7 to 9 strands

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

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

The centre and edge distances of the tendon anchorages must not be smaller than the values given in the Annexes depending on the minimum concrete strength. In case of anchorages L7 and L9 the large side of the bearing plate (side length a according to Annex A4) shall be installed parallel to the large concrete side (the maximum spacing of concrete axis).

The values of the centre or edge distances of the anchors given in the Annexes may be reduced in one direction up to 15 %, however, not to a smaller value than the external dimensions of the additional reinforcement (stirrups or the outer diameter of the helix, Annex A5). In this case the centre and the edge distances in the other direction shall be increased for keeping the same concrete area in the anchor zone.

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

2.6 Reinforcement in the anchorage zone

The anchorages (including reinforcement) for the transfer of the prestressing forces to the structural concrete are verified by means of tests. The resistance to the forces occurring in the structural concrete in the anchorage 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. This reinforcement must not be taken into account as part of the statically required reinforcement. However, existing reinforcement in a corresponding position more than 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 staggered.

In the anchorage zone vertically led gaps for concreting shall be provided for concreting properly. If in exceptional case[2] - due to an increased amount of reinforcement - the helix or the concrete cannot be properly placed, the helix can be replaced by different equivalent reinforcement.

2.7 Slip at the anchorages

The slip at the anchorages (see Annex B2, section 3.4) shall be taken into account in the static calculation and the determination of the tendon elongation.

2.8 Fatigue resistance

With the fatigue tests 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 demonstrated.

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

Deutsches Institut für Bautechnik DIBt

3. Installation

3.1 General

Assembly and installation of the tendons shall only be performed by qualified post-tensioning specialist companies which have the required technical skills and experiences with this ENERCON-Post-tensioning System. The company's site manager shall have a certificate of the manufacturer certifying that he is instructed by the manufacturer and has the required knowledge and experience with this post-tensioning system. Standards and regulations valid on site and CWA 14646:2003 shall be considered.

The manufacturer is responsible for informing all parties involved about the use of the ENERCON strand tensioning system. Supplementary technical documents are issued by the manufacturer if required.

The tendons and the components shall be handled carefully.

3.2 Welding

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

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

b) For ensuring of the central position the helix may be attached to the bearing plate or cast-iron anchor by tack welding.

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

3.3 Installation of the tendon

The central position of the helix or stirrups shall be ensured by tack-welding to the bearing plate or the cast-iron anchor or by means of mounting brackets. The bearing plate or cast-iron anchor and the anchor head shall be in direction vertical to the axis of the tendon.

The tendon shall be placed straightforward the first meter at the anchorage.

PE pipes shall be fixed in the right position and the length of the trumpets shall ensure the right deflection angle of the strands (see section 1.8 of European Technical Assessment).

The connection between trumpet and duct shall be sealed carefully by tape in order to prevent the penetrating of concrete.

3.4 Wedging force, slip at anchorages, wedge securing and corrosion protection mass

If the calculated prestressing force is less than 0.7 $P_{m0}(x)$ or if knurled wedges type 30 are used, the wedges of fixed anchorages shall be pre-wedged with 1.1 $P_{m0}(x)$ (see Annex B1, section 2.2).

Without pre-wedging the slip within the anchorage to be taken into account for the determination of the elongations is 4 mm at the fixed anchorages. In the case of hydraulic pre-wedging with 1.1 $P_{m0}(x)$ no slip shall be taken into account for the determination of the elongations.

The wedges of all anchorages (fixed anchors) which are no more accessible during tensioning shall be secured by means of securing plates and bolts. The wedging area of fixed anchors to be cast in concrete shall be filled with corrosion protection mass (Denso-Jet, Vaseline FC 284 or Nontribos MP-2) and provided with a sealing cap filled with corrosion protection mass (see Annexes A3). Compositions of the different types of these masses have been deposited with the Deutsches Institut für Bautechnik by the manufacturer.

The wedges of the stressing anchors shall be wedged after tensioning with at least 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).

3.5 Tensioning

Before tensioning the minimum mean concrete strength shall comply with the values given in Annex B1, section 2.4.

Taking into account the constraints is possible to restress the tendons by releasing and re-using the wedges. After restressing and anchoring, wedge marks on the strands resulting from first stressing shall be moved to the outside by at least 15 mm.

The minimum straight length for tensioning behind the anchorages (strand protrusion) is given in Annex A2. All strands of a tendon shall be stressed simultaneously. This can be done by centrally controlled individual jacks or by a bundle jack.

3.6 Grouting

3.6.1 Grout and Grouting procedures

Grout according section 1.9 of ETA shall be used. Grouting procedures shall be carried out in accordance with EN 446:1996.

3.6.2 Water rinse

Normally, tendons shall not be rinsed with water.

3.6.3 Grouting speed

The grouting speed shall be in the range between 3m/min and 12m/min.

3.6.4 Grouted section and re-grouting

The length of a grouted section shall not exceed 120 m. When exceeding these tendon lengths, additional grouting openings shall be provided. Where the tendon is led via distinct high points, re-groutings shall be performed in order to avoid voids. For re-groutings corresponding measures shall be taken into account already in design.

3.6.5 Surveillance

Surveillance according to EN 446:1996 shall be carried out.

3.7 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.

During transport the smallest admissible diameter of curvature of tendons with duct up or tendons without duct is 1.65 m.

4 Description of Post-Tensioning System

4.1 Tendons

The tendons consist of 7-wire strands with a nominal diameter of 0.60" (15,3 mm) and a nominal cross section of 140 mm² or with a nominal diameter of 0.62" (15,7 mm) and a nominal cross section of 150 mm². Steel grades Y1770S7 or Y1860S7 are allowed. Anchorages depending on the tendon sizes are identically for both steel grades.

Table B 5: The strands are bundled to the following tendons and stressing forces:

Steel Grade Nominal Diameter		**Y1770 0.60"**	**Y1770 0.62"**	**Y1860 0.60"**	**Y1860 0.62"**
Tendon Designation	**No. of strands**	**$P_{m0}(x)$ [kN]**	**$P_{m0}(x)$ [kN]**	**$P_{m0}(x)$ [kN]**	**$P_{m0}(x)$ [kN]**
L7	7	1266	1357	1333	1428
L9	9	1628	1744	1714	1836
L12	12	2171	2326	2285	2448
L15	15	2713	2907	2856	3060

Based on $f_{p0,1k}$ = 1520 N/mm² (Sorte Y 1770S7) and 1600 N/mm² (Grade Y 1860S7)

$P_{m0(x)} = 0,85 \text{ x } f_{p0,1k} \text{ x } A_p$

The number of strands in a tendon can be reduced by omitting single strands always maintaining a symmetrical pattern, see Annex B1, section 2.2, Table B3

The strands of tendons are combined in a duct without spacer. They are stressed simultaneously and anchored individually in the anchor head by means of wedges.

Round profiled corrugated ducts are used according to EN 523 and connected by threaded couplers. All duct connections are sealed carefully by PVC tape.

4.2 Radius of curvature of the tendons in the structure

The smallest admissible radius of curvature of the tendons with duct according to EAD 160004-00-0301 depending on the strand strength, the cross section of the strand and the diameter of the duct is given in Table B 6 to B 11 (at the place of use it must be checked whether they are permissle).

$$R_{min} = \frac{2 \cdot F_{pm0} \cdot d_{strand}}{p_{R,max} \cdot d_{duct,i}} \geq 2,50 \text{ m} \qquad (1)$$

where

R_{min} minimum radius of curvature in [m]

$F_{m0}(x)$ Prestressing Force of tendon = 0.85 A_p $f_{p0.1k}$ in [kN] according Annex B1, Section 2.2

d_{strand} strand diameter in [mm]

$p_{R,max}$ maximum pressure under the strand ($p_{R,max}$ = 130, 150 or 230 kN/m)

$d_{duct,i}$ inner duct diameter in [mm]

The minimum radius of curvature R_{min} shall be given with an accuracy of 0.1 m (shall be rounded up).

Table B 6: Smallest radius of curvatur[3] for strands Y1770 S7 with A_p = 140 mm² and 150 mm² with a maximum pressure $p_{R,max}$ = 130 kN/m

Tendon	**Radius of curvature [m] (Inner diameter of the duct [mm])**					
	Ap = 140 mm²			**Ap = 150 mm²**		
L7	5,50 (55)	5,00 (60)	4,60 (65)	6,00 (55)	5,50 (60)	5,10 (65)
L9	5,90 (65)	5,50 (70)	5,20 (75)	6,50 (65)	6,10 (70)	5,70 (75)
L12	6,90 (75)	6,40 (80)	5,70 (90)	7,50 (75)	7,10 (80)	6,30 (90)
L15	8,00 (80)	7,60 (85)	7,10 (90)	8,80 (80)	8,30 (85)	7,90 (90)

Table B 7: Smallest radius of curvature³ for strands Y1770 S7 with A_p = 140 mm² and 150 mm² with a maximum pressure $p_{R,max}$ = 150 kN/m

Spannglied	**Krümmungsradius R_{min} [m] (Hüllrohrinnendurchmesser $d_{duc,i}$ [mm])**					
	Ap = 140 mm²			**Ap = 150 mm²**		
L7	4,70 (55)	4,40 (60)	4,00 (65)	5,20 (55)	4,80 (60)	4,40 (65)
L9	5,20 (65)	4,80 (70)	4,50 (75)	5,70 (65)	5,30 (70)	4,90 (75)
L12	6,00 (75)	5,60 (80)	5,00 (90)	6,50 (75)	6,10 (80)	5,50 (90)
L15	7,00 (80)	6,60 (85)	6,20 (90)	7,70 (80)	7,20 (85)	6,80 (90)

Table B 8: Smallest radius of curvatur³ for strands Y1770 S7 with A_p = 140 mm² and 150 mm² with a maximum pressure $p_{R,max}$ = 230 kN/m

Spannglied	**Krümmungsradius R_{min} [m] (Hüllrohrinnendurchmesser d_{duci} [mm])**					
	Ap = 140 mm²			**Ap = 150 mm²**		
L7	3,10 (55)	2,90 (60)	2,60 (65)	3,40 (55)	3,10 (60)	2,90 (65)
L9	3,40 (65)	3,10 (70)	2,90 (75)	3,70 (65)	3,50 (70)	3,20 (75)
L12	3,90 (75)	3,70 (80)	3,30 (90)	4,30 (75)	4,00 (80)	3,60 (90)
L15	4,60 (80)	4,30 (85)	4,10 (90)	5,00 (80)	4,70 (85)	4,50 (90)

Table B 9: Smallest radius of curvatur³ for strands Y1860 S7 with A_p = 140 mm² and 150 mm² with a maximum pressure $p_{R,max}$ = 130 kN/m

Spannglied	**Krümmungsradius R_{min} [m] (Hüllrohrinnendurchmesser $d_{duc,i}$ [mm])**					
	Ap = 140 mm²			**Ap = 150 mm²**		
L7	5,80 (55)	5,30 (60)	4,90 (65)	6,30 (55)	5,80 (60)	5,40 (65)
L9	6,30 (65)	5,80 (70)	5,40 (75)	6,90 (65)	6,40 (70)	6,00 (75)
L12	7,20 (75)	6,80 (80)	6,00 (90)	7,90 (75)	7,40 (80)	6,60 (90)
L15	8,50 (80)	8,00 (85)	7,50 (90)	9,30 (80)	8,70 (85)	8,30 (90)

[3] The given smallest admissible radii of curvature refer on the maximum presstressing forces P_{max} according to Tables B 1 or B 3. If admissible in the place of use, and if strands with higher characteristic yield stressed will be used, the given radii of curvature shall be linearly increased by multiplying them with the factor ($f_{p0,1k}$ / 1520) or ($f_{p0,1k}$ / 1600) and rounded up in steps of 0.1 m. See also Annex B1, section 2.2 and footnote 1.

Table B 10: Smallest radius of curvatur³ for strands Y1860 S7 with A_p = 140 mm² and 150 mm² with a maximum pressure $p_{R,max}$ = 150 kN/m

Spannglied	**Krümmungsradius R_{min} [m] (Hüllrohrinnendurchmesser $d_{duc,i}$ [mm])**					
	Ap = 140 mm²			**Ap = 150 mm²**		
L7	5,00 (55)	4,60 (60)	4,20 (65)	5,50 (55)	5,00 (60)	4,60 (65)
L9	5,40 (65)	5,00 (70)	4,70 (75)	6,00 (65)	5,50 (70)	5,20 (75)
L12	6,30 (75)	5,90 (80)	5,20 (90)	6,90 (75)	6,50 (80)	5,70 (90)
L15	7,30 (80)	6,90 (85)	6,50 (90)	8,10 (80)	7,60 (85)	7,20 (90)

Table B 11: Smallest radius of curvatur³ for strands Y1860 S7 with A_p = 140 mm² and 150 mm² with a maximum pressure $p_{R,max}$ = 230 kN/m

Spannglied	**Krümmungsradius R_{min} [m] (Hüllrohrinnendurchmesser $d_{duc,i}$ [mm])**					
	Ap = 140 mm²			**Ap = 150 mm²**		
L7	3,30 (55)	3,00 (60)	2,80 (65)	3,60 (55)	3,30 (60)	3,00 (65)
L9	3,60 (65)	3,30 (70)	3,10 (75)	3,90 (65)	3,60 (70)	3,40 (75)
L12	4,10 (75)	3,80 (80)	3,40 (90)	4,50 (75)	4,20 (80)	3,80 (90)
L15	4,80 (80)	4,50 (85)	4,30 (90)	5,30 (80)	5,00 (85)	4,70 (90)

5 Anchorages

The anchorage with anchor plate or cast-iron anchor body and anchor head is used as active anchor or accessible passive anchor. If the anchor head is tack welded to the anchor plate/anchor body and sealed, this type can also be used as an embedded anchorage. Within the anchorage zone the corrugated duct is replaced by a trumpet (PE or steel) with a larger diameter, in which the strands can be deflected by a maximum of 2.6° respectively (see section 1.8 of European Technical Assessment). If using a steel trumpet, this one shall be equipped with a PE-inlet. Consecutive part is the anchor plate / cast-iron anchor body and anchor head with 7, 9, 12 or 15 conical borings – depending on the tendon size – in which the strands are anchored with round wedges, each consisting of three segments.

For anchorage of dia. 0.62” strands wedges with marking “0.62” on the front face shall be installed. The wedges of the embedded passive anchors have to be sealed and secured by a retainer plate.

The bursting forces caused by the load transfer to the concrete member shall be carried by a helix made of ribbed steel. Additional reinforcement such as straight bars or stirrups is required. At the fixed anchors without pre-wedging the slip is 4 mm.

At the stressing anchors the slip is 3 mm (see Annex B2, section 3.4).

6 Stressing

A hydraulic pump unit and a special jack are used for the stressing of tendons. All strands of a tendon are stressed simultaneously. Stressing in load steps and resetting of the jacks is easily done. After stressing, the round wedges are power seated by means of a seating device within the jack. A wedge slip of approx. 3 mm remains after the wedge seating procedure.

Straight tendons strands can be stressed individually by mono jacks.

7 Grouting

For bond and corrosion protection of the strands, the ducts are grouted after stressing. The grout is injected into the grouting cap or through grout pipes. The ducts are vented at the ends of the tendons by means of venting pipes or grouting caps.

Intermediate venting points are necessary in case of long tendons. Grouting shall be executed in accordance with national regulations and standards.

1 Performance of the Product

1.1 Losses due to friction and wobble effects

The losses due to friction may usually be determined in the calculation by using the friction coefficients μ and the unintentional angular displacement k (wobble coefficient) given in the Annex A2. The values μ and k depend on the given duct dimensions and distances between tendon supports.

The given values of k only apply if the strands are in the ducts at the time of concreting.

If the strands are arranged after concreting, the given values μ shall only be used in the calculation if the ducts are adequately stiffened during concreting, e.g. by means of PE and/or PVC pipes, or if reinforced ducts are used in connection with smaller distances between tendon supports.

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

ENERCON - Post-tensioning System, type i	Annex C
Performance of the Product Prestressing losses due to Friction and Wobble Effects	

Material of Components

Designation	Material	Number	Standard
Bearing plates	S235JR	1.0038	EN 10025-2:2004
Cast-iron Anchor Body	deposited at Deutsches Institut für Bautechnik		
Wedges	deposited at Deutsches Institut für Bautechnik		
Anchor Heads	C45+N	1.0503	EN 10083-2:2006
Helixes for S, F, Fe	R_e = 500 MPa f_{yk} ≥ 500 MPa, ε_{uk} ≥ 50 ‰		valid provisions at the place of use
Additional Reinforcement for S, F, Fe	R_e = 500 MPa		EN 10080:2005-08
Securing plates for Wedges	S235JR	1.0038	EN 10025-2:2004
Trumpets	steel or PE deposited at Deutsches Institut für Bautechnik		
PE Pipes and Caps	PE deposited at Deutsches Institut für Bautechnik		
Corrosion Protection Mass Nontribus MP-2 [1] (grease)	deposited at Deutsches Institut für Bautechnik		
Corrosion Protection Mass Vaseline FC 284 [1] (wax)	deposited at Deutsches Institut für Bautechnik		
Corrosion Protection Mass Denso - Jet [1] (wax)	deposited at Deutsches Institut für Bautechnik		

The technical documentation of the components of this European Technical Approval is deposited at the Deutsches Institut für Bautechnik

[1] corrosion protection mass (wax or grease) according to the composition deposited by the supplier at the Deutsches Institut für Bautechnik. Characteristic material properties shall comply with EAD 160027-00-0301.

ENERCON - Post-tensioning System, type i

Materials and References
Material of Components

Annex D

Codes and References

prEN 10138-3:2009-08	Prestressing Steels – Part 3: Strand
EAD 160004-00-0301:2016-09	European Assessment Document - Post-Tensioning Kits for Prestressing of Structures
EAD 160027-00-0301:2016-09	European Assessment Document – Special Filling Products for Post-Tensioning Kits
EN 523:2003-11	Steel Strip Sheaths for Prestressing tendons
EN 447:1996	Grout for Prestressing Tendons – Basic Requirements
EN 206-1:2001-07	Concrete – Part 1: Specification, Performance, Production an Conformity
EN 206-1/A1:2004-10	Concrete – Part 1: Specification, Performance, Production an Conformity; German Version EN 206-1:200/A1:2004
EN 206-1/A2:2005-09	Concrete – Part 1: Specification, Performance, Production an Conformity; German Version EN 206-1:200/A2:2005
EN 446:1996	Grout for Prestressing Tendons – Grouting procedures
EN 10204:2005-01	Metallic Products – Types of Inspection Documents
EN 10025-2:2005-04	Holt Rolled Products of Structural Steels – Part 2: Technical Delivery Conditions for Non-Alloy Structural Steels
EN 10083-2:2006-10	Quenched and Tempered Steels – Part 2: Technical Delivery Conditions for Unalloyed
CWA 14646:2003-01	Requirements for the installation of post-tensioning kits for prestressing of structures and qualification of the specialist company and its personnel