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European Technical Assessment

ETA 07/0003 of 17/05/2019

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General Part

Technical Assessment Body issuing the European Technical Assessment: Instituto de Ciencias de la Construcción Eduardo Torroja (IETcc)	
Trade name of the construction product	TECPRESA POST-TENSIONING SYSTEM
Product family to which the construction product belongs	Post-tensioning systems for prestressing of structures
Manufacturer	Técnicas del pretensado y servicios auxiliares, S.L. (TECPRESA) c/ Charles Darwing n.º 4 Polígono Industrial Mapfre 28806 Alcalá de Henares, Madrid (SPAIN) www.tecpresa.com
Manufacturing plant(s)	Técnicas del pretensado y servicios auxiliares, S.L. (TECPRESA) c/ Charles Darwing n.º 4 Polígono Industrial Mapfre 28806 Alcalá de Henares (Madrid)
This European Technical Assessment contains	26 pages including 4 Annexes, which form an integral part of this assessment. Annex D contains confidential information and is not included in the European Technical Assessment when that assessment is publicly disseminated
This European Technical Assessment is issued in accordance with Regulation (EU) No 305/2011, on the basis of	EAD 160004-00-0301 Post-tensioning kits for prestressing of structures
This version replaces	ETA 07/0003 issued on 11/05/2017

SPECIFIC PARTS

1. Technical description of the product

1.1 Definition of the construction product

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

TECPRESA POST-TENSIONING SYSTEM

consisting of 1 to 37 strands with nominal tensile strength 1770 MPa or 1860 MPa (Y1770S7 or Y1860S7 according to prEN 10138-3:2009, Table 4), nominal diameter 15.2 mm (0.60" - 139 mm²) and 15.7 mm (0.62" - 150 mm²) used in normal-weight concrete with the following anchorages:

- stressing (active) anchorage, fixed (passive) anchorage with anchor plate, anchor block and fixed couplers for tendons of 1, 4, 7, 9, 12, 15, 19, 25, 31 and 37 strands.

Additional components of the present post-tensioning system are:
- Reinforcement steel in the anchorage zones
- Ducts and connection elements
- Corrosion protection

The anchorage of the strands in wedge plates and couplers is done by means of wedges.

The components of the kit are detailed in the following sections. Figures and further characteristics of components are given in Annex A.

1.2 Strands

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

Table 1: Dimension and properties of 7-wire strands				
European standard	prEN 10138-3[1]			
Designation acc. European standard	Y1770		Y1860	
Tensile strength (MPa)	1770		1860	
Nominal diameter (mm)	15.2	15.7	15.2	15.7
Nominal cross section (mm²)	139	150	139	150
Nominal mass (g/m)	1086	1172	1086	1172
Elongation at maximal force (%)	≥ 3.5			
Relaxation at 1000 hours for initial force $0.70 \cdot f_{ma}$ (%)	≤ 2.5			
Relaxation at 1000 hours for initial force $0.80 \cdot f_{ma}$ (%)	≤ 4.5			
Fatigue behaviour ($0.70 \cdot f_{ma}$; 190 MPa)	$\geq 2 \cdot 10^6$ cycles			
D-value of deflected tensile test (%)	≤ 28			
Modulus of elasticity E_p (MPa)	195 000			

To avoid confusion, only strands with one tensile strength shall be used on one site.

Only strands stranded in the same direction shall be used in a tendon.

[1] prEN 10138-3:2009. Prestressing steels – Part 3: strands.

1.3 Wedges

Wedges (see Annex A) are conical elements consisting of three parts fixed together by a spring ring.

Two types of ring wedges are used. Within one anchorage or coupler, only one type of ring wedge shall be used.
The same wedge is used for 15.2 mm and 15.7 mm nominal diameter strands.

1.4 Anchor blocks and couplers

The TECPRESA anchorages are based in the wedge anchoring principle:

- The tensile element is fitted with anchorages at both ends.
- Strands are anchored by wedges, which seat in the conical holes of the anchor blocks.

Anchorages are said to be “stressing type” when they are designed to allow the performance of stressing operations.

Anchorages are said to be “passive type” or “fixed type” when they are not specifically designed to allow the performance stressing operations. They have a design similar to that of the stressing type, but they have some additional components as protection caps or wedge retention plates.

Couplers are devices designed to connect two tensile elements that are tensioned one after the other in two separate concreting phases.

TECPRESA couplers are fixed couplers. They are initially used as stressing anchorages for one tendon and, later, they are used to connect another tendon as a prolongation of the former one. The coupler will act as passive anchorage for the prolongation tendon. Fixed couplers are not designed to displace during stressing of the prolongation tendon and for this reason the pulling force arriving to the coupler during stressing of the prolongation tendon shall never be larger than the existing compression force at the coupler anchorage, which remains from the former stressing.

Optionally, anchor blocks may be supplied with a special external protection treatment of zinc bi-chromate.

The schematic figures of all the standard TECPRESA anchorages are shown in Annex A.

The set of available TECPRESA anchorages allows using prestressing kits up to 37 strands with nominal ultimate tensile strengths from 248 kN to 10 323 kN.

1.5 Coupler connection cylinder

The coupler connection cylinder connects the active and the passive coupler anchor blocks. For this, it has internal threads where both anchor blocks may be threaded.

The schematic figure of TECPRESA coupler anchor is shown in Annex A.

1.6 Trumpets

Anchor blocks bear on trumpets, which are fixed to the prestressed structure.

TECPRESA trumpets have three basic components:

1.6.1 Bearing plates

The bearing plates are thick and square iron plates with central holes to allow easy crossing of tendon strands.

1.6.2 Conical body

The conical body has been designed to work just as a concrete formwork without resistance requirements. It can be made of thin steel sheaths or plastic materials as HDPE, ABS or similar.

1.6.3 Neck cylinder

The neck cylinder is the element designed to connect the conical body of the trumpet with the duct.

For further definition of trumpets see graphical description in Annex A.

1.7 Ducts and tubes

The TECPRESA System uses the following different types of ducts:

- corrugated steel strip ducts, in accordance with EN 523:2003[2].
- corrugated plastic ducts which met the requirements according to EAD 160004-00-0301 clause 2.2.10 and in accordance with regulations valid at the place of uses can be used.
- smooth steel ducts according to EN 10255[3], ISO 4200[4], EN 10216-1[5] or EN 10217-1[6].
- polypropylene (PP) or polyethylene (PE) ducts PE 80 or PE 100 according to standard EN 12201-2[7].

Steel pipes and plastic ducts and their accompanying boundary conditions of use are not covered by this ETA.

1.8 Grout

The injection products are not basic components of this ETA. Grout according to EN 447:2007[8] or EAD 160027-00-0301[9] shall be used.

1.9 Protection cap

Protection caps are usually made of steel or plastic and fitted by screws.

[2] EN 523:2003. Steel strip sheaths for prestressing tendons – Terminology, requirements and conformity
[3] EN 10255:2004+A1:2007: Non-Alloy steel tubes suitable for welding and threading - Technical delivery conditions.
[4] ISO 4200:1991. Plain end steel tubes, welded and seamless -- General tables of dimensions and masses per unit length.
[5] EN 10216-1:2013. Seamless steel tubes for pressure purposes - Technical delivery conditions - Part 1: Non-alloy steel tubes with specified room temperature properties.
[6] EN 10217-1:2002/A1:2005. Welded steel tubes for pressure purposes - Technical delivery conditions - Part 1: Non-alloy steel tubes with specified room temperature properties.
[7] EN 12201-2:2011+A1:2013. Plastics piping systems for water supply, and for drainage and sewerage under pressure - Polyethylene (PE) - Part 2: Pipes.
[8] EN 447:2007. Grout for prestressing tendons – Specification for common grout
[9] European Assessment Document 160027-00-0301: Special filling products for post-tensioning kits. September 2016. OJEU 2017/C 435/07.

1.10 Reinforcement at the anchorage zones

The required bursting reinforcement for each anchorage model is described in Annex A.

2 Specification of the intended use in accordance with the applicable EAD.

The provisions made in this European Technical Assessment are based on an assumed working life of the TECPRESA kit of 100 years, provided that the conditions for packaging, transport, storage, installation (see Annex C), finally use, maintenance and repair (if necessary) stablished by ETA holder and are met.

The indications given on the working life cannot be interpreted as a guarantee given neither by the product manufacturer nor by EOTA nor by IETcc-CSIC issuing this ETA, but are regarded only as a means for expressing the expected economically reasonable working life of the product.

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

The main characteristics of the TECPRESA System components are summarized and schematically described in Annexes of this European Technical Assessment. More detailed information related to confidential specifications (e.g.: materials, processing, surface finishing, dimensions, tolerances, manufacturing methods and control procedures) is included in the Technical Report submitted by TECPRESA to the IETcc for the assessment of the System. The TECPRESA Technical report has been filed by IETcc with the rest of documentation concerning this ETA and may be available, whenever necessary, to the Notified Body responsible for the assessment and verification of constancy of performance.

3.1 Mechanical resistance and stability (BWR 1)

The assessment of characteristics regarding the mechanical resistance and stability performances deals for the most part with resistance to static loads, effective load transfer to the structure and resistance to fatigue.

The methods for verifying, evaluating and assessing suitability and test procedures comply with those detailed in EAD 160004-00-0301.
Assessment of gathered experience was carried out in conformity to EAD 160004-00-0301.

Table 2 : Essential characteristics of the product regarding BWR1		
Nº	**Essential characteristic**	**Performance**
1	Resistance to static load	The acceptance criterion in EAD 160004-00-0301 clause 2.2.1 is fulfilled: maximum test load ≥ $0.95 \cdot f_{pm}$ and ≥ $0.95 \cdot f_{pk}$; total elongation ≥ 2 %.
2	Resistance to fatigue	The acceptance criteria in EAD 160004-00-0301 clause 2.2.2 are fulfilled: the stress amplitude of 80 MPa of the anchorages and couplers at the maximum load of $0.65 \cdot f_{pk}$ at 2×10^6 load cycles was verified.
3	Load transfer to structure	The acceptance criterion to EAD 160004-00-0301 clause 2.2.3 is fulfilled.
4	Friction coefficient	The acceptance criterion to EAD 160004-00-0301 clause 2.2.4 is fulfilled.

Table 2 : Essential characteristics of the product regarding BWR1		
Nº	**Essential characteristic**	**Performance**
5	Deviation/ deflection (limits) for internal bonded and internal unbonded tendon	The acceptance criterion to EAD 160004-00-0301 clause 2.2.5 is fulfilled.
6	Deviation/ deflection (limits) for external tendon	The acceptance criterion to EAD 160004-00-0301 clause 2.2.6 is fulfilled.
7	Assessment of assembly	The acceptance criterion to EAD 160004-00-0301 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	The acceptance criterion to EAD 160004-00-0301 clause 2.2.13 is fulfilled

No performance assessed for monostrand, since this is not a component of the kit.

3.2 Safety in case of fire (BWR 2)

No performance assessed

3.3 Hygiene, health and the environment (BWR 3)

No performance assessed

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

According to the decision 98/456/EC of the European Commission[10] the System 1+ of assessment and verification of constancy of performances (see EC delegated regulation (EU) No 568/2014 amending Annex V to Regulation (EU) No 305/2011) applies.

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 on IETcc.

Issued in Madrid on 17th May 2019

By

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Nombre de reconocimiento (DN): c=ES, o=CONSEJO SUPERIOR DE INVESTIGACIONES CIENTIFICAS, ou=CERTIFICADO ELECTRONICO DE EMPLEADO PUBLICO, ou=IETCC, ou=52507605, serialNumber=IDCES-52507605P, sn=CASTILLO TALAVERA, givenName=ANGEL, cn=CASTILLO TALAVERA ANGEL - DNI 52507605P
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Director
on behalf of Instituto de Ciencias de la Construcción Eduardo Torroja

[10] Published in the Official Journal of the European Communities L201/112 of 3 July 1998, page 112.
See www.new.eur-lex.europa.eu/oj/direct-access.html)

ANNEX A: Product description

A1 Wedges and anchor block holes

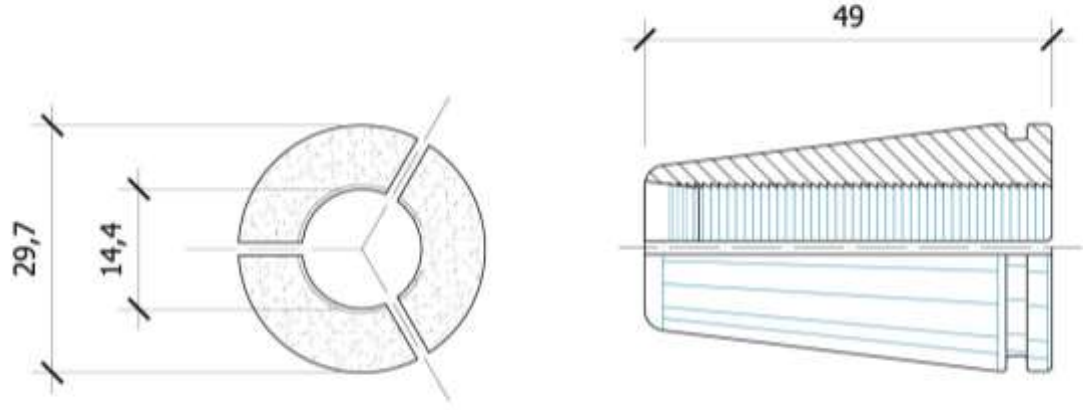

Figure 1. TECPRESA wedge TPEW and TPEW2

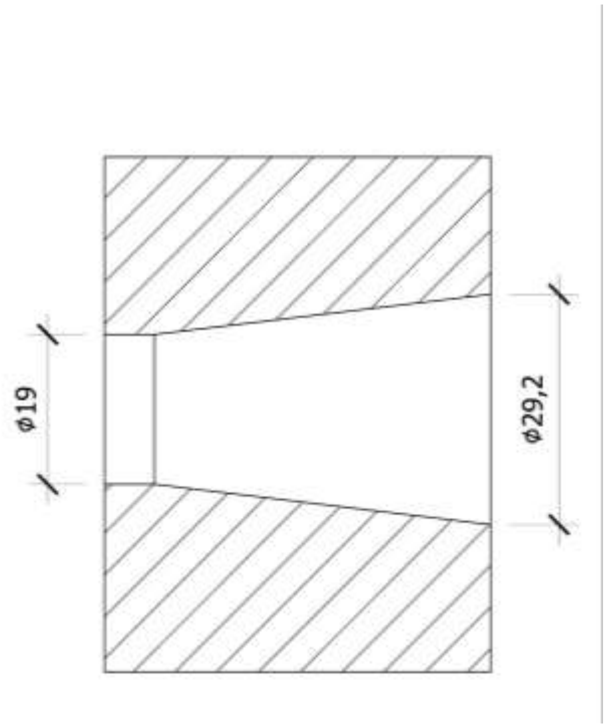

Figure 2. TECPRESA anchor block hole detail

A2 Anchor head typologies

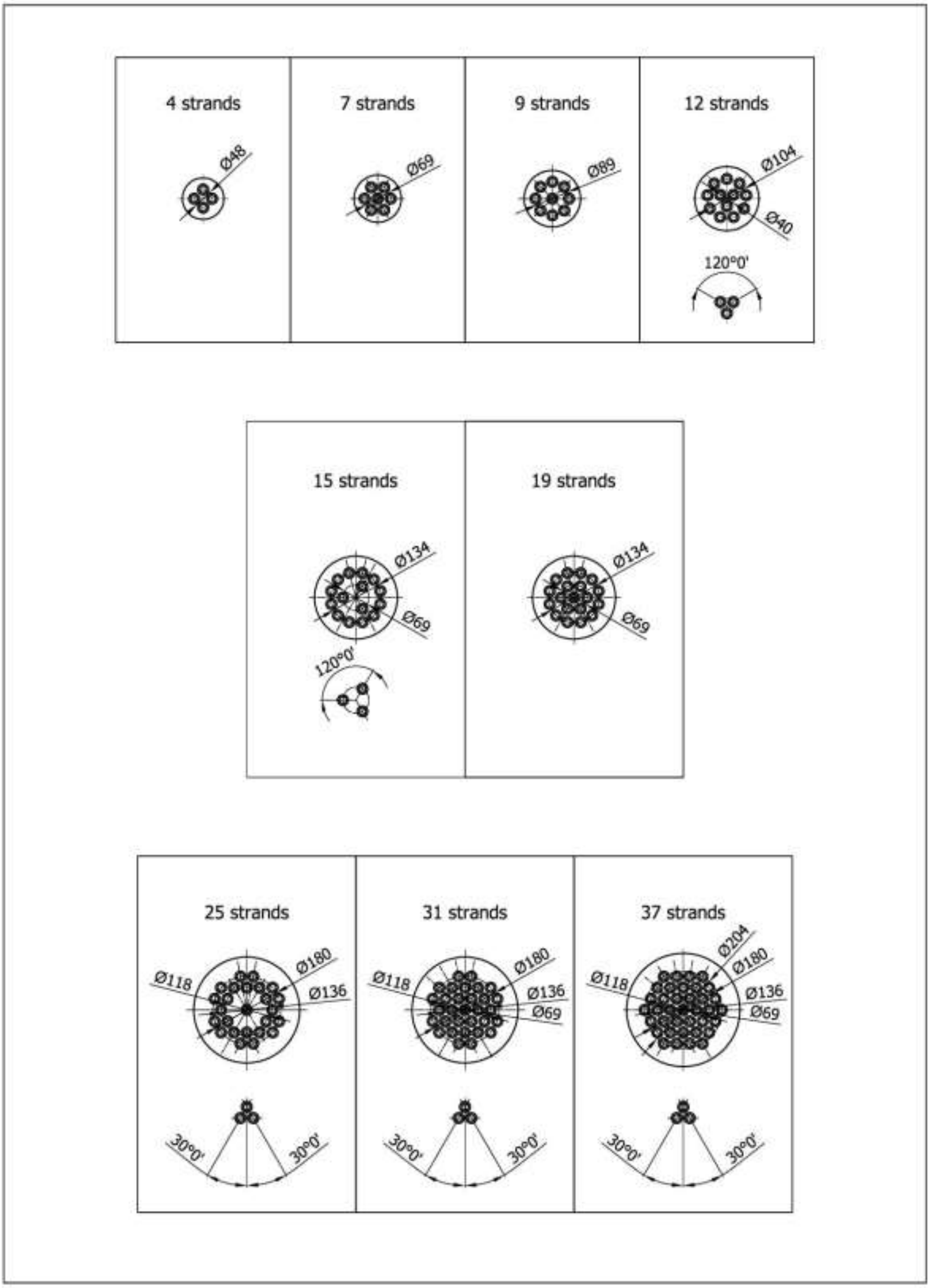

Figure 3. TECPRESA anchor head typologies

In case of partially filled tendons, the position of the strands in the anchor blocks will be selected to keep, if possible, radial symmetry.

A3 Technical data of the anchorages

A.3.1 TPEA stressing anchorages

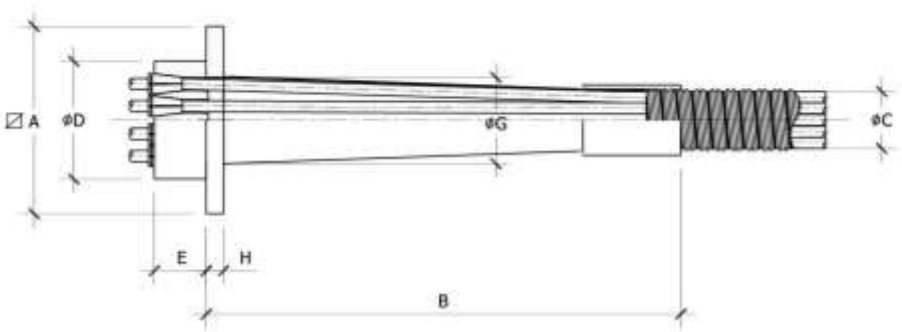

Figure 4. TPEA stressing anchorage

Table A3.1: Main TPEA anchorage dimensions in mm									
Number of strands	***4***	***7***	***9***	***12***	***15***	***19***	***25***	***31***	***37***
A Trumpet bearing plate side	170	200	240	270	300	340	410	440	500
B Trumpet length	325	400	545	685	960	825	1290	1163	1225
H Trumpet bearing plate thickness	15	20	25	25	30	30	45	45	50
G Trumpet bearing plate inner diameter	67	88	108	123	155	155	200	200	224.5
D Anchor block diameter	110	125	150	170	220	220	280	280	300
E Anchor block thickness	65	70	70	78	80	85	95	110	125
C Corrugated steel inner duct diameter	51	65	75	80	90	100	110	120	140
C Corrugated plastic inner duct diameter	58	76	76	85	100	100	115	130	140
C Polymeric duct ext. diameter	63	75	90	90	110	125	125	140	160

All duct dimensions are recommended values for tendons with bare strands. Actual values may vary depending on project requirements.

4-strand anchorage could be used with flat duct with recommended inner dimensions of 72 x 21 mm.

For smooth steel ducts or special projects check with Tecpresa.

A.3.2.1 Required reinforcement in the anchorage zone (Bursting reinforcement) Case I: Concrete strength at stressing f_{cm} = 27.5 MPa

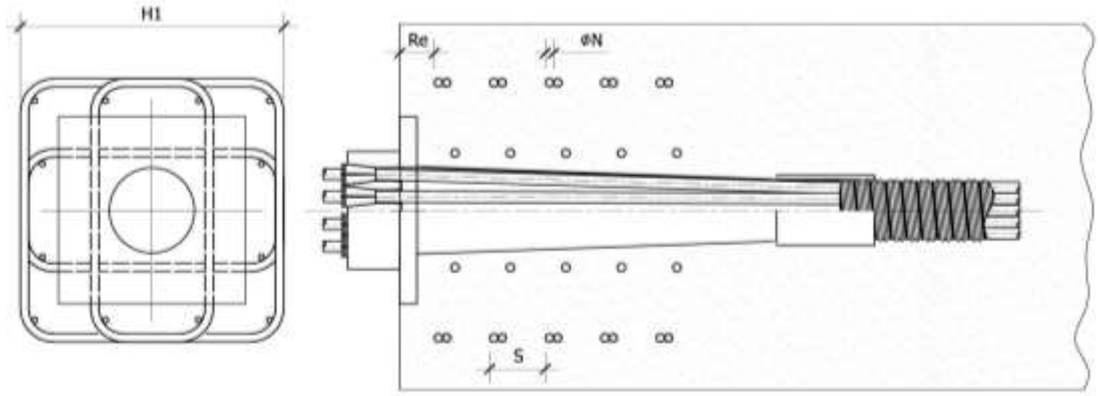

Figure 5. Anchorage bursting reinforcement

Table A3.2.1: Bursting reinforcement case I: Concrete strength at stressing f_{cm} = 27.5 MPa								
Number of strands	***7***	***9***	***12***	***15***	***19***	***25***	***31***	***37***
Reinforcement steel $f_{yk} \geq$	500 N/mm²	500 N/mm²	500 N/mm²	500 N/mm²	500 N/mm²	500 N/mm²	500 N/mm²	500 N/mm²
Reinforcement diameter (mm)	12	12	12	16	16	20	20	20
(N) Number of reinforcement levels	4	4	4	5	5	4	5	6
Dimension of square stirrups (1 per reinforcement level)	290x290	340x340	380x380	430x430	500x500	600x600	640x640	720x720
Dimension of rectangular stirrups (2 per reinforcement level)	290x130	340x155	380x177	430x194	500x220	600x270	640x288	720x320
(Re) Distance between external surface and first stirrup (mm)	50	50	50	50	50	50	50	50
(S) Space between reinforcement levels	75	90	105	90	105	170	140	125
(Dt) Minimum distance between tendons (mm)	290	340	380	430	500	600	640	720
(Dp) Minimum distance from tendon to external surfaces (mm)	$(0.5 \cdot D_t)$ + required minimum concrete cover							

Distances between structure edges and anchorages or between anchorages may be reduced until a 15 % in one direction if they are increased proportionally in the orthogonal direction.

4-strand anchorage does not require bursting reinforcement.

A.3.2.2 Required reinforcement in the anchorage zone (Bursting reinforcement) Case II: Concrete strength at stressing f_{cm} = 40.0 MPa

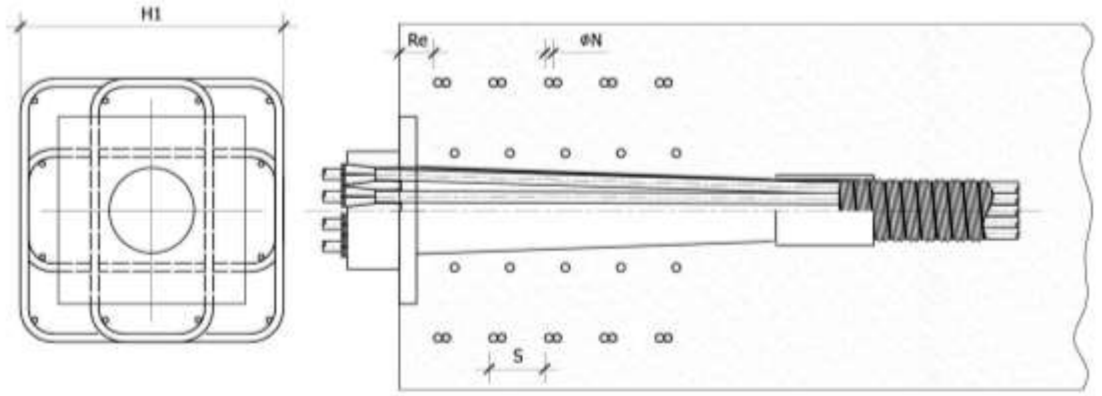

Figure 6. Anchorage bursting reinforcement

Table A3.2.2: Bursting reinforcement case II: Concrete strength at stressing f_{cm} = 40.0 MPa								
Number of strands	***7***	***9***	***12***	***15***	***19***	***25***	***31***	***37***
Reinforcement steel f_{yk} ≥	500 N/mm²	500 N/mm²	500 N/mm²	500 N/mm²	500 N/mm²	500 N/mm²	500 N/mm²	500 N/mm²
Reinforcement diameter (mm)	12	12	12	16	16	20	20	20
(N) Number of reinforcement levels	4	4	5	4	5	5	5	5
Dimension of square stirrups (1 per reinforcement level)	250x250	300x300	330x330	380x380	430x430	520x520	550x550	630x630
Dimension of rectangular stirrups (2 per reinforcement level)	250x120	300x140	330x155	380x195	430x220	520x265	550x280	630x320
(Re) Distance between external surface and first stirrup [mm]	50	50	50	50	50	50	50	50
(S) Space between reinf. levels	60	80	65	100	90	110	115	135
(Dt) Minimum distance between tendons (mm)	250	300	330	380	430	520	550	630
(Dp) Minimum distance tendon to external surfaces [mm]	$(0.5 \cdot D_t)$ + required minimum concrete cover							

Distances between structure edges and anchorages or between anchorages may be reduced until a 15 % in one direction if they are increased proportionally in the orthogonal direction

4-strand anchorage does not require bursting reinforcement.

A.3.3 Passive anchorages (Type TPEPA)

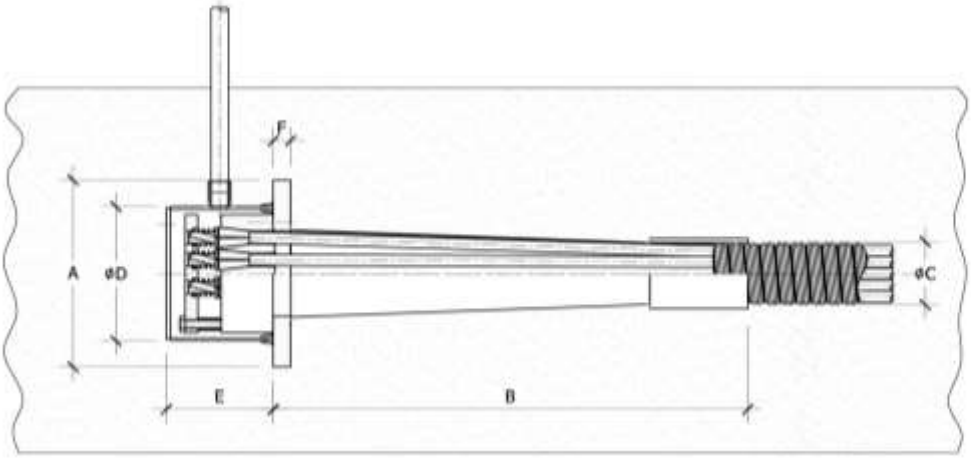

Figure 7. TPEPA passive anchorage

Table A3.4: Main TPEPA passive anchorages dimensions (in mm)									
Number of strands	***4***	***7***	***9***	***12***	***15***	***19***	***25***	***31***	***37***
(A) Trumpet side	170	200	240	270	300	340	410	440	500
(B) Trumpet length	325	400	545	685	960	825	1290	1163	1225
(F) Bearing plate thickness	15	20	25	25	30	30	45	45	50
(D) Protection cap external diam.	124	149	174	194	244	244	316	316	331
(E) Protection cap height	139	144	144	149	154	164	174	191	206

The TECPRESA passive anchorages require the same bursting reinforcement than the active ones (see Tables A3.2 and A3.3 in section A3).

The dimensions of the anchor block are not shown, but they are identical to the ones shown in Figure 4 and Table A3.1.

Duct dimensions are not shown, but they are identical to the ones shown in Figure 4 and Table A3.1.

A.3.4 Coupler anchorages (type TPEC)

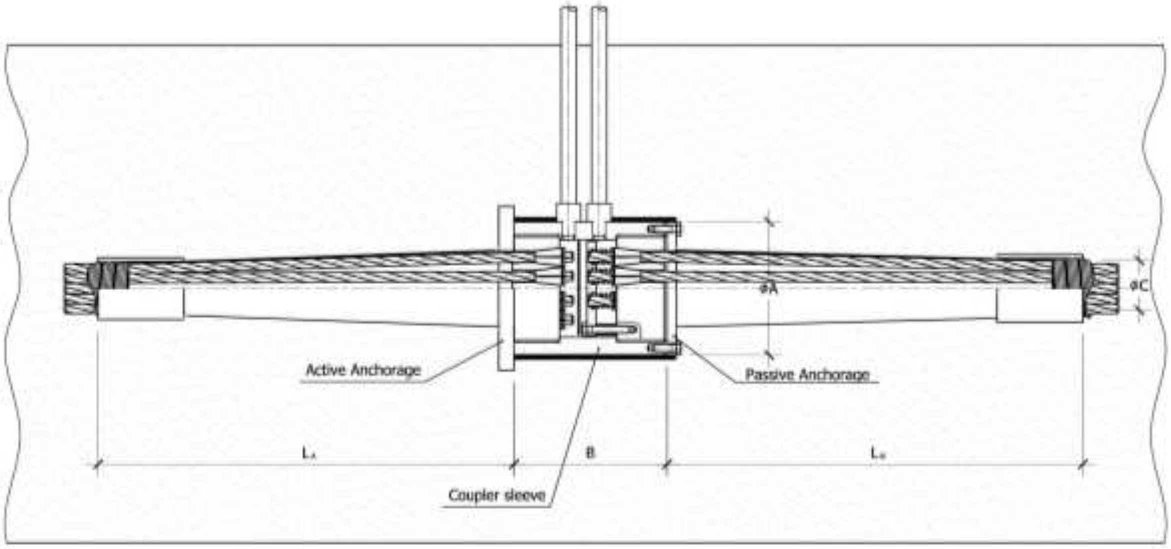

Figure 8. TPEC Coupler anchorage

Table A3.5: Main coupler anchorages dimensions (in mm)									
Number of strands	***4***	***7***	***9***	***12***	***15***	***19***	***25***	***31***	***37***
A Connection cylinder ext. diameter	140	168	190	219	273	273	324	340	390
B Connection cylinder length	221	231	231	247	254	264	285	315	336
$\mathbf{L_A}$ Active trumpet length	325	400	545	685	960	825	1290	1163	1225
$\mathbf{L_B}$ Passive trumpet length	325	400	545	685	960	825	1290	1163	1225

The TECPRESA system requires the installation of bursting reinforcement at the active trumpet side of the coupler. No bursting reinforcement is required at the passive trumpet side.

The required bursting reinforcement is the same as the one required for the stressing anchorages (see section A3.2).

Threaded active and passive blocks have the same thickness than the standard anchorage anchor blocs.

Duct dimensions are not shown, but they are identical to the ones shown in Figure 4 and Table A3.1.

A.3.5 TPEA1 active anchorage for 1 strand.

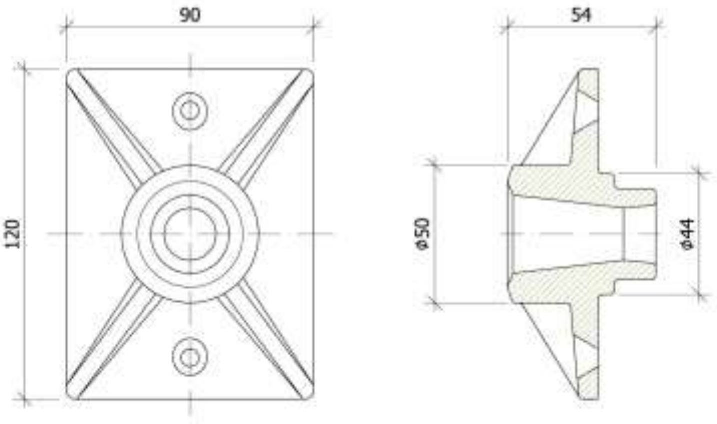

Figure 9: TPEA1 active anchorage for 1 strand 0.6”.

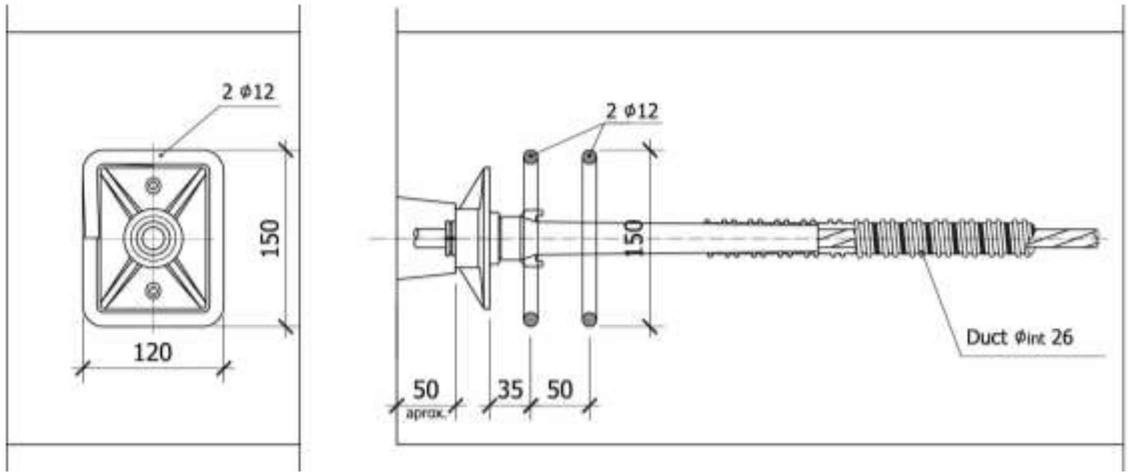

Figure 10: Required reinforcement in the anchorage zone
(concrete strength at stressing f_{cm} = 25 MPa)

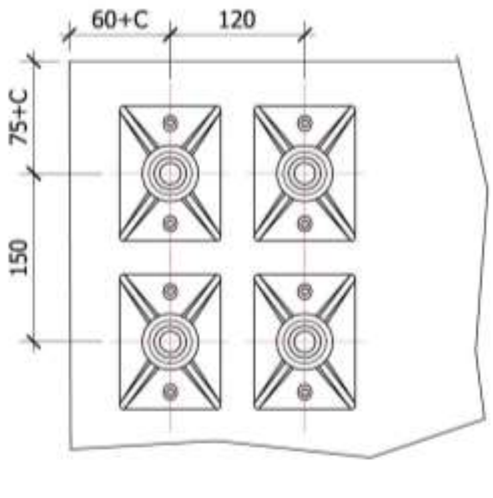

Figure 11: Typical anchorage arrangement

ANNEX B: TECHNICAL CORNERSTONES

B.1 Intended use

The TECPRESA system is intended for use in the prestressing of structures and has the following basic use categories:

- Internal bonded tendon for concrete and composite structures.
- Internal unbonded tendons for concrete or composite structures.
- External tendons for concrete or composite structures

Additionally, the TECPRESA system is also intended for the following optional use categories:

- Restressable tendons.
- Exchangeable tendons.
- Tendons for use in structural masonry construction as internal tendons.

The structural members are to be designed in accordance with National Regulations.

B.2 Forces in prestressing tendons

Tendon stressing force F_0 (force applied to the active anchorage during tensioning) shall not exceed the value $F_0 = A_p \cdot \sigma_{p,max}$.

where

A_p is the nominal cross section of the strand and $\sigma_{p,max}$ is the maximum allowable steel stress during tensioning.

$\sigma_{p,max}$ = minimum value $\{k_1 \cdot f_{pk}\ ,\ k_2 \cdot f_{p0.1k}\}$

The coefficients k_1 and k_2 are 0.8 and 0.9, respectively, according to Eurocode 2, but for certain countries where national provisions are more restrictive. In those cases, more restrictive values for the maximum stressing forces should be applied.

The main characteristics of the strands used by the TECPRESA system are the following:

Table B1: Strand characteristics

Nominal diameter Φ mm	Ultimate guaranteed stress f_{pk} N/mm²	0.1% conv. yield stress $f_{p0.1k}$ N/mm²	Nominal cross section s mm²	Ultimate guaranteed force F_{pk} kN	0.1% conv. Yield force $F_{p0.1k}$ kN	Max. initial prestressing force F_0 $\min\{k_1 \cdot f_{pk}, k_2 \cdot f_{p0.1k}\}$
15.2	1770	1558	139	246	216	195
15.2	1860	1637	139	259	228	205
15.7	1770	1558	150	266	234	210
15.7	1860	1637	150	279	246	221

The characteristic forces of TECPRESA tendons, related to the different types of strands which may be used are shown in the following Tables B2 and B3.

Table B2: Forces in prestressed tendons (Strand Y1860S7)

Number of strands	prEN 10138-3 1860 MPa 0,60" / 15,2 mm			prEN 10138-3 1860 MPa 0,62" / 15,7 mm		
	Nominal cross section s mm^2	Ultimate guaranteed force Fpk kN	Maximum initial prestressing force F_0 kN	Nominal cross section s mm^2	Ultimate guaranteed force Fpk kN	Maximum initial prestressing force F_0 kN
1	139	259	205	150	279	221
2	278	518	410	300	558	442
3	417	777	615	450	837	663
4	556	1036	820	600	1116	884
5	695	1295	1025	750	1395	1105
6	834	1554	1230	900	1674	1326
7	973	1813	1435	1050	1953	1547
8	1112	2072	1640	1200	2232	1768
9	1251	2331	1845	1350	2511	1989
10	1390	2590	2050	1500	2790	2210
11	1529	2849	2255	1650	3069	2431
12	1668	3108	2460	1800	3348	2652
13	1807	3367	2665	1950	3627	2873
14	1946	3626	2870	2100	3906	3094
15	2085	3885	3075	2250	4185	3315
16	2224	4144	3280	2400	4464	3536
17	2363	4403	3485	2550	4743	3757
18	2502	4662	3690	2700	5022	3978
19	2641	4921	3895	2850	5301	4199
20	2780	5180	4100	3000	5580	4420
21	2919	5439	4305	3150	5859	4641
22	3058	5698	4510	3300	6138	4862
23	3197	5957	4715	3450	6417	5083
24	3336	6216	4920	3600	6696	5304
25	3475	6475	5125	3750	6975	5525
26	3614	6734	5330	3900	7254	5746
27	3753	6993	5535	4050	7533	5967
28	3892	7252	5740	4200	7812	6188
29	4031	7511	5945	4350	8091	6409
30	4170	7770	6150	4500	8370	6630
31	4309	8029	6355	4650	8649	6851
32	4448	8288	6560	4800	8928	7072
33	4587	8547	6765	4950	9207	7293
34	4726	8806	6970	5100	9486	7514
35	4865	9065	7175	5250	9765	7735
36	5004	9324	7380	5400	10044	7956
37	5143	9583	7585	5550	10323	8177

Table B3: Forces in prestressed tendons (Strand Y1770S7)

Number of strands	prEN 10138-3 1770 MPa 0,60" / 15,2 mm			prEN 10138-3 1770 MPa 0,62" / 15,7 mm		
	Nominal cross section s mm^2	Ultimate guaranteed force Fpk kN	Maximum initial prestressing force F_0 kN	Nominal cross section s mm^2	Ultimate guaranteed force Fpk kN	Maximum initial prestressing force F_0 kN
1	139	246	195	150	266	210
2	278	492	390	300	532	420
3	417	738	585	450	798	630
4	556	984	780	600	1064	840
5	695	1230	975	750	1330	1050
6	834	1476	1170	900	1596	1260
7	973	1722	1365	1050	1862	1470
8	1112	1968	1560	1200	2128	1680
9	1251	2214	1755	1350	2394	1890
10	1390	2460	1950	1500	2660	2100
11	1529	2706	2145	1650	2926	2310
12	1668	2952	2340	1800	3192	2520
13	1807	3198	2535	1950	3458	2730
14	1946	3444	2730	2100	3724	2940
15	2085	3690	2925	2250	3990	3150
16	2224	3936	3120	2400	4256	3360
17	2363	4182	3315	2550	4522	3570
18	2502	4428	3510	2700	4788	3780
19	2641	4674	3705	2850	5054	3990
20	2780	4920	3900	3000	5320	4200
21	2919	5166	4095	3150	5586	4410
22	3058	5412	4290	3300	5852	4620
23	3197	5658	4485	3450	6118	4830
24	3336	5904	4680	3600	6384	5040
25	3475	6150	4875	3750	6650	5250
26	3614	6396	5070	3900	6916	5460
27	3753	6642	5265	4050	7182	5670
28	3892	6888	5460	4200	7448	5880
29	4031	7134	5655	4350	7714	6090
30	4170	7380	5850	4500	7980	6300
31	4309	7626	6045	4650	8246	6510
32	4448	7872	6240	4800	8512	6720
33	4587	8118	6435	4950	8778	6930
34	4726	8364	6630	5100	9044	7140
35	4865	8610	6825	5250	9310	7350
36	5004	8856	7020	5400	9576	7560
37	5143	9102	7215	5550	9842	7770

B.3 Curvature radii

B.3.1 Radius of curvature for internal bonded and unbounded tendons

According to EAD 160004-00-0301 in case that no national regulation for radii of curvature the following principle applies:

$$R_{min} = \frac{2 \cdot F_{pm0} \cdot d_{strand}}{p_{R,max} \cdot d_{duc,i}} \geq 2{,}50\text{m}$$

Where

R_{min}	minimum radius of curvature in [m]
F_{m0}	Prestressing Force of tendon = 0.85 A_p $f_{p0.1k}$ in [kN]
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).

B.3.2 Radius of curvature for external tendons

According to EAD 160004-00-0301 for determining radii of curvature, the following principle applies:

1.- apply national regulations
2.- refer to values proposed below:

Table B4: Curvature radii for external tendons

Tendons with strands	Minimum radius of curvature at deviator
Up to 12 Φ 15mm	2.5 m
Up to 19 Φ 15mm	3.0 m
Up to 37 Φ 15mm	4.0 m

Interpolation is allowed between sizes given in table

B.4 Concrete strength

Concrete complying with EN 206-1:2001, EN 206-1/A1:2004 and EN 206-1/A2:2005 shall be used. At the time of transmission of the full prestressing force to the concrete member, the mean concrete strength of the normal weight concrete in the anchorage zone shall be at least according to the Annex A3.

For partial prestressing of the full prestressing force, the minimum value of the concrete compressive strength can be interpolated linearly.

B.5 Centre and edge distances of the tendon anchorages, concrete cover

The centre and edge distances of the tendon anchorages shall not be less than the values given in the Annex A3 depending on the actual mean concrete strength.

Distances between tendons may be reduced until 15 % in one direction if proportionally amplified in the correspondent perpendicular direction. However, in no case, these distances may be smaller than the trumpet bearing plate size or the larger dimension of the trumpet bursting reinforcement.

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

The concrete cover under no circumstance will be less than 20 mm nor smaller than the concrete cover of the reinforcement installed in the same cross section.

Standards and regulations on concrete cover valid in place of use shall be considered.

B.6 Load transfer in the structural concrete, reinforcement in the anchorage zone

The large concentration of forces in the anchorage zones requires the placement of appropriate reinforcement. Part of this reinforcement is usually defined by the project designer (surface and general equilibrium reinforcement) which determines it in accordance to standard design procedures, but another part of it, called bursting reinforcement depends directly on the used pretensioning system and, consequently, shall be specified by the post-tensioning system.

Anchorage bursting reinforcement is placed just under the anchorage to make acceptable the very high local stresses appeared at this zone during stressing.

The bursting reinforcement for all TECPRESA anchorage models have been theoretically determined and, in accordance to EAD 160004-00-0301 prescriptions, has been full size tested in the most representative anchorage cases (12/0.6", 19/0.6" and 37/0.6").

Tables A.3.2.1 and A3.2.2 included in Annex A3 show the specified bursting reinforcement for all TECPRESA anchorage models in two concrete strength cases.

Active and passive anchorages have identical bursting reinforcement.

Coupler anchorages may be divided in two parts: the active part and the passive part. Bursting reinforcement shall be installed under the active trumpet of the anchorage coupler. No bursting reinforcement is needed under the passive anchorage trumpet.

The local zone reinforcement specified in the ETA and confirmed in the load transfer test may be modified for a specific project design, if required, in accordance with national regulations and relevant approval of the local authority and of the ETA holder, to provide equivalent performance.

Individual bursting reinforcement arrangements may be adapted to simplify the installation of anchorage families closely positioned (stirrups or longitudinal bars may be shared).

Bursting reinforcement, as any other type of reinforcement, shall not displace during concreting and shall allow correct and homogeneous concreting.

The bursting reinforcement specified in A.3.2.1 and A3.2.2 consider rectangular-shaped stirrups. Spiral stirrups may be used if the conversion is made following the correct design rules.

B.7 Wedge seating at the anchorages

The wedge seating at the anchorages (see section C.4) shall be taken into account in the static calculation and the determination of the tendon elongation.

B.8 Fatigue resistance

With the fatigue tests carried out in accordance with EAD 160004-00-0301, the stress range of 80 MPa of the anchorages and couplers at the maximum load of $0.65 \cdot f_{pk}$ at 2×10^6 load cycles was verified.

B.9 Couplers

When stressing tendons with couplers at their dead, the stressing force shall be controlled and limited to avoid lifting of the coupler from its bearing plate. TECPRESA couplers are fix couplers and do not permit movements after stressing.

B.10 Losses of prestressing force due to friction and wobble effect

The stressing force is introduced at the active or live side of the tendon. The transmission of force from active side to passive side is not complete but there is a certain reduction due to friction between tensile elements and between tensile elements and duct.

The formula, which represents the distribution of the stressing force along the tendon layout, is the following:

$$F(x) = F_0 \cdot e^{-\mu \cdot (\alpha + k \cdot x)}$$

Where

F(x) is the stressing force at the distance x from the stressing side.
α is the cumulated angular deviation from active anchorage (point x=0) until point x.
μ is the friction coefficient over curved lengths expressed in rad^{-1}.
k is the unintentional angular deviation coefficient expressed in rad/m.

The TECPRESA system recommends the following values for the *μ* and *k* coefficients:

Table B5: Friction coefficients μ and k		
Application	**μ (rad^{-1})**	**k (rad/m)**
Internal multistrand tendon with corrugated steel strip sheath	0.17 ~ 0.19	0.005 ~ 0.010
Internal multistrand tendon with plastic sheath	0.12 ~ 0.14	0.005 ~ 0.010
Internal multistrand tendon with smooth steel tube	0.16 ~ 0.24	0.005 ~ 0.010

Values in Table B5 consider no significant corrosion in the strands or ducts and are valid from slightly lubricated tendons (lower range limits) to tendons without lubrication (higher range limits).

Short and fully straight internal tendons may also consider k= 0.

ANNEX C: INSTALLATION

C.1 General

The tendon may be manufactured on the site or in the manufacturing plant (prefabricated tendons). 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 Tecpresa Post-tensioning system.

The company's site manager shall have a certificate of the manufacturer certifying having been instructed by the Manufacturer and has the required knowledge and experience with Tecpresa post-tensioning system. National Standards and regulations valid on site shall be considered.

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

The tendons and the components shall be handled carefully.

C.2 Welding

Prestressing strands and anchorage steel components shall be protected or kept away from welding areas.

C.3 Installation of the tendon

The trumpet shall be aligned perpendicular to the axis of the tendon.

The duct will be fixed to support reinforcement bars each meter along the tendon layout except in large curvature lengths where the duct will be supported each 0.5 meters. The support bars shall assure that duct will have no displacements during installation and concreting.

Trumpet and duct connections shall be sealed, in order to prevent the penetrating of concrete.

C.4 Wedge seating

Active and passive anchorages have the same wedges and they seat proportionally to the applied stressing force.

According to the test results the anchorage wedges seat 5 mm when stressing force is 80 % of tendon ultimate force.

Wedge seating at passive anchorages can be determined as a function of the stressing force reaching them.

The TECPRESA couplers are fix type and consequently they act as active or passive anchorage depending on the stressed tendon side. The wedge seating corresponding to these couplers may, consequently, be assumed as an active or passive anchorage wedge seating.

C.5 Tensioning and stressing records

C.5.1 Tensioning

At time of stressing, the minimum mean concrete strength shall comply with the values given in Annex A3.

Stressing shall strictly follow the TECPRESA procedures and values have to be recorded in the stressing protocol and be compared to the analytical values.

C.5.2 Stressing record

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

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

If during tensioning the difference between measured and calculated elongation or tensioning force is more than 5 % for the sum of all tendons at the cross section or 15 % of the calculated value for a single tendon, then the engineer shall be informed and the causes shall be found.

C.5.3 Prestressing jacks and space requirements. Safety-at-work

For stressing, hydraulic jacks are used. The TECPRESA tendons are designed to be stressed with multistrand jacks, however in some special cases, stressing with monostrand jacks may be permitted.

Stressing jacks shall be calibrated in conformity with TECPRESA procedures, and national regulations of Member States.

To stress the tendons, minimal clearance directly behind the anchorages according to dimensions given by the Manufacturer shall be considered. The minimum straight length for tensioning behind the anchorages (strand protrusion) depends on the jack used on site.

The safety-at-work and health protection regulations shall be complied.

Information about the stressing equipment has been submitted to IETcc.

C.6 Protection of tendons

Permanent protection of prestressing tendons have to be executed as soon as possible after tension is applied.

Injection shall strictly follow the TECPRESA procedures and be made using TECPRESA equipment.

The results of injecting need to be recorded into the grouting protocol.

In case that stressed tendons have to be not injected for long periods of time (more than 4 weeks) temporary protection shall be applied (e.g. protective coating made of water dissolvable oil which does not require removal by water flushing).
Local standards and national regulations valid in place of use shall be considered.

C.6.1 Filling materials

Tendons may be filled with cement grout, wax or grease. The most common filling is the cement grout. Wax and grease filling are used for particular system applications and consequently the injection procedures and equipment will be defined in particular bases.

C.6.1.1 Cement grout

Cement grout is made from three basic products: Portland cement, water and admixtures. These products are mixed in specified proportions and following a specified mechanical mixing process to assure a final stable, uniform grout, which is injected in the post-tensioned tendon ducts.

Cement grout shall be fabricated and tested in accordance to the requirements of the European Standards EN 447[11] and EN 445[12].

Special cement grouts, not cover by EN 447[11] but in accordance to the specifications of EAD 160027-00-0301[13], may also be used.

Grouting procedures shall be carried out in accordance with Standard EN 446[14].

In some cases, due to particular reasons, specialized injection techniques, as "vacuum injection" or "forced secondary injection" may be used.

Vents on the ducts shall be provided at both ends and at the points of the tendon where air or water may accumulate.

In the case of ducts of considerable length, vents or inlets may be required at intermediate positions.

C.6.1.2 Wax

Bitumastic petroleum-based wax may be used to inject some special applications of unbonded internal tendons. Injection wax characteristics shall be in accordance to the requirements of EAD 160027-00-0301[13].

C.6.1.3 Grease

Mineral oil-based greases may be used to inject some special applications of unbounded internal tendons. Injection grease characteristics shall be in accordance to the requirements of EAD 160027-00-0301[13].

[11] EN 447:2007. Grout for prestressing tendons. Specification for common grout.
[12] EN 445:2007. Grout for prestressing tendons. Test methods.
[13] European Assessment Document 160027-00-0301: Special filling products for post-tensioning kits. September 2016. OJEU 2017/C 435/07.
[14] EN 446:2007. Grout for prestressing tendons. Grouting procedures.

C.7 Packaging, transport and storage

Applying temporary protection to prestressing strands and to anchorage steel components is recommended to prevent corrosion during transportation from production factory to job sites.

Transport and handling of prestressing strands and anchorage steel components shall be done in such a manner as to avoid any mechanical, chemical or physical damage. For transport and handling of the strands, the provisions of the strand manufacturer shall be observed.

Prestressing strands and anchorage steel components shall be stored free from humidity. Plastic components and ducts shall be protected from UV radiation.

Prestressing strands and anchorage steel components shall be protected or kept away from welding areas.