MK4

Innovative Solutions

post-tensioning

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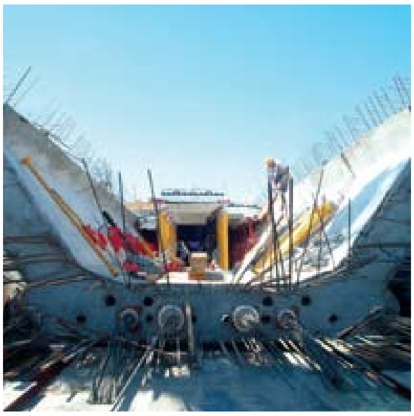
MK4 SYSTEM

Introduction

MeKano4 is specialised company that offers technical solutions for the construction of bridges and structures, by providing to the market a wide product and service range leading quality and services around the world.

Within our scope of activities, there is the design, supply and installation of stay cables, postensioning, bridge bearings and expansion joints for bridges, together with the supply of ground anchors and high tensile bars.

The MK4 postensioning system proposed, includes a gear range of anchorages, accessories and the necessary equipment to respond to the technical requirements for the construction of bridges and other structures.



The design and calculation of all the components were performed according to the new European code ETAG-013, which verification is an obligation in all post tensioning structures built in the European Union.

Our experience in many fields of post-tensioning applications and our team of engineers and technicians are the guarantee for our success and to face new challenges in the structural engineering field. As application, we are providing postensioning and cable stayed solutions for any structure as bridges, buildings, tanks of liquefied gas LNG, silos, covertures, communication towers, nuclear power stations, suspended structures, etc.

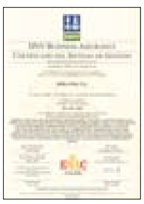
The services provided by MeKano4 include the following aspects:

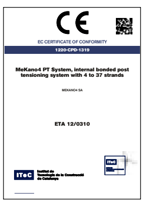
- Technical assistance in all the phases of the project; from the design to the final execution.
- A large range of live end and dead end anchorages and couplers, being always ready for any development or change according to the specifics needs of the project.
- The designed system was successfully tested according to the new European standard ETAG-013 for postensioning systems.
- The possibility to use metallic and PE/PP ducts depending on the project specifications.
- Automatic and lightweight stressing equipment.
- Study of alternative design or construction method as an improvement for the optimum solution for every project.

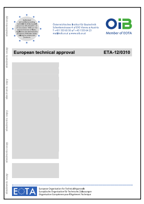
Quality

MeKano4 has developed a complete Quality Assurance Programme conforming to ISO 9001:2000 and according to the requirements of the new European code ETAG-013 for Postensioning, including the design, production, supply and installation of all the required PT works, as anchorages, auxiliary equipment; pushing strands, stressing and injection. By this way, this complete quality system covers all postensioning work performed by MeKano4.

QUALITY SYSTEM CERTIFICATION ISO 9001 DNV





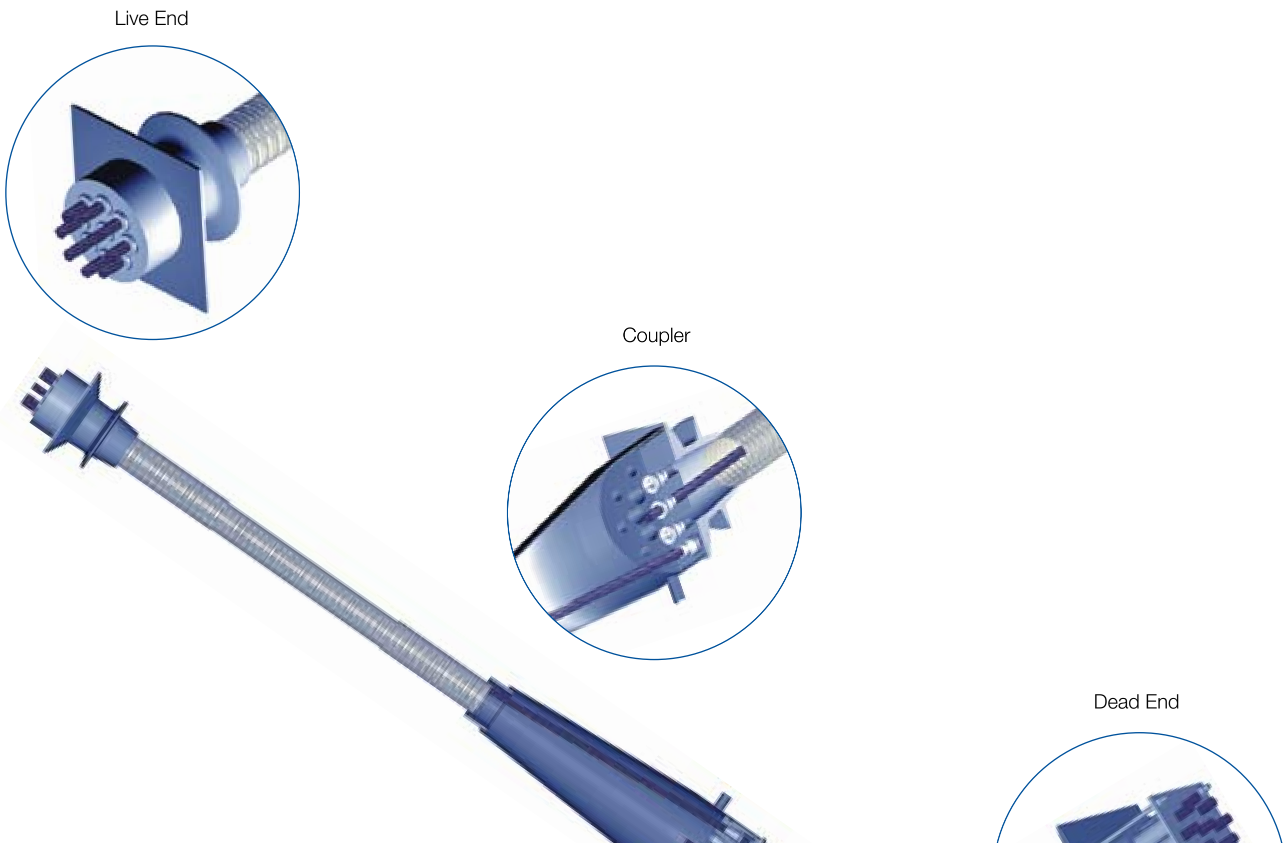


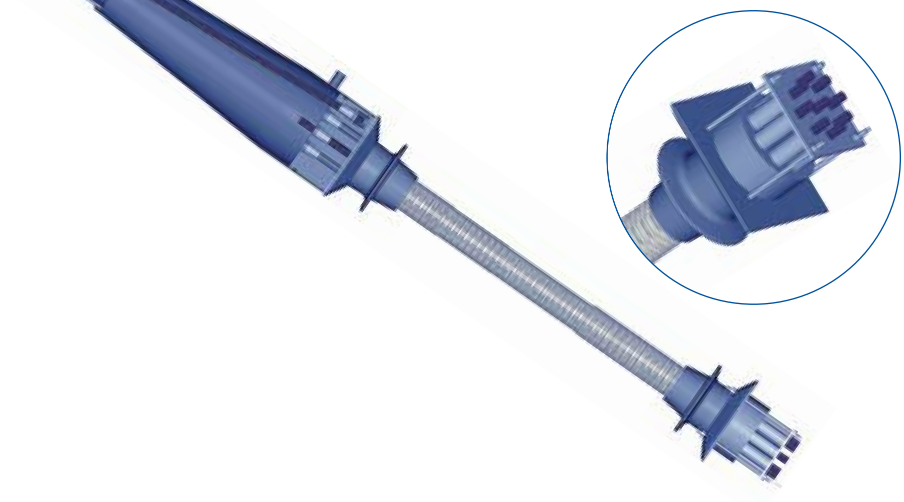
THE STRESSING TENDON

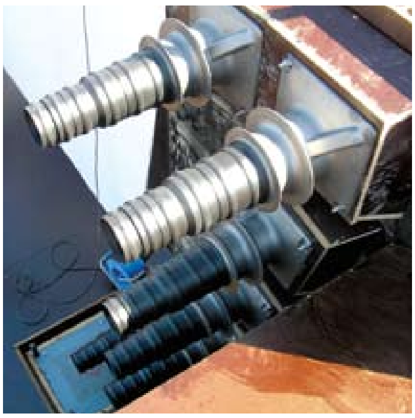
The tendon is the basic element of a post tensioning system. A tendon comprises one or more strands, constrained at both ends by a compact, efficient and easily installed anchorage and encapsulated throughout within a duct.

In the photograph a general scheme is shown of a tendon consisting of two part tendons joined by a coupler.

All tendons can either be pre-assembled and pulled into the duct or the strands pushed individually into the duct with the aid of a strand pusher, before or after concreting to suit the construction sequence. All tendons are stressed with the aid of hydraulic jacks.







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STRANDS

Strands

The strands used for post tensioning tendons are comprised of 7-wires low relaxation steel. The most common diameters are 0.6” (15.2/15.7 mm) and 0.5” (12.7/12.9 mm) corresponding to tensile strengths of 1770/1860 N/mm^2 and 1860 N/mm^2 respectively.

The following table gives the main characteristics of each size of strand.

Strand Type	Standard	F_{pk}	Nominal ø	Cross Section	Weight	Min. Breaking Load F_{pk}	Relaxation 1000h at 70% of F_{pk}	Yield strength 0,1% strain
			mm	mm^2	g/m			
0,6” (15 mm)	EN 10138-3	1860 MPa	15,2	140	1.095	260	2,50%	224
	ASTM A416M-99	270 ksi	15,24	140	1.102	260,7	2,50%	234,6
	BS 5896:1980	1770 MPa	15,7	150	1.180	265	2,50%	225
	EN 10138-3	1860 MPa	16	150	1.170	279	2,50%	250
0,5” (13 mm)	ASTM A416M-99	270 ksi	12,7	98,71	775	183,7	2,50%	165,3
	BS 5896:1980	1860 MPa	12,9	100	785	186	2,50%	158
	EN 10138-3	1860 MPa	13	100	781	186	2,50%	160

Nominal ø	Standard	Initial Post-Tensioning Force P_0 (kN)		
mm		Eurocode 2 85% $F_{p0,1}$ or 75% F_{pk}	EHE 08 75% F_{pk}	BS 5400-4 70% F_{pk}
15,2	EN 10138-3	190,4	195,0	182,0
15,24	ASTM A416M-99	195,5	195,5	182,5
15,7	BS 5896:1980	191,3	198,8	185,5
16	EN 10138-3	204,0	209,3	195,3
12,7	ASTM A416M-99	137,8	137,8	128,6
12,9	BS 5896:1980	134,3	139,5	130,2
13	EN 10138-3	136,0	139,5	130,2

Ducts

Post-tensioned tendons are encapsulated within the deck in a duct which is usually manufactured in corrugated steel (sometimes galvanised) with a wall thickness between 0.3 mm and 0.5 mm. In the table the sizes of the most frequently used ducts can be found.

The ducts are normally supplied in 4-6 m lengths and are coupled on site. Ducts are injected with cementatious grout, wax or other corrosion resistant compounds after stressing.

Strand	Tendon Type	Duct of Tendon	
		Inside ø mm	Outside ø mm
0,5" (13 mm)	4 7	51	56
	9	62	67
	12 15	72	77
	19	85	90
	22	90	95
	27	100	105
	31 35	110	115
0,6" (15 mm)	4 5	51	56
	7	62	67
	9	72	77
	12	85	90
	15	90	95
	19	100	105
	24	110	115
	27 31	120	125
	37	130	137
	43	140	147

HDPE and PP Ducts

For enhanced corrosion protection and fatigue resistance of the tendons, the use of corrugated high strength polyethylene (HDPE) and polypropylene (PP) products is highly recomended. We can supply the following diameters: 59, 76, 100, 115,130 mm. Please contact our technical department for further information.

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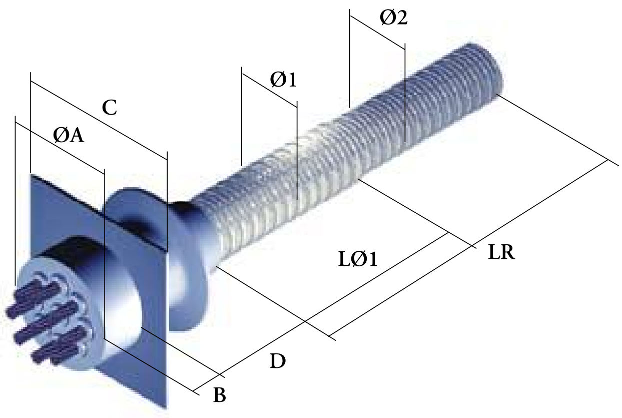
LIVE END ANCHORAGE MSA

Live End Anchorage MSA

All anchorages are designed to the same principles, varying only in size and number of strands. Live End anchorages facilitate the introduction of a post tensioning force in the tendon with the tensioning operations carried out by hydraulic jacks.

The MSA Live End anchorages have been designed to comply with the most deman-ding of international standards such as PTI, BS, etc.

Each basic anchorage consists of a cast trumpet anchor plate and wedges. All the elements of the anchorages and corresponding dimensions have been carefully selected in order to achieve the greatest economy in design. (see table below)



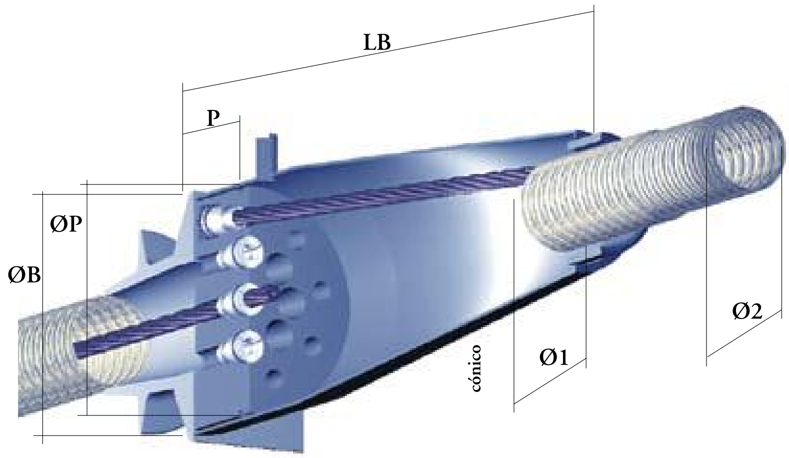
Strand Type	Tendon Type	Trumpet Type	øA	B	C	D	Lø1	LR	ø1	ø2	Min. Curv. Radius
			mm	mm	mm	mm	mm	mm	mm	mm	mm
0,6" (15 mm)	4	T-4	110	50	170	155		600		51/56	3.000
	5	T-4	110	50	170	155		600		51/56	3.000
	7	T-5	129	61	194	150		600		62/67	3.000
	9	T-6	144	60	220	175		900		72/77	4.000
	12	T-7	165	72	254	200		900		85/90	4.000
	15	T-8	186	78	282	235		900		90/95	4.500
	19	T-19	200	94	314	230	250	1.200	103/108	100/105	5.000
	24	TR-24	239	95	356	640		1.200		110/115	5.000
	27	TR-31	252	105	395	720		1.500		120/125	6.000
	31	TR-31	268	115	395	720		1.500		120/125	6.000
	37	TR-37	296	128	444	770		1.500		130/137	6.500
	43	TR-43	330	144	490	1.100		1500		140/147	6.500
0,5" (13 mm)	4	T-4	110	45	170	155		600		51/56	3.000
	5	T-4	110	45	170	155		600		51/56	3.000
	7	T-4	110	45	170	155		600		51/56	3.000
	9	T-5	125	50	194	150		600		62/67	3.000
	12	T-6	143	55	220	175		900		72/77	4.000
	15	T-7	160	60	254	200	500	900	85/90	72/77	4.000
	19	T-8	179	70	282	235	500	900	90/95	85/90	4.000
	22	T-19	192	75	314	230	500	1.200	100/105	90/95	4.500
	27	T-24	227	85	356	640	500	1.200	110/115	100/105	5.000
	31	T-24	233	92	356	640		1.200		110/115	5.000
	35	T-24	239	95	356	640		1.200		110/115	5.000

MULTIPLE COUPLER

Multiple Coupler MCB

An economic range of couplers has been designed for ease of assembly on site. Couplers are used to give continuity to the tendons which due to their length or the construction method used in the project, cannot be installed or tensioned as one unit.

The first-stage of the tendon is stressed and anchored in the normal way and the dead end of the second-stage tendon is then assembled around it.
The complete coupler assembly is enclosed within a conical/cylindrical cover (trumpet) which has a grout inlet.



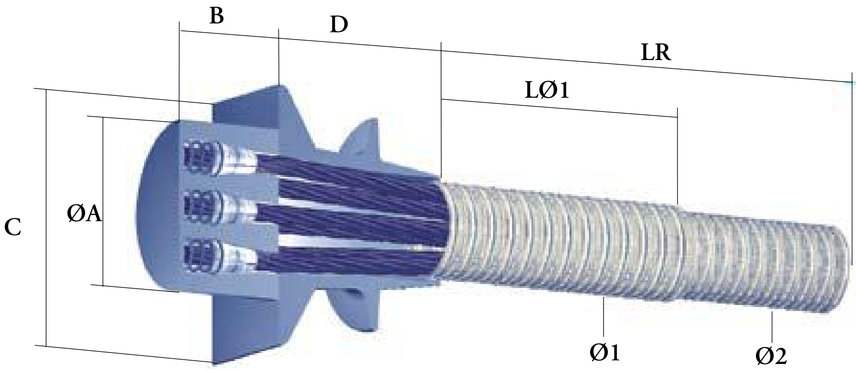
Strand Type		Tendon Type	Trumpet Type	øB	LB	ø1	ø2	øP	P
				mm	mm	mm	mm	mm	mm
0,6" (15 mm)	Conical	4	T-4	140	385	62	51	134	87
0,6" (15 mm)	Conical	5	T-4	156	463	62	51	150	87
0,6" (15 mm)	Conical	7	T-5	188	615	72	62	180	98
0,6" (15 mm)	Conical	9	T-6	208	664	85	72	200	97
0,6" (15 mm)	Conical	12	T-7	252	749	95	85	244	97
0,6" (15 mm)	Conical	15	T-8	270	784	100	90	265	102
0,6" (15 mm)	Conical	19	T-19	274	773	110	100	265	127
0,6" (15 mm)	Cylindrical	24	TR-24	325	1.015	120	110	315	122
0,6" (15 mm)	Cylindrical	27	TR-31	350	1.280	130	120	341	127
0,6" (15 mm)	Cylindrical	31	TR-31	350	1.280	130	120	341	127
0,6" (15 mm)	Cylindrical	37	TR-37	390	1.300	135	130	375	155
0,6" (15 mm)	Cylindrical	43	TR-43	455	1.600	150	140	445	180
0,5" (13 mm)		4	T-4	156	463	62	51	150	87
0,5" (13 mm)		5	T-4	156	463	62	51	150	87
0,5" (13 mm)		7	T-4	156	463	62	51	150	87
0,5" (13 mm)		9	T-5	188	615	72	62	180	97
0,5" (13 mm)		12	T-6	208	664	85	72	200	97
0,5" (13 mm)		15	T-7	252	749	85	72	244	97
0,5" (13 mm)		19	T-8	270	784	95	85	265	102
0,5" (13 mm)		22	T-19	274	773	100	90	265	120
0,5" (13 mm)		27	T-24	325	1.015	110	100	315	122
0,5" (13 mm)		31	T-24	325	1.015	120	110	315	122
0,5" (13 mm)		35	T-24	325	1.015	120	110	315	122

DEAD END ANCHORAGES

Automatic Dead End Anchorage MPA

The unique MK4 Automatic Dead End anchorage MPA is intended to be used at one end of a tendon, the other end being fitted with a live end anchorage MSA.

Its principal characteristic is the automatic retention of the strands by the anchor plate and its primary use is in situations where extrusion grips cannot be fitted satisfactorily due to space limitations.

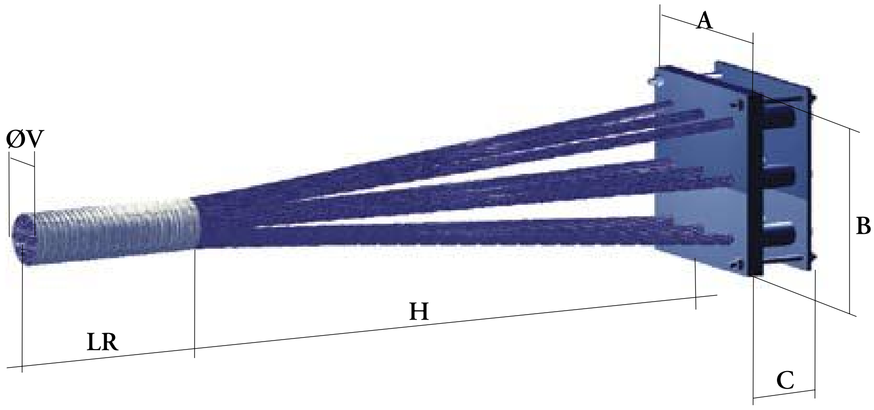


Strand Type	Tendon Type	Trumpet Type	øA	B	C	D	Lø1	LR	ø1	ø2	Min. Curv. Radius
			mm	mm	mm	mm	mm	mm	mm	mm	mm
0,6" (15 mm)	4	T-4	110	88	170	155		600		51/56	3.000
	5	T-4	110	88	170	155		600		51/56	3.000
	7	T-5	129	93	194	150		600		62/67	3.000
	9	T-6	144	93	220	175		900		72/77	4.000
	12	T-7	165	105	254	200		900		85/90	4.000
	15	T-8	186	111	282	235		900		90/95	4.500
	19	T-19	200	128	314	230	250	1.200	103/108	100/105	5.000
	24	TR-24	239	128	356	640		1.200		110/115	5.000
	27	TR-31	252	138	395	720		1.500		120/125	6.000
	31	TR-31	268	148	395	720		1.500		120/125	6.000
	37	TR-37	296	161	444	770		1.500		130/137	6.500
	43	TR-43	330	177	490	1.100		1500		140/147	6.500
0,5" (13 mm)	4	T-4	110	78	170	155		600		51/56	3.000
	5	T-4	110	78	170	155		600		51/56	3.000
	7	T-4	110	78	170	155		600		51/56	3.000
	9	T-5	125	83	194	150		600		62/67	3.000
	12	T-6	143	88	220	175		900		72/77	4.000
	15	T-7	160	93	254	200	500	900	85/90	72/77	4.000
	19	T-8	179	103	282	235	500	900	90/95	85/90	4.000
	22	T-19	192	108	314	230	500	1.200	100/105	90/95	4.500
	27	T-24	227	118	356	640	500	1.200	110/115	100/105	5.000
	31	T-24	233	123	356	640		1.200		110/115	5.000
	35	T-24	239	128	356	640		1.200		110/115	5.000

Semi-bonded Dead End Anchorage MPSB

The anchorage MPSB comprises a bearing plate, extrusion grips and retainer plate. These anchorages are intended to be embedded in the structure and so take advantage of the bond between the strand and concrete.

Where the force has to be transferred to the concrete exclusively via the bearing plate, PE sleeves may be used over the portion of strands between the end of the duct and bearing plate.

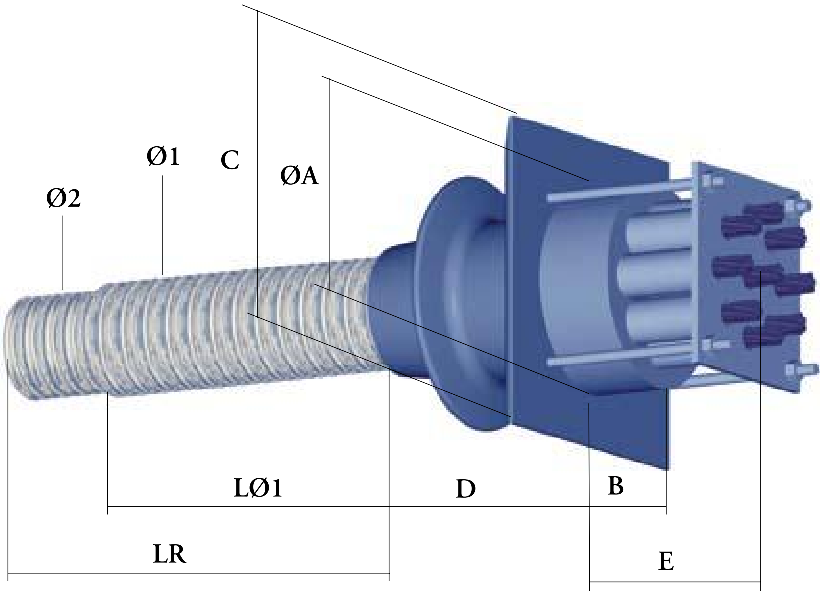


Strand Type	Tendon Type	A	B	C	H	LR	øV	Min. Curv. radius
		mm	mm	mm	mm	mm	mm	mm
0,5" (13 mm)	4	160	160	115	600	600	51/56	3.000
	5	160	240	115	600	600	51/56	3.000
	7	240	240	115	750	600	62/67	3.000
	9	240	240	115	750	900	72/77	4.000
	12	240	320	115	900	900	85/90	4.000
	15	240	400	115	900	900	90/95	4.500
	19	320	400	115	900	1.200	100/105	5.000
0,6" (15 mm)	4	140	140	100	600	600	51/56	3.000
	5	140	200	100	600	600	51/56	3.000
	7	200	200	100	600	600	51/56	3.000
	9	200	200	100	600	600	62/67	3.000
	12	200	260	100	900	900	72/77	4.000
	15	200	330	100	900	900	72/77	4.000
	19	270	330	100	900	900	85/90	4.000
	22	330	330	100	1.200	1.200	90/95	4.500

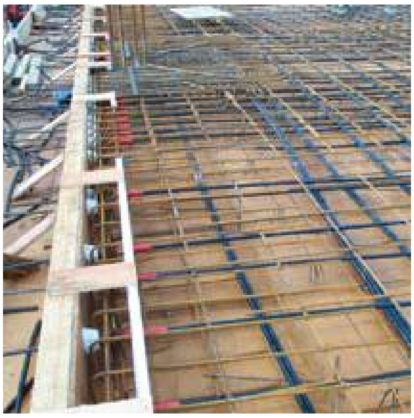
Dead End Anchorage with Extrusion Grip MPT

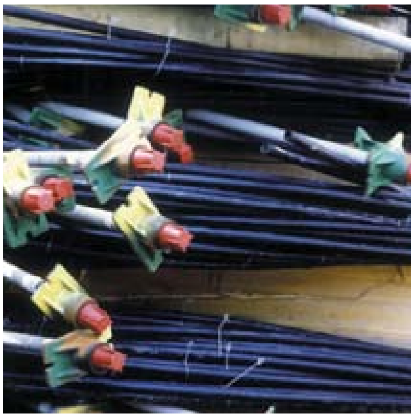
In situations where the anchorages have to be cast into the concrete or are inaccessible, a range of Dead End (Passive) anchorages are provided.

These Dead End anchorages MPT comprise trumpet, anchor plate, extrusion grips and retention plate.



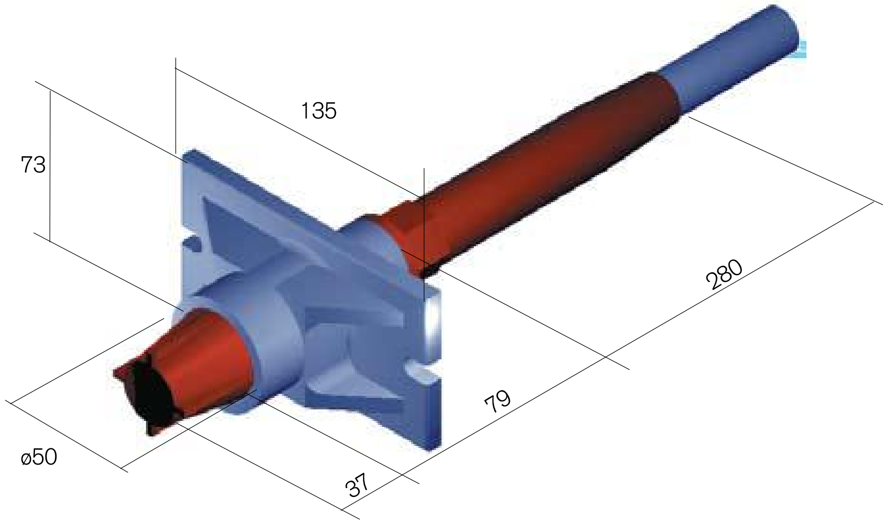
Strand Type	Tendon Type	Trumpet Type	øA	B	C	D	E	Lø1	LR	ø1	ø2	Min. Curv. Radius
			mm	mm	mm	mm		mm	mm	mm	mm	mm
0,6" (15 mm)	4	T-4	110	45	170	155	125		600		51/56	3.000
	5	T-4	110	45	170	155	125		600		51/56	3.000
	7	T-5	129	55	194	150	135		600		62/67	3.000
	9	T-6	144	55	220	175	135		900		72/77	4.000
	12	T-7	165	65	254	200	145		900		85/90	4.000
	15	T-8	186	70	282	235	150		900		90/95	4.500
	19	T-19	200	85	314	230	165	250	1.200	103/108	100/105	5.000
	24	TR-24	239	90	356	640	170		1.200		110/115	5.000
	27	TR-31	252	95	395	720	175		1.500		120/125	6.000
	31	TR-31	268	100	395	720	180		1.500		120/125	6.000
	37	TR-37	296	115	444	770	195		1.500		130/137	6.500
0,5" (13 mm)	4	T-4	110	45	170	155	125		600		51/56	3.000
	5	T-4	110	45	170	155	125		600		51/56	3.000
	7	T-4	110	45	170	155	125		600		51/56	3.000
	9	T-5	125	45	194	150	125		600		62/67	3.000
	12	T-6	143	50	220	175	130		900		72/77	4.000
	15	T-7	160	55	254	200	135	500	900	85/90	72/77	4.000
	19	T-8	179	65	282	235	145	500	900	90/95	85/90	4.000
	22	T-19	192	70	314	230	150	500	1.200	100/105	90/95	4.500
	27	T-24	227	80	356	640	160	500	1.200	110/115	100/105	5.000
	31	T-24	233	85	356	640	162		1.200		110/115	5.000
	35	T-24	239	90	356	640	170		1.200		110/115	5.000





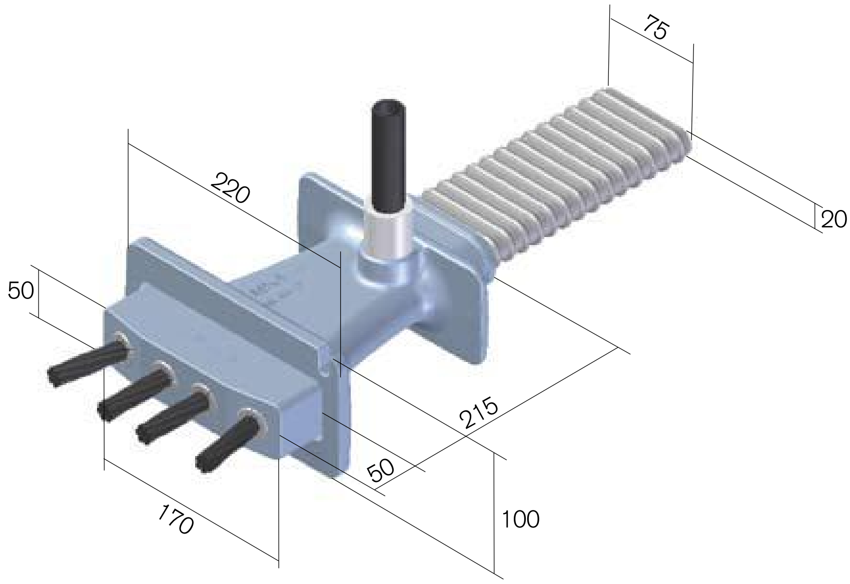
Live End Anchorage MUNB 1/0.6”

The MK4 unbonded mono-strand system uses 15 mm (0.6”) diameter strand and a live end anchorage MUNB 1/0.6” which can also be used as a passive anchorage by incorporating a seal cap and a spring. The strands feature a factory applied corrosion protection system consisting of grease encasement in a polyethylene sheath.



Flat Live End Anchorage ML4/0.6”

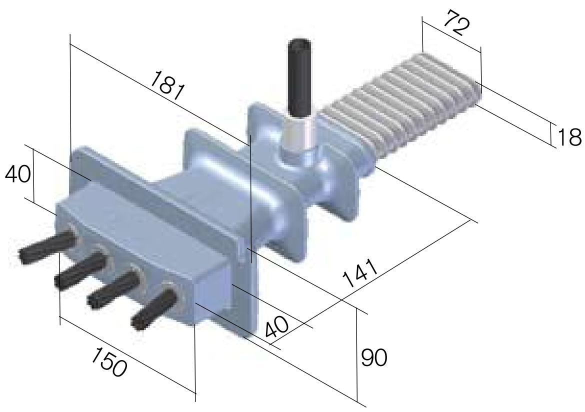
MK4 anchorages for slab post tensioning in buildings, bridge decks and other applications consist of up to 5-strands of 15 mm (0.6”) diameter placed in a flat duct with corresponding anchorages ML4/0.6”. The strands are tensioned and locked off individually using a mono-strand jack.



LIVE END ANCHORAGES FOR SLABS

Flat Live End Anchorage ML4/0,5”

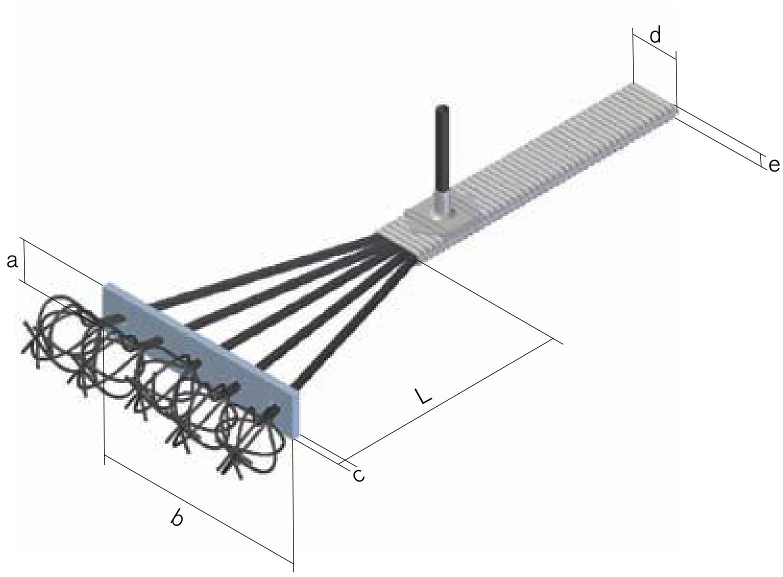
Another anchorage used in the slabs is ML4/0,5”, it has a similar design of ML4/0,6”, but it is for strands of 0,5”. The used duct is of 72×18 mm.



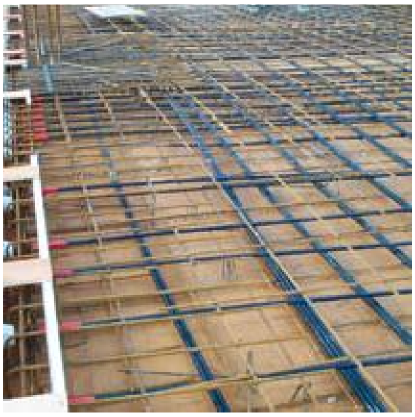
Flat Dead End Anchorage MPC

For the dead end of the flat anchorages ML, we propose the anchorage type MPC, easy to execute and with high efficiency. The anchorage lengths and the dimensions of the plate are indicated in the table.

For more information contact with technical department.



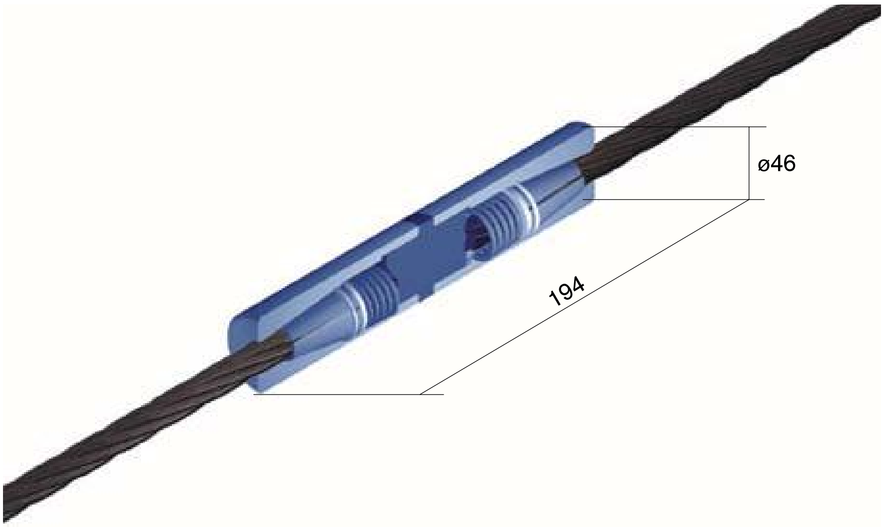
	a	b	c	d	e	L
4/0,5”	50	300	5	75	20	950
5/0,5”	50	375	5	75	20	950
4/0,6”	50	300	5	75	20	950
5/0,6”	50	375	5	95	20	950



Unitary Coupler MCU

The unitary coupler Type MCU is a single strand coupler –its main advantage being that it can be used in a limited work space.

It is an ideal system for bridge decks with limited thickness, where a multiple junction MCB might not fit into the allowable space.



Stressed Unitary Coupler MUT

This Connector/Coupler consists of a twin barrel casting with opposing wedges which serves both as a coupler and a stressing point to which the jack can be applied.

Due to the unique geometry this connector/coupler can be used in applications where another type of coupler will not fit. The MUT unit is primarily used for the tensioning of circular structures such as tanks and silos and stressing is carried out using a mono-strand jack.

MK4 TENDON PROPERTIES

STRAND 0,6”												
Tendon		Strand ø16 mm Y 1860 S7 to EN 10138-3				Strand ø15,24 mm Grade 270 to ASTM A416M-99				Duct	Cement	Jack
Type	Nº of Strands	Breaking Load F_{pk} (kN)	Tens. Force (1) P_0 (kN)	Weight Kg/m	Section mm²	Breaking Load F_{pk} (kN)	Tens. Force (2) P_0 (kN)	Weight Kg/m	Section mm²	Inside ø mm	Kg/ml	
1-0,6”	1	279	204	1,17	150	260,7	195,5	1,102	140			ARROW
4-0,6”	2	558	408	2,34	300	521	391	2,20	280	51	2,6	MS-1
	3	837	612	3,51	450	782	586	3,31	42		2,4	
	4	1.116	816	4,68	600	1.042	782	4,41	560		2,2	
5-0,6”	5	1.395	1.020	5,85	750	1.303	977	5,51	700	51	2,0	MS-2
7-0,6”	6	1.674	1.224	7,02	900	1.564	1.173	6,61	840	62	3,2	
	7	1.953	1.428	8,19	1.050	1.824	1.368	7,71	980		3,0	
9-0,6”	8	2.232	1.632	9,36	1.200	2.085	1.564	8,82	1.120	72	4,3	MS-3
	9	2.511	1.836	10,53	1.350	2.346	1.759	9,92	1.260		4,1	
12-0,6”	10	2.790	2.040	11,70	1.500	2.607	1.955	11,02	1.400	85	6,2	
	11	3.069	2.244	12,87	1.650	2.867	2.150	12,12	1.540		6,0	
	12	3.348	2.448	14,04	1.800	3.128	2.346	13,22	1.680		5,8	
15-0,6”	13	3.627	2.652	15,21	1.950	3.389	2.541	14,33	1.820	90	6,6	MS-4
	14	3.906	2.856	16,38	2.100	3.649	2.737	15,43	1.960		6,4	
	15	4.185	3.060	17,55	2.250	3.910	2.932	16,53	2.100		6,2	
19-0,6”	16	4.464	3.264	18,72	2.400	4.171	3.128	17,63	2.240	100	8,2	
	17	4.743	3.468	19,89	2.550	4.431	3.323	18,73	2.380		8,0	
	18	5.022	3.672	21,06	2.700	4.692	3.519	19,84	2.520		7,8	
	19	5.301	3.876	22,23	2.850	4.953	3.714	20,94	2.660		7,6	
24-0,6”	20	5.580	4.080	23,40	3.000	5.214	3.910	22,02	2.800	110	9,8	MS-6
	21	5.859	4.284	24,57	3.150	5.474	4.105	23,14	2.940		9,6	
	22	6.138	4.488	25,74	3.300	5.735	4.301	24,24	3.080		9,4	
	23	6.417	4.692	26,91	3.450	5.996	4.496	25,35	3.220		9,2	
	24	6.696	4.896	28,08	3.600	6.526	4.692	26,45	3.360		9,0	
27-0,6”	25	6.975	5.100	29,25	3.750	6.517	4.887	27,55	3.500	120	11,4	MS-7
	26	7.254	5.304	30,42	3.900	6.778	5.083	28,65	3.640		11,2	
	27	7.533	5.508	31,59	4.050	7.038	5.278	29,75	3.780		11,0	
31-0,6”	28	7.812	5.712	32,76	4.200	7.299	5.474	30,86	3.920	120	10,8	
	29	8.091	5.916	33,93	4.350	7.560	5.669	31,96	4.060		10,6	
	30	8.370	6.120	35,10	4.500	7.821	5.865	33,06	4.200		10,4	
	31	8.649	6.324	36,27	4.650	8.081	6.060	34,16	4.340		10,2	
37-0,6”	32	8.928	6.528	37,44	4.800	8.342	6.256	35,26	4.480	130	12,8	MS-8
	33	9.207	6.732	38,61	4.950	8.603	6.451	36,37	4.620		12,6	
	34	9.486	6.936	39,79	5.100	8.863	6.647	37,47	4.760		12,4	
	35	9.765	7.140	40,95	5.250	9.124	6.842	38,57	4.900		12,2	
	36	10.044	7.344	42,12	5.400	9.385	7.038	39,67	5.040		12,0	
	37	10.323	7.548	13,29	5.550	9.645	7.233	40,77	5.180		11,8	
43-0,6”	38	10.602	7.752	44,46	5.700	9.907	7.429	41,88	5.320	140	14,7	MS-14
	39	10.881	7.956	45,63	5.850	10.167	7.625	42,98	5.460		14,5	
	40	11.160	8.160	46,80	6.000	10.428	7.820	44,08	5.600		14,2	
	41	11.439	8.364	47,97	6.150	10.689	8.016	45,18	5.740		14,0	
	42	11.718	8.568	49,14	6.300	10.949	8.211	46,28	5.880		13,8	
	43	11.997	8.772	50,31	6.450	11.210	8.407	47,39	6.020		13,5	

(1) P_0 according Eurocode 2 [85% $F_{p0,1}$ or 75% F_{pk}]
(2) P_0 according EHE 08 [75%F_{pk}]
Notes: For compact strands options please contact with our technical departament.

STRAND 0,5”

Tendon		Strand ø13 mm Y 1860 S7 to EN 10138-3				Strand ø12,7 mm Grade 270 to ASTM A416M-99				Duct	Cement	Jack
Type	Nº of Strands	Breaking Load F_{pk} (kN)	Tens. Force (1) P_0 (kN)	Weight Kg/m	Section mm²	Breaking Load F_{pk} (kN)	Tens. Force (2) P_0 (kN)	Weight Kg/m	Section mm²	Inside ø mm	Kg/ml	
1-0,5”	1	186	136	0,78	100	183,7	137,8	0,775	99			ARROW
4-0,5”	2	372	272	1,56	200	367	275	1,55	197	51	2,7	MS-1
	3	558	408	2,34	300	551	416	2,33	296		2,6	
	4	744	544	3,12	400	734	551	3,10	394		2,4	
5-0,5”	5	930	680	3,91	500	918	689	3,88	493	51	2,3	MS-2
7-0,5”	6	1.116	818	4,69	600	1.102	826	4,65	592	51	2,2	
	7	1.302	952	5,47	700	1.285	964	5,43	690		2,0	
9-0,5”	8	1.488	1.088	6,25	800	1.469	1.102	6,20	789	62	3,3	MS-3
	9	1.674	1.224	7,03	900	1.653	1.240	6,98	888		3,1	
12-0,5”	10	1.860	1.360	7,81	1.000	1.837	1.378	7,75	987	72	4,5	
	11	2.046	1.496	8,59	1.100	2.020	1.515	8,53	1.087		4,4	
	12	2.232	1.632	9,37	1.200	2.204	1.653	9,30	1.184		4,2	
15-0,5”	13	2.418	1.768	10,15	1.300	2.388	1.791	10,08	1.283	72	4,1	MS-4
	14	2.604	1.904	10,93	1.400	2.571	1.929	10,85	1.381		3,9	
	15	2.790	2.040	11,72	1.500	2.755	2.067	11,63	1.480		3,8	
19-0,5”	16	2.976	2.176	12,50	1.600	2.939	2.204	12,40	1.579	85	6,0	
	17	3.162	2.312	13,28	1.700	3.122	2.342	13,18	1.678		5,8	
	18	3.348	2.448	14,06	1.800	3.306	2.480	13,95	1.776		5,7	
	19	3.534	2.584	14,84	1.900	3.490	2.618	14,73	1.875		5,6	
22-0,5”	20	3.720	2.720	15,62	2.000	3.674	2.756	15,50	1.974	90	6,4	
	21	3.906	2.856	16,40	2.100	3.857	2.896	16,28	2.072		6,3	
	22	4.092	2.992	17,18	2.200	4.041	3.031	17,05	2.171		6,1	
27-0,5”	23	4.278	3.128	17,96	2.300	4.225	3.169	17,83	2.270	100	8,1	MS-6
	24	4.464	3.264	18,74	2.400	4.408	3.307	18,60	2.369		8,0	
	25	4.650	3.400	19,53	2.500	4.592	3.445	19,38	2.467		7,9	
	26	4.836	3.536	20,31	2.600	4.776	3.582	20,15	2.566		7,7	
	27	5.022	3.672	21,09	2.700	4.959	3.720	20,93	2.665		7,6	
31-0,5”	28	5.208	3.808	21,87	2.800	5.143	3.858	21,70	2.763	110	9,8	
	29	5.394	3.944	22,65	2.900	5.327	3.996	22,48	2.862		9,7	
	30	5.580	4.080	23,43	3.000	5.511	4.134	23,25	2.961		9,5	
	31	5.766	4.216	24,21	3.100	5.694	4.271	24,03	3.060		9,4	
37-0,5”	32	5.952	4.352	24,99	3.200	5.878	4.409	24,80	3.158	110	9,2	
	33	6.138	4.488	25,77	3.300	6.062	4.547	25,58	3.257		9,1	
	34	6.324	4.624	26,55	3.400	6.245	4.685	26,35	3.356		9,0	
	35	6.510	4.760	27,34	3.500	6.429	4.823	27,13	3.454		8,8	

(1) P_0 according Eurocode 2 [85% $F_{p0,1}$ or 75% F_{pk}]

(2) P_0 according EHE 08 [75%F_{pk}]

Notes: For compact strands options please contact with our technical departament.

Multi-Stressing Jacks. MS Series

The MK4 stressing jacks represent the fourth generation in multistressing equipment.

They incorporate innovative developments including compact design, high precision and ease of handling.

The MK4 stressing jacks are essentially centre hole rams of the double acting type with fixed cylinder and moving piston and are designed to work at a pressure of 700 bar.

The jacks internal unit can be rotated thereby facilitating easy alignment with the tendon.

The jacks can be operated in either the standard horizontal position or vertically and features an automatic hydraulic “lock off” device to positively seat the wedges and, thereby, minimise load losses at transfer.

All jacks are calibrated before delivery to site to establish individual force/pressure characteristics.

General Characteristics	ATB-1	ARROW-3	MS-1	MS-2	MS-3	MS-4	MS-6	MS-7	MS-8	MS-14
External Sleeve Diameter (mm)	170	135	317	352	484	559	652	703	754	890
Total Lenght of the jack (mm)	504	991	850	741	742	764	881	903	930	960
Maximum Lenght (mm)	610	1.196	1.150	960	952	966	1.136	1.156	1.185	1.160
Stressing Pressure Area (cm^2)	45,36	40.08	175,93	223,64	433,53	678,56	904,78	1.099,53	1.347,74	2.160,04
Stressing Stroke (mm)	105	205	300	219	210	202	255	253	255	200
Maximum Working Pressure (Bar)	637	605	580	690	700	700	660	600	660	700
Maximum Working Force (kN)	284	256	1.020	1.542	3.033	4.748	5.969	7.254	8.892	15.100
Total Weight (Kg)	18	35	155	275	385	565	820	900	1.010	2.350

MK4 Monostressing Jacks. Arrow Series

The Arrow Jack is primarily designed for the stressing of single strand active anchorages Type MUNB 1/0.6" and Flat Anchorages Type ML. This jack is lightweight (easily manhandable) and incorporates a power lock off to ensure that the wedges are correctly seated inside the barrel, thus preventing the release of the strand under force.

Hydraulic Pumps

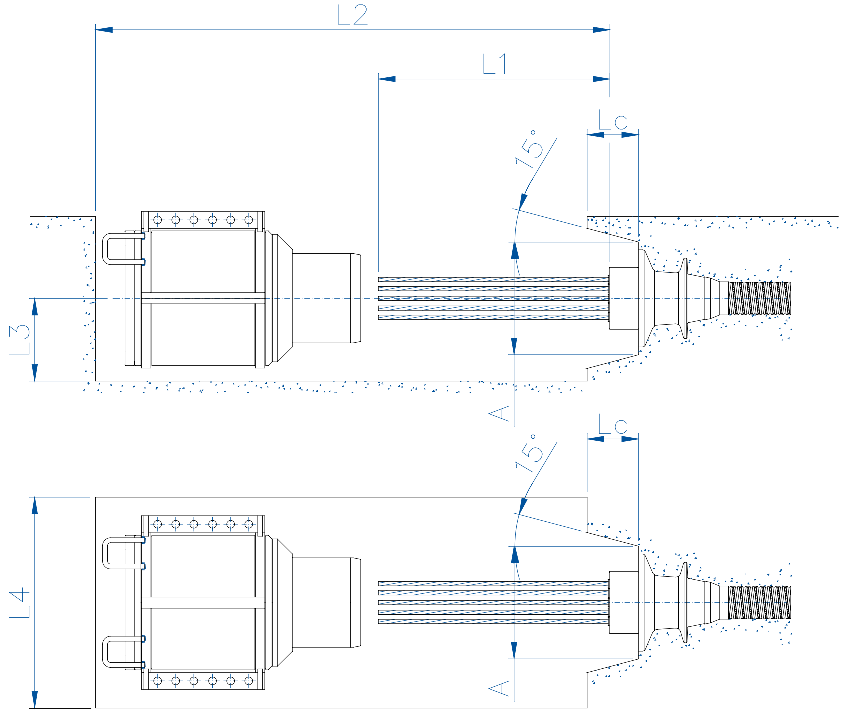
A full range of hydraulic pump equipment and central console units trolley mounted is available.

In addition to the standard hydraulic pump BPT1 used with Arrow Jacks, MS1 and MS2, the new large capacity hydraulic pump BPT11 is available. This pump is intended to be used in tandem with the larger multi-strand jacks and is capable of operating the largest MK4 jack that is currently in production.

General Characteristics	
Oil Delivery	9,51/min
Maximum Oil Working Pressure	700 bar
Weight	400 Kg
Oil	ISO 46 or ISO 68 Hydrailic
Power	11kW 1.450 rpm
Cooling	Air Heat Intercharger
Electric Controls	24 V
Electric Supply	3 phase 380 V + neutral + ground (64 A - 50 Hz)
Dimensions (weight, width, length)	950 mm, 595 mm, 1.050 mm

Blockout Dimensions and Requirments

Attached table showing the block-out dimensions and over-length of strands with the space requirements for location of jacks.



Strand	Tendon Type	L1	L2	L3	L4	A	LC
		mm	mm	mm	mm	mm	mm
0,6" (15 mm)	4	800	1.750	188	410	220	120
	5	800	1.650	200	450	220	120
	7	800	1.650	200	450	244	131
	9	850	1.700	240	580	270	130
	12	850	1.700	240	580	304	142
	15	900	1.750	280	660	332	148
	19	900	1.750	280	660	364	164
	24	1.000	2.000	380	760	406	165
	27	1.000	2.000	380	800	445	175
	31	1.000	2.000	380	800	445	185
	37	1.000	2.100	430	860	494	198
	43	950	2.060	430	1.000	510	210
0,5" (13 mm)	4	800	1.750	188	410	220	115
	5	800	1.750	188	410	220	115
	7	800	1.750	188	410	220	115
	9	800	1.650	200	450	244	120
	12	850	1.700	240	580	270	125
	15	850	1.700	240	580	304	130
	19	900	1.750	280	660	332	140
	22	900	1.750	280	660	364	145
	27	1.000	2.000	380	760	445	155
	31	1.000	2.000	380	760	445	160
	35	1.000	2.000	380	760	445	165

Note: Changes may be made to the information contained in this brochure at any time as new techniques and/or materials are developed.

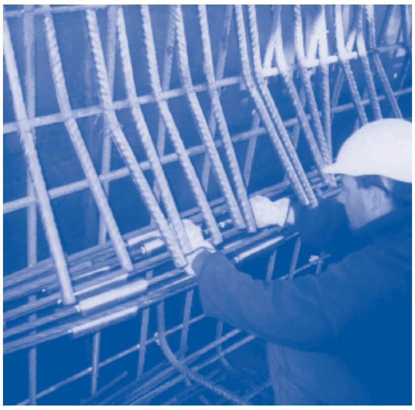
MK4

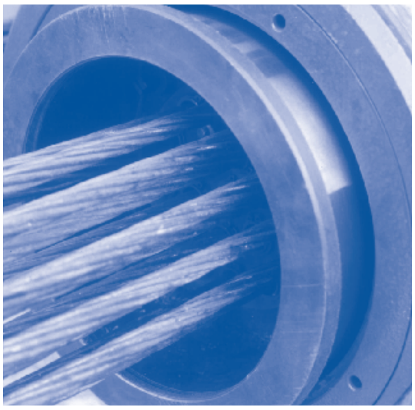
Innovative Solutions

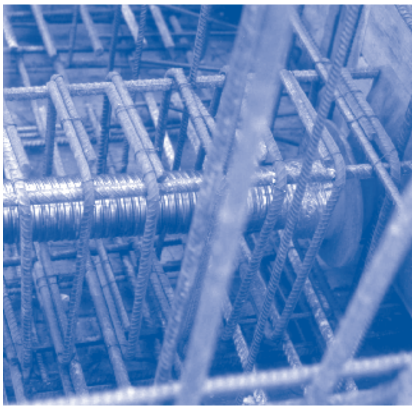
post-tensioning

CALCULATION NOTES

CONTENTS







Introduction

For the design and application of post-tensioned tendons, consideration should be given to factors such as the following:

I •Limitation of the prestressing force
II •Loss of prestress
III •Tendon elongation
IV •Anchor block

The calculation methods that follow meet the requirements of the European Standard. EUROCODE 2 "Project of concrete structures" and the "Post-tensioning Manual" of the PTI (Post-tensioning Institute).

If these notes are used in countries where other standards are applicable a check should be made to ensure that calculations comply with local requirements.

Some paragraphs introduce notes referring to other standards, in this case the name of the standard is indicated.

I. Limitation of the prestressing force

Maximum initial prestress
Immediately after anchoring, the force in the post-tensioned tendon should not exceed the following values:

• EUROCODE-2 The minimum of the following values:
  • 75% of the characteristic strength of the tendon
  • 85% Yield strength (0,1% proof load)

• BS 5400-4 •70% of the characteristic strength of the tendon

Jacking force

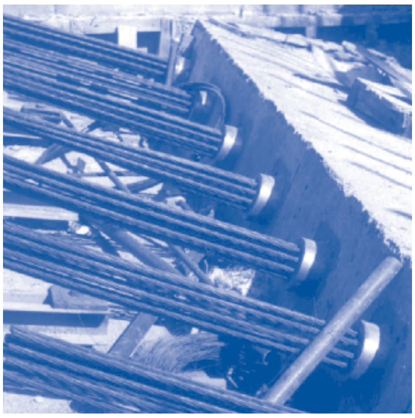
The Jacking force may be increased during stressing over the value of the maximum initial prestress up to the following limits:

• EUROCODE-2 The minimum of the following values:
  • 80% of the characteristic strength of the tendon
  • 90% Yield strength (0,1% proof load)

• BS 5400-4 •80% of the characteristic strength of the tendon

These jacking force maximum values can only be applied temporarily to the tendon. Force in the tendon shall not exceed maximum initial prestress after transfer from the jack to the anchorage.

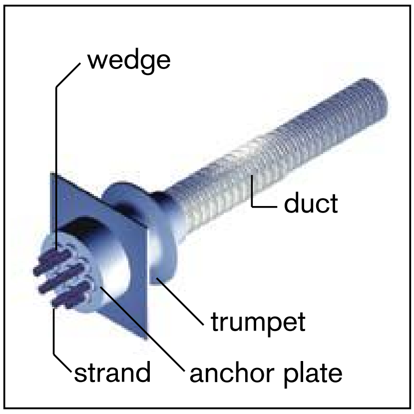
II. Loss of Prestress



The initial post-tensioning force applied to the live anchorage (P_o) is transmitted along the tendon, but decreases as a consequence of instantaneous and long term losses. The effective post-tensioning force (P_x) at each tendon point can be deduced as follows:

$$P_x = P_o - \Delta P_i - \Delta P_{dif}$$

where:
P_x = post-tensioning force at a point located at x meters from the anchorage.
P_o = stressing force o initial post-tensioning force at anchorage (x=0).
ΔP_i = instantaneous post-tensioning losses.
ΔP_{dif} = long term post-tensioning losses.

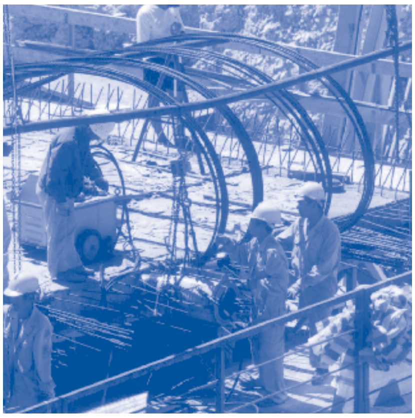


In order to define with accuracy the value of P_o, calibration curves for the equipment (jacks and manometers) shall be provided.

For the instantaneous losses the following parameters have to be considered:
a) Friction of the duct with the tendon.
b) Draw in of the anchorage wedges.
c) Elastic deformation of the concrete.

For long term losses the following need to be considered:
d) Shrinkage of the concrete.
e) Creep of the concrete.
f) Relaxation of the steel.

A. Instantaneous Losses



a) Friction Losses in the Duct

The losses due to friction are calculated in accordance with Coulomb formulae.

$$\Delta P_i = P_o \left(1 - e^{-(\mu\alpha + kx)}\right)$$

where:
μ = coefficient of angular friction (in rad^{-1}).
α = accumulated angular deviation between points 0 and x (radians).
k = Wobble coefficient per unit lenghth of tendon (in m^{-1}).

The friction coefficient depends on various factors such as the condition of the duct inner surface, the condition of the strand external surface and the tendon layout. When $\mu\alpha + kx \leq 0{,}3$ the following approximate linear equation is used:

$$\Delta P_i = P_o \ (\mu\alpha + kx)$$

Friction coefficient		μ (rad^{-1})	k (10^{-3} m^{-1})
Non lubricated tendons	Range Calculation Value	0,21	1,3
Lubricated tendons	Range Calculation Value	0,18	1,1
Unbonded tendons	Range Calculation Value	0,06	0,5

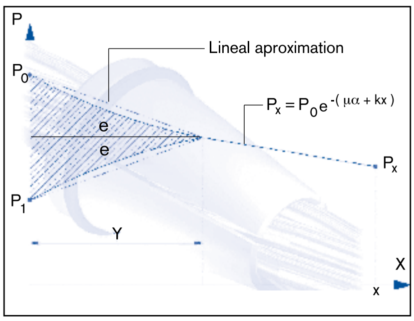
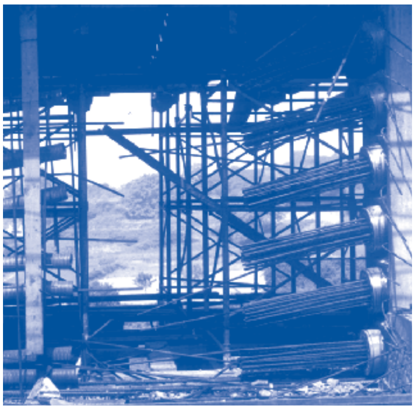
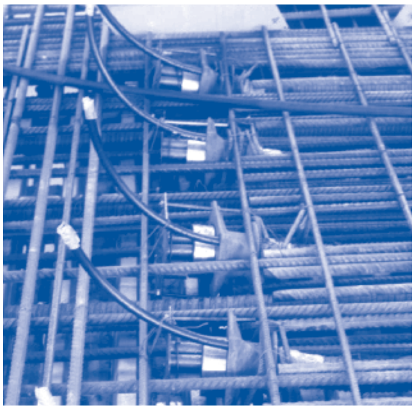


Figure 1





b) Loss of Prestress at Transfer

A loss of prestress occurs when the load is transferred from the stressing jack to the anchorage of the tendon. This loss of prestress during transfer is the result of a shortening of the tendon at transfer due to the draw in of the anchorage wedges, slippage of strand relative to the wedges and the adjustment of the anchorage plate on the trumpet.

After stressing, the wedges are then firmly pushed into its anchorage by the application of a hydraulic wedge seating feature. The jack is then retracted thus transmitting the force of the tendon to the anchorage plate.

As a result of this procedure the wedge still penetrates into the anchorage for several millimetres, until equilibrium of the tension and deformation is achieved. Slippage of the strand and adjustment of anchorage plate are almost negligible. The culmination of all these factors, results in a shortening of the tendon and therefore in a loss of prestressing force, and is referred to as “Draw in of the wedge” amounting between 4 to 6 mm for the MeKano4 prestressing system.

Due to friction losses the loss of prestressing due to draw in of the wedges affects only a certain length of the tendon from a maximum loss at the stressing anchorage till a nil loss at a length “l_a“ from the anchorage.

In the case of short tendons, special attention should be given to the effect of the losses due to the draw in of the wedges, since tension losses due to the same tendon shortening are far higher in this case.

$$l_a = \frac{\alpha E_p A_p}{P_o\,(\mu\alpha + k l_a)}$$

l_a is calculated in an iterative process.

Where:
l_a = Length affected by the draw in of the wedge (m).
α = Draw in of the wedge (4-6 mm) (m).
E_p = Modulus of Elasticity of the prestressing steel (kN/mm^2).
A_p = Area of prestressing tendons (mm^2).

Losses due to draw in of the wedge (P_2) are calculated as follows:

$$\Delta P_2 = 2P_o \left(1 - e^{-(\mu\alpha + k l_a)}\right)$$

c) Loss of Prestress due to Elastic Deformation of Concrete

During the stressing process of the tendons, concrete suffers an immediate elastic shortening due to the compression force that is being introduced. If all tendons of the concrete section are not stressed simultaneously, there is a progressive loss of prestress due to the shortening of the tendons produced by the deformation of the concrete. Assuming that all tendons experience a uniform shortening and are stressed one after the other in a unique operation, losses can be calculated with the following expression:

$$\Delta P_3 = \frac{n-1}{2n}\,\frac{E_p}{E_{cj}}\,A_p\,\sigma_{cp}$$

Where:

σ_{cp}: Concrete compressive stress at the level of the c.o.g. of the tendons due to the post-tensioning force and actuating forces at the stressing moment.

$$\sigma_{cp} = \frac{P_0 - \Delta P_1 - \Delta P_2}{A_c} + \frac{(P_0 - \Delta P_1 - \Delta P_2)e^2 - M_{cp} \cdot e}{I_c}$$

E_{cj}: Modulus of elasticity of the concrete at j days.
e: Eccentricity of the tendon with reference to centre of gravity of the concrete section.
I_c: Second moment of area of the concrete section.
M_{cp}: Maximum moment in the concrete section.
A_c: Area of the concrete section.
n: Number of stressed tendons in the concrete section.
j: Age at application of prestressing force.

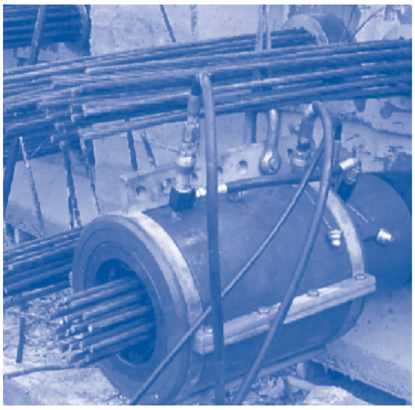
B. Long Term Losses

These prestress losses occur as a result of concrete creep and shrinkage as well as strand steel relaxation.
Long term losses are calculated using the following formula:

$$\Delta P_{dif} = \frac{n\varphi(t,t_0)\,\sigma_{cp} + E_p\varepsilon_{cs}(t,t_0) + 0.80\,\Delta\sigma_{pr}}{1 + n\frac{A_P}{A_c}\left(1 + \frac{A_c y_p^2}{I_c}\right)(1 + x\,\varphi(t,t_0))} A_P$$

Where:

n: Ratio between modulus of elasticity of the prestressing steel and the modulus of elasticity of the concrete: E_p/E_c
$\varphi(t,t_0)$: Creep coefficient at the time of tensioning the tendons.
σ_{cp}: Concrete compressive stress at the level of the c.o.g. of the tendons due to the post tensioning force, dead load and superimposed dead load.
ε_{cs}: Strain due shrinkage of the concrete.
Assumed as approximate value: ε_{cs} = 0.4 mm/m at time infinite.
σ_{pr}: Stress due to the steel relaxation:



$$\Delta\sigma_{pr} = \rho_f \frac{P_0 - \Delta P_1 - \Delta P_2 - \Delta P_3}{A_p}$$

ρ_f: Relaxation value of prestressing steel at time infinite.
Assumed as approximate values: ρ_f = 0,029 at 60% of GUTS
ρ_f = 0,058 at 70% of GUTS
(GUTS – guaranteed ultimate tensile strength of prestressing steel)
y_p = e: Distance between the centre of gravity of the concrete section and centre of gravity of the prestressing tendons.
x = 0,8: coefficient of concrete age.
M_{cp}: Moment due to dead load and superimposed dead load in the concrete section.

III. Tendon elongation

Stressing operation of tendons is carried out in a controlled process where elongation and gauge pressures are measured at all steps.

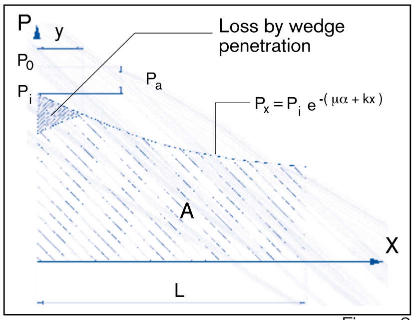


Figure 2

The final elongation of a tendon, obtained by in situ calculation, is compared to the theoretical elongation value in order to check if the result is acceptable.
The elongation of a post-tensioned tendon is assumed to be linear and is calculated with the use of the Hooke's Law.

$$\Delta l = \varepsilon \cdot l = \frac{\sigma_s\, l}{E_p}$$

Where:
Δl: Tendon elongation.
l: Length of the tendon.
$\varepsilon \cdot l$: Tendon strain per unit of length.
σ_s: Prestressing steel tensile stress ($\sigma_s = P/A_p$).

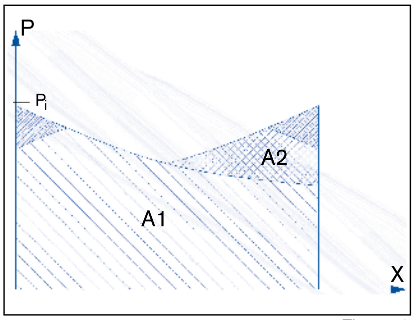


Figure 3

Due to the post tensioning losses, the elongation is given as a function of the force exerted on every section of the tendon.

$$\Delta l = \int_o^l \frac{\sigma_s}{E_p}\, dx$$

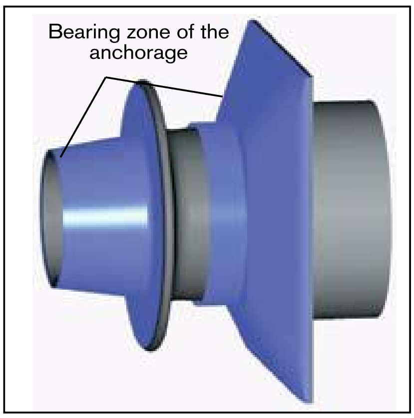
The elongation is proportional to the area under the curve of the post-tensioning force applied on the tendon (refer to figure 2).

$$\Delta l = \frac{1}{A_p\, E_p} \int_o^l P_x\, dx$$

Where:
l: Length of the tendon.
P_x : Prestressing force at section "x" (Jacking force minus friction losses).

If the tendon has two live end anchors, it can be post-tensioned from both ends and thus the elongation of the tendon is now proportional to the area under the graph of both post tensioning forces applied at both ends of the tendon, i.e. proportional to area A1+A2 (refer to figure 3).

IV. Anchor block



The anchor block is defined as the highly stressed zone of concrete around the two end points of a post tensioned tendon. It extends from the tendon anchorage to that section of the concrete at which linear distribution of stress is assumed to occur over the whole cross section.

For the design of the anchor blocks it is convenient to consider and check two different kind of stresses and forces that are produced around the prestressing anchorage:

a) bearing stresses.
b) bursting tensile forces.

Checking the bearing stresses will help to determine if the type of anchorage that has been chosen is valid and if the concrete compressive stress is acceptable.

Checking the bursting tensile forces will be necessary to evaluate the required anchorage bursting reinforcement.

A. Bearing Stresses

The force that is transmitted through the bearing zone of the anchorage to the end block produces a high concrete compressive strength that can be evaluated as follows:

$$\sigma_c = \frac{P}{A_b}$$

Where:
P: Force applied on the anchorage.
A_b: Bearing area of the anchorage.

The bearing area for the different trumpets of the MK4 system anchors is as listed in the following table.
The compression tension in the bearing zone of the anchorage should be checked at two different stages:

- At transfer load (Jacking force).

$$\sigma_{co} = \frac{P_o}{A_b}$$

P_o: Maximum Jacking force applied to the anchorage at stressing.
A_b: Bearing area of the anchorage.
σ_{co}: Concrete compressive stress at transfer load.
σ_{co} should not exceed the lowest of the following two values of cpo (permissible compressive concrete stress at transfer load).

$$\sigma_{co} \leq \sigma_{copo} = 0.8 f_{ci} \sqrt{\left(\frac{A'_b}{A_b} - 0.2\right)}$$

$$\sigma_{co} \leq \sigma_{copo} = 1.25 f_{ci}$$

Where:
f_{ci}: Concrete compressive strength at the time of stressing.
A'_b: Area of the anchor block - Maximum area of concrete concentric with the anchorage and limited by the concrete borders of the section or another anchor block.

- At service load

$$\sigma_{cs} = \frac{P_s}{A_b}$$

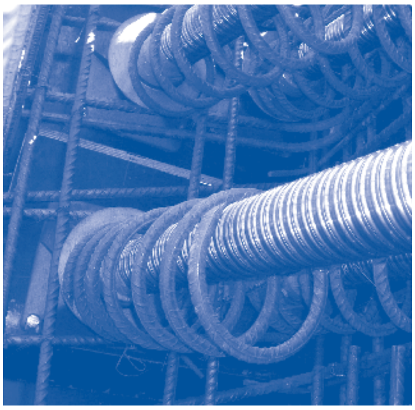
σ_{cs}: Concrete compressive stress at service load.
P_s: Prestressing force of the post-tensioned tendon at service.

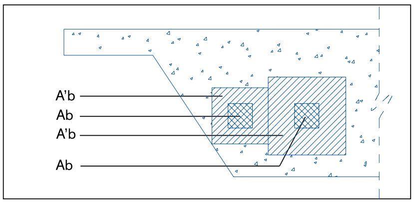
Service load can be calculated deducting all type of prestress losses from the initial force at the anchorage zone.

Assumed Service load: 80% of the jacking force.

σ_{cs} should not exceed the lowest of the two following values of σ_{cps} (permissible compressive concrete stress at transfer load).

Anchorage Type		Anchorage Bearing Area
0,6" (15 mm)	0,5" (13 mm)	cm^2
	4/0,5"	328
	5/0,5"	328
4/0,6"		328
	7/0,5"	328
5/0,6"		328
	9/0,5"	454
7/0,6"		454
	12/0,5"	582
9/0,6"		582
	15/0,5"	778
12/0,6"		778
	19/0,5"	981
	22/0,5"	1.218
15/0,6"		981
	27/0,5"	1.561
19/0,6"		1.218
	31/0,5"	1.561
	35/0,5"	1.561
24/0,6"		1.561
27/0,6"		2.050
31/0,6"		2.050
37/0,6"		2.487
43/0,6"		2.822

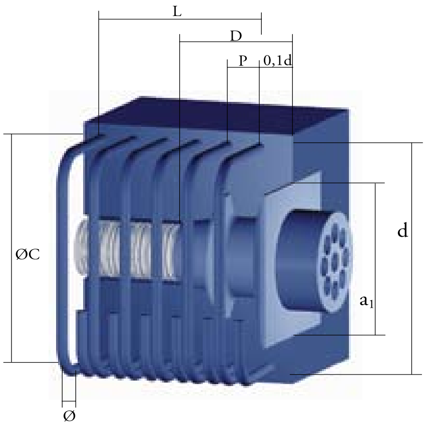




$$\sigma_{cs} \leq \sigma_{cps} = 0.6 f_c \sqrt{\left(\frac{A'_b}{A_b}\right)}$$

$$\sigma_{cs} \leq \sigma_{cps} = 1.25 f_c$$

Where:
fc: Characteristic concrete compressive strength.



B. Bursting Tensile Forces

In the anchor block some severe transversal tensile forces appear that should be absorbed by steel reinforcement. These bursting tensile forces are produced from the curvature of the force line and are originated at the bearing zone of the anchorage where the force lines divert until they reach a uniform distribution.

Figure 6 shows the distribution of stresses due to the bursting tensile force, perpendicular to the centre line of the tendon.

To determine the value of the bursting tensile forces the following formula can be used.

$$f_s A_s = Z = 0.25 P_o \left(1 - \frac{\Omega a_l}{d}\right)$$

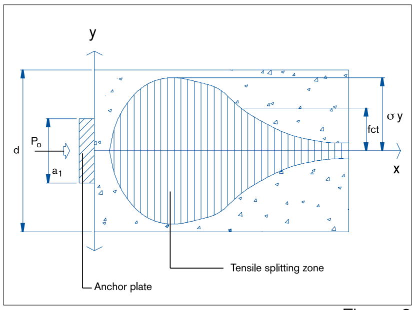


Figure 6

Where:
z: Total bursting tensile force.
f_s: Design strength for the bursting reinforcement.
Assumed design strength:
400 N/mm^2* (for 500 N/mm^2 Yield load Steel).
A_s: Area of steel required for the bursting reinforcement.
P_o: Maximum jacking force at stressing.
Ω: Shape factor.
Assumed shape factors:
Ω=1 for anchors with a unique bearing plate without ribs.
Ω=0,93 for MeKano4 anchors with ribs.

*Note: Besides limiting the design strength for the bursting reinforcement to a maximum of 80% of the yield load, it is also convenient to limit the stress to a value corresponding to a steel strain of 0.002. This last limit has to be reduced to a steel strain of 0.001 on areas where the concrete cover is less than 50 mm.

Anchorage bursting reinforcement for the MK4-MS anchors is listed in the following table. To prepare the table following assumptions have been made:

Prestressing force = 85% of the characteristic strength of the tendon.
Ratio between anchorage upper plate side and anchor block side (a_1/d) = 0.5.
Concrete compressive strength: 28 N/mm^2 (Cylindrical test sample)

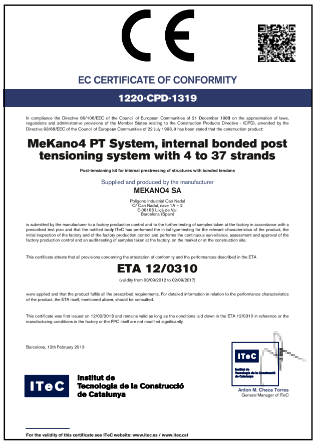
CALCULATION NOTES

Anchorages		Trumpet	a_1	D	L	P	øC	cir.	ø
15 mm	13 mm		mm	mm	mm	mm	mm	units	mm
	4/0,5"	T-4	170	155	240	80	210	4	10
	5/0,5"	T-4	170	155	240	80	210	4	10
4/0,6"		T-4	170	155	240	80	210	4	12
	7/0,5"	T-4	170	155	240	80	210	4	12
5/0,6"		T-4	170	155	240	60	210	5	12
	9/0,5"	T-5	194	150	285	95	260	4	14
7/0,6"		T-5	194	150	280	70	260	5	14
	12/0,5"	T-6	220	175	320	80	310	5	14
9/0,6"		T-6	220	175	325	65	310	6	14
	15/0,5"	T-7	254	200	360	90	350	5	16
12/0,6"		T-7	254	200	375	75	350	6	16
	19/0,5"	T-8	282	235	400	80	400	6	16
	22/0,5"	T-19	314	230	440	110	440	5	20
15/0,6"		T-8	282	235	420	60	400	8	16
	27/0,5"	TR-24	356	520	510	170	500	4	25
19/0,6"		T-19	314	230	450	90	440	6	20
	31/0,5"	TR-24	356	520	510	170	500	4	25
	35/0,5"	TR-24	356	520	500	125	500	5	25
24/0,6"		TR-24	356	520	500	125	500	5	25
27/0,6"		TR-31	395	570	575	115	560	6	25
31/0,6"		TR-31	395	570	570	95	560	7	25
37/0,6"		TR-37	444	670	630	90	620	8	25
43/0,6"		TR-43	490	1.100	720	80	680	10	25

Note: a_1/d=0,5 Concrete compressive strength=28 N/mm^2

If the value of a_1/d is not equal to 0.5 and the concrete compressive strength is different to 28 N/mm^2, the bursting reinforcement listed on the table does not apply and a new bursting reinforcement for the anchorage should be calculated.

Note: Changes may be made to the information contained in this brochure at any time as new techniques and/or materials are developed.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1220-CPD-1319
MeKano4 PT System, internal bonded post tensioning system with 4 to 37 strands
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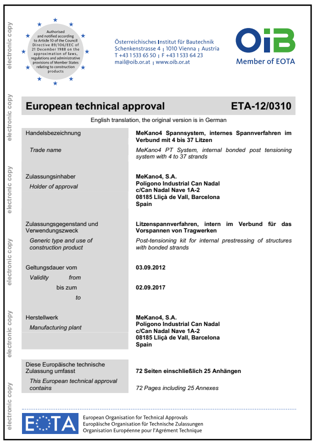
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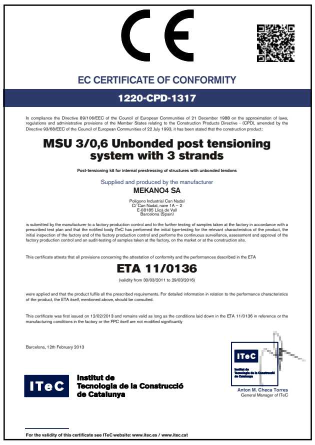
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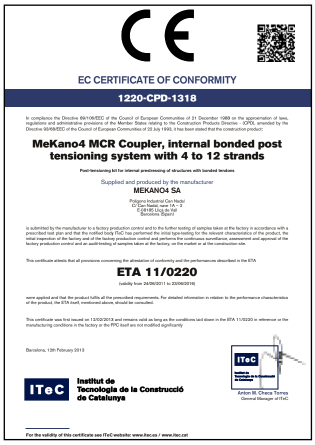
EC CERTIFICATE OF CONFORMITY
1220-CPD-1318
MeKano4 MCR Coupler, internal bonded post tensioning system with 4 to 12 strands
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ETA 11/0220

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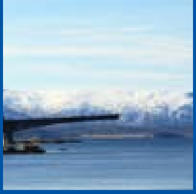

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