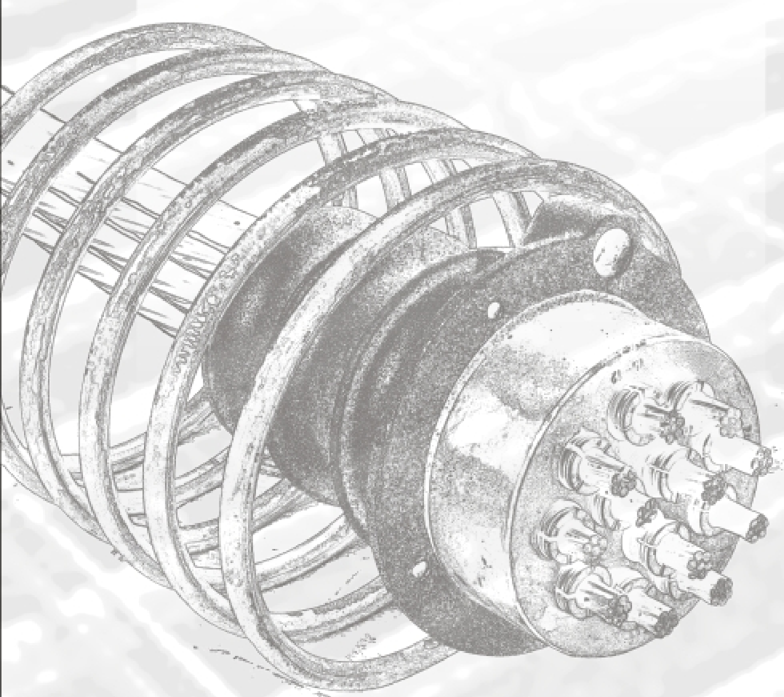
HERCULES

LMK Post Tensioning System

Contents



Cantilevered Segmental Constructions

The System

HERCULES LMK Post Tensioning System studied & designed by Engineers of various disciplines with long-standing activity and experience in construction and project management, in order to meet the requirements of complex PT projects by providing know-how, quality and consistency in applications.

The System's vision has always been focused on applying new technologies and contributing to high quality services respecting at the same time safety and environmental issues.

HERCULES LMK PT System responds proactively to the trends of Int'l markets having successfully accomplished numerous post-tensioning projects involving in all types of construction methodologies, from simply supported beams to slabs, cantilevers, incremental launching and segmental structures, gaining experience in the application of the post-tensioning technology by installing more than 100,000 tons of 7-wire PC strands.

HERCULES LMK PT System accompanied by full technical support & assistance by a team of engineers having participated in prestigious infrastructure projects in the road and railway industry.

Incremental Launching Technique

Box-Girder Construction

Cantilevered Bridge Construction

Launching Erection of Simply Supported Beams

Main Features

GENERAL

HERCULES LMK is a post-tensioning system which applies the tensioning force aft er concreting or after the installation of pre-casted segments, throughout a system of anchorages and tendons, which when filled with grout are bonded to the structure.

HERCULES LMK system is widely used at the construction of post-tensioned concrete systems, i.e. bridges, buildings, silos, tanks and other constructions for internal & external as well tensioning.

HERCULES LMK system can achieve economical benefits for the construction, avoiding the need for a pre-stressing bed by applying the prestressing force in phases, giving to the Consultants/Designers and Contractors the advantages of a simplified construction.

HERCULES LMK system gives the possibility to use a variety of tendons by 7-wire high strength steel strand of 0,5“and 0,6” diameter in a way to cover most of the construction cases. Special anchorages with smaller or bigger capacity than the typical, can be manufactured if required, in order to be used in special designs, constructions and cable supported bridges.

ADVANTAGES

HERCULES LMK system covers Int'l specifications and guidelines of FIB(International Concrete Federation), having the following advantages:

- Wide selection of compact anchorages with more load distribution surfaces making their laying to the formwork easier.
- Easy connection with standard and enlarged steel or plastic sheaths (flat & round).
- Arrangement for frontal grouting.
- More space for reinforcing and concreting at the end block areas.
- Light weight anchorages facilitating the handling and installation.
- Smaller deviation of the tendons.
- Less auxiliary reinforcement.
- Lower friction losses.
- Recesses of smaller dimensions in the concrete


Anchor Heads & Swages


Typical Assembled Stressing Anchorage

Strands

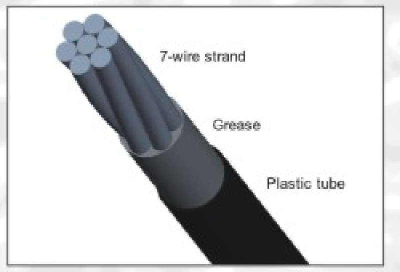
7-WIRE STRANDS

The strands are made of high tensile strength steel produced by the low relaxation process, consist of 7 steel wires (one central wire wrapped helically by other 6 wires) of 13mm (0,5'') or 15mm (0,6'') nominal diameter, having characteristics listed in Table 1 below.

The strands are generally supplied already stabilized (low relaxation) and certified according to the regulations by an independent labs and certified testing facilities. They are supplied in coils having the following typical dimensions:

-Outer Diameter: 1200~1500mm
-Inner Diameter: 700~800mm
-Width: 700~750mm
-Weight: 3000~4000Kg


Strand Coil



HERCULES LMK system can use any type of PC strand meeting the projects requirements. When necessary oiled, greased or waxed strand can be applied using HDPE/PP sheats, i.e. in case of external prestressing, commonly called as unbonded types. If needed, strands can also be supplied galvanized considering that their mechanical properties are different from the standard types (lower yield and breaking values).

Tendons consist of a specific number of 7-wires according to the design. The number of strands defines usually the type of anchorage (LMK's typical range of production of anchorages from 1 to 37 strands).

Norm	Nominal Diameter		Steel Name	Weight	Nominal Area	Characteristic Values							
						Breaking		Proof Load at 0,1%		Load at 1% elongation		Anchorage	Tensile Stress
						Tensile Stress	Max Load	Load at 0,1% Elasticity	Tensile Stress	Low Relaxation		Indicative Max Force min{0,8 F_m / 0,9 $F_{p(0,1\%)}$}	under Fmax
				M	S_n	R_m	F_m	$F_{p(0,1\%)}$	$f_{p(0,1\%)}$	$F_{p(1\%)k}$	$f_{p(1\%)k}$	F_{max}	f_{max}
	mm	inches	Code	Kg/m	mm^2	MPa - N/mm^2	KN	KN	MPa - N/mm^2	KN	MPa or N/mm^2	KN	MPa or N/mm^2
prEN 10138	12,5	0,5"	Y1770S7	0,726	93,0	1770	165	145	1559	--	--	130,5	1403
prEN 10138	12,5	0,5"	Y1860S7	0,726	93,0	1860	173	152	1634	--	--	136,8	1471
prEN 10138	12,9	0,5"	Y1770S7	0,781	100,0	1770	177	156	1560	--	--	140,4	1404
prEN 10138	12,9	0,5"	Y1860S7	0,781	100,0	1860	186	164	1640	--	--	147,6	1476
prEN 10138	15,2	0,6"	Y1770S7	1,086	139,0	1770	246	216	1554	--	--	194,4	1399
prEN 10138	15,2	0,6"	Y1860S7	1,086	139,0	1860	259	228	1640	--	--	205,2	1476
prEN 10138	15,3	0,6"	Y1770S7	1,093	140,0	1770	248	218	1557	--	--	196,2	1401
prEN 10138	15,3	0,6"	Y1860S7	1,093	140,0	1860	260	229	1636	--	--	206,1	1472
prEN 10138	15,7	0,6"	Y1770S7	1,172	150,0	1770	266	234	1560	--	--	210,6	1404
prEN 10138	15,7	0,6"	Y1860S7	1,172	150,0	1860	279	246	1640	--	--	221,4	1476
ASTM A416	12,7	0,5"	Grade 250	0,730	92,9	1725	160	--	--	144,1	1551	128,0	--
ASTM A416	12,7	0,5"	Grade 270	0,780	98,7	1860	184	--	--	165,3	1675	147,2	--
ASTM A416	15,2	0,6"	Grade 250	1,094	139,4	1725	240,2	--	--	216,2	1550	192,2	--
ASTM A416	15,2	0,6"	Grade 270	1,102	140,0	1860	260,7	--	--	234,6	1676	208,6	--

Table 1-Informative

Threading

SHEATHS

The bundle of strands is threaded though sheaths made of corrugated steel strip or high density polyethylene (HDPE) or polypropylene (PP) depending on projects requirements. By simply varying the strands size and number we can utilize tendons of any required capacity.

To assure a better protection of the strands from corrosion it is advisable to use corrugated galvanized steel strip as well as corrugated HDPE/PP sheaths, especially in cases where electrically isolated tendons are required.

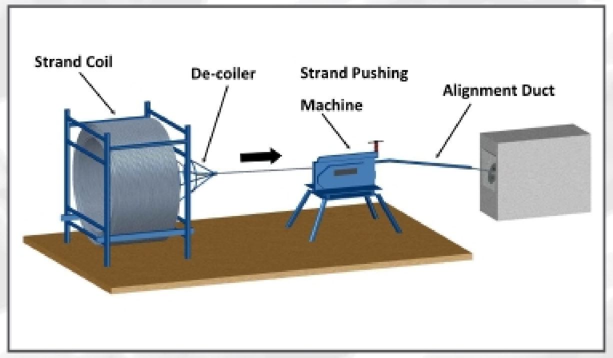
Depending on quantities and projects requirements, sheaths can be produced either at workshop and delivered to the job-site or can be manufactured on the spot.

Steel sheaths are flexible, bright, interlocked and grout tight, fabricated using the method of continuous cold rolling and stapling of a flat steel strip in widths of 30~60mm (galvanized or standard) covering a wide range of tendon sizes. The steel strip gauge used to manufacture the sheaths is in accordance with Int'l standards following projects requirements having a minimum thickness ranging from 0,30mm up to 0,60mm depending on diameter and category (normal or rigid/stiffness).

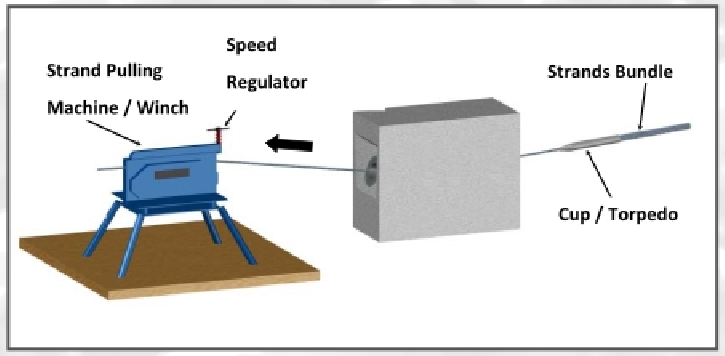
The sheaths are normally supplied in lengths of 5-6 m and are connected together by means of couplers. These coupling systems, having a minimum length of 250 mm, are identical to the sheath having a slightly larger diameter to be screwed onto the sheath (case of steel) or using push fit, heat shrink and welding techniques (plastic sheaths).

Steel Strip Gauge

In case of cast-in-situ construction, strands are threaded (Fig. 1A) using strand pushing machines prior or after concreting, according to the projects needs (pushing methodology). As an alternative, strands can be installed using the pull through method with special sockets and winch (Fig. 1B). In such case sheaths shall be at least 6,35mm (1/4 inch) larger than the nominal diameter of the strand bundles and the cross section area shall be at least 2.5 times bigger than the net steel area .



Pushing Method - Fig. 1A



Pulling Method - Fig. 1B

Sheaths

INSTALLATION

The bearing plates commonly are fixed to the formwork which, when properly greased, can be easily removed after concrete curing. All couplings along the sheath tendon must be carefully sealed with adhesive tape in case of steel sheathing or using special sleeves (heat shrinking sleeves etc) and other welding techniques in case of plastic ducts.

The installation of the sheaths is taking place simultaneously with reinforcement's installation.
Therefore, co-operation between the working teams is necessary avoiding delays and installation defects.

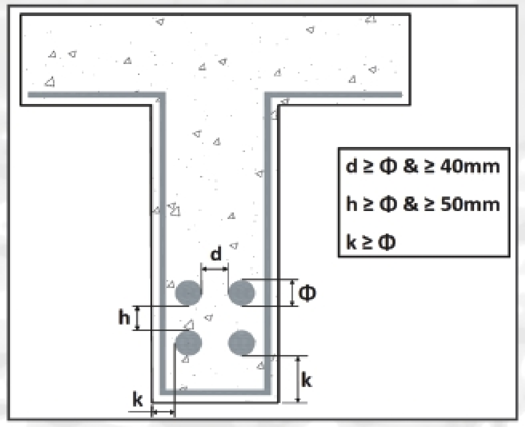
The proper installation of sheaths at the specified by the design geometry it is of utmost importance. The supporting points are commonly made of stirrups of Φ12mm reinforcement, at a distance of 1m (or as per design requirements) and tied with tie-wire on the reinforcement. In case the strands are going to be threaded after concreting, these supports should be installed at a spacing of at least 0,5m.

As a rule of thumb the concrete cover of the sheath should be at least equal to their diameter (d) and not less than 40~50mm (Fig. 2).

When many tendons are present in a section, it is necessary to foresee adequate spacing for concreting and properly vibration avoiding any direct contact with the sheaths, thus protecting them from damages, geometry misalignments and improper concrete compaction.

In cases when strands are going to be threaded after concreting, the steel strip sheaths usually need to be thicker by 0,05mm and enlarged having a diameter 10mm above the typical one.

External tendons are made of plastic tubes and filled with special wax or grease depending on design requirements.



Sheaths Arrangement - Fig. 2

Steel Sheaths

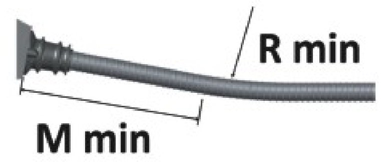
HDPE/PP Sheaths

Steel Corrugated Sheath

Flat & Round Plastic Sheath

Typical Steel Sheath Diameters & Tendons Geometry

Table 2

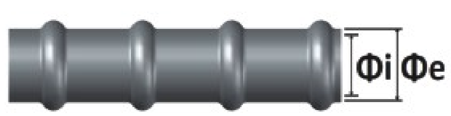


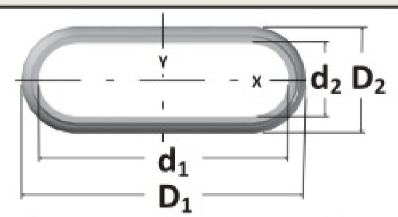
STEEL	SHEATH		COUPLER		GEOMETRY	
	Φi	Φe	Φi'	Φe'	M min (Tangent Length)	R min (Radius of Curvature)
TYPE	mm	mm	mm	mm	mm	mm
2 ~ 4M15	45	50	51	55	500	3500
5 ~ 7M15	55	60	60	65	600	4500
8 ~ 12M15	75	80	80	85	750	6000
13 ~ 15M15	80	85	85	90	900	6500
16 ~ 19M15	90	95	95	100	1000	7500
20 ~ 22M15	100	105	105	110	1100	8000
23 ~ 27M15	110	115	115	120	1200	9000
28 ~ 31M15	115	120	120	125	1300	10000
32 ~ 37M15	140	145	145	150	1500	12000

Corrugated sheath diameter can be modified according to design requirements

Typical Plastic Sheath Diameters

Table 3





HDPE/PP	ROUND SHEATH		FLAT SHEATH			
	Φi	Φe	d_1 x d_2	D_1 x D_2	M min (Tangent Length)	R min (Radius of Curvature)
TYPE	mm	mm	mm x mm	mm x mm	mm x mm	Xmm x Ymm
2 ~ 4M15	59	64	73 x 22	77 x 26	500	2500 x 6000
5M15	59	64	90 x 23	94 x 26	500	2500 x 6000
6 ~ 7M15	59	64	--	--	--	--
8 ~ 12M15	76	81	--	--	--	--
13 ~ 15M15	86	91	--	--	--	--
16 ~ 22M15	100	106	--	--	--	--
23 ~ 31M15	115	121	--	--	--	--
32 ~ 37M15	150	157	--	--	--	--

Tightness between anchorages and ducts at connection areas is realized either by adhesive tape or welding, push fit and heat shrinking techniques. In case of flat anchorages with monostrands, sealant plug material can be utilized as an alternative together with un-bonded single strands coated with grease and enclosed in a plastic sheath.


FLAT PLASTIC DUCTS


PUSH FIT PLASTIC COUPLER WITH SEAL


PUSH FIT PLASTIC COUPLER


SEGMENTAL BRIDGE COUPLING


INSTALLATION OF DUCTS & COUPLERS


BUTT WELDING


HEAT SHRINK COUPLER


STEEL DUCTS & COUPLERS

Anchorages

TYPES

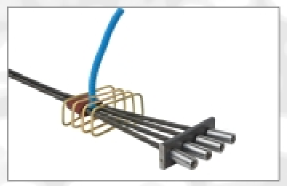
Mechanical Stressing Anchorages type "LMK-S" - Fig. 3 - are formed by a steel anchor head, where strands are individually gripped by wedges passing through a bearing plate.

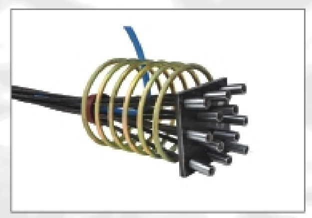
Fixed anchorages are swaged types "LMK-FS" with rectangular anchor plate - Fig. 4 and "LMK-FSB" with bearing plate" - Fig. 5, if not accessible as per Design requirements.

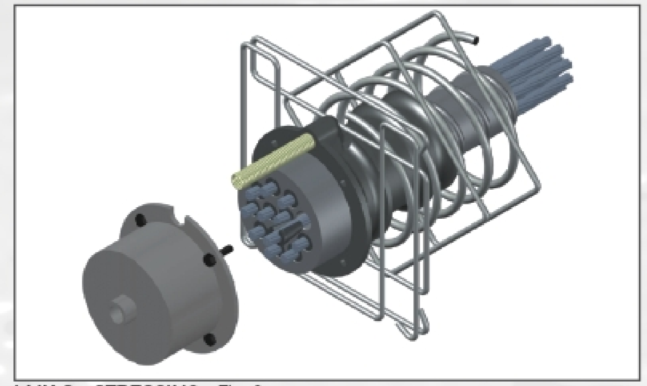
Coupling of the tendons between adjoining construction members either with mechanical movable types "LMK-MC" - Fig. 6 (continuous tendons at construction joints) or fixed types "LMK-FC or FFC" having round/flat bearing plates - Fig. 7 & 8.

Flat anchorages are type stressing "LMK-SFL" - Picture 9 or swaged fixed "LMK-FFL" - Fig. 10, used for slab post-tensioning, lateral and thin slab stressing for building floors/walls and bridges as well. Slab post-tensioning enables deflections and cracks under service conditions to be kept under control by permitting larger and thinner at the same time spans.

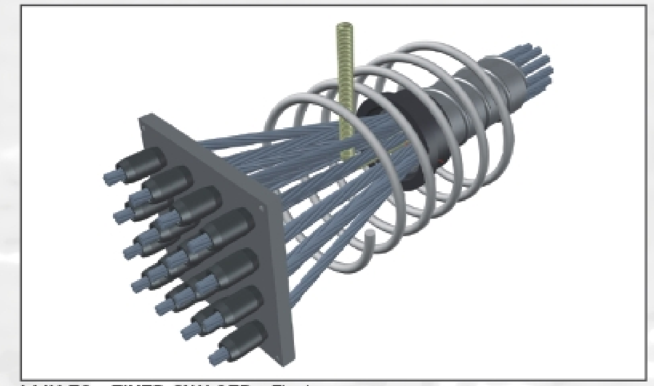
All the data given to the technical cards are complying to the higher capacity of strand, 0,6'' (279kN) super type (150mm^2) 1860 N/mm^2.



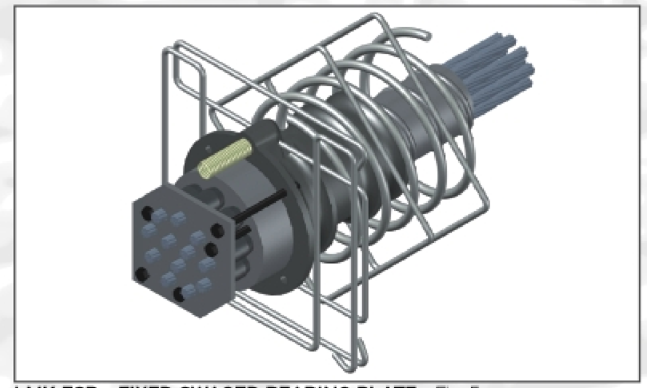




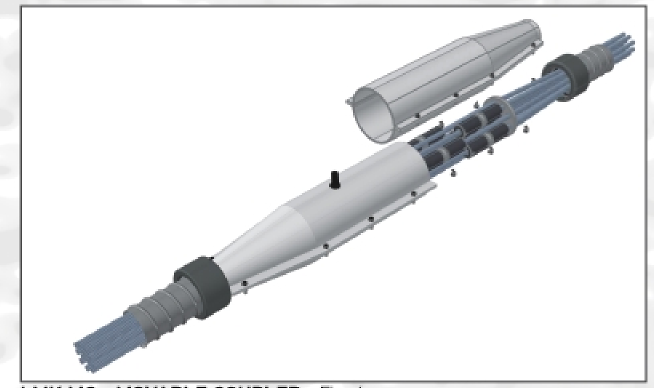
LMK S - STRESSING - Fig. 3



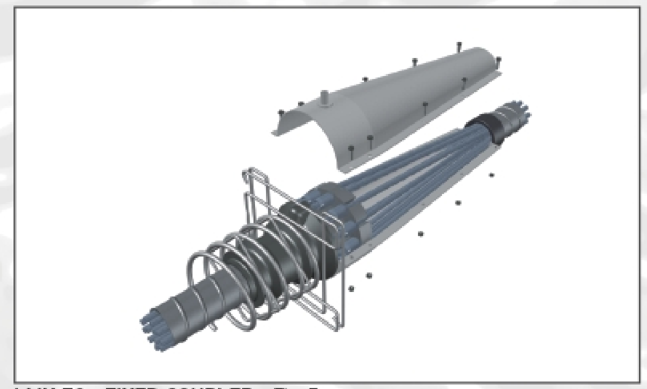
LMK FS - FIXED SWAGED - Fig.4



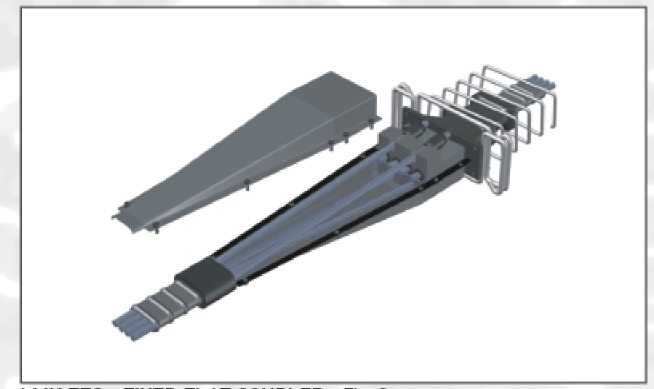
LMK FSB - FIXED SWAGED BEARING PLATE - Fig. 5



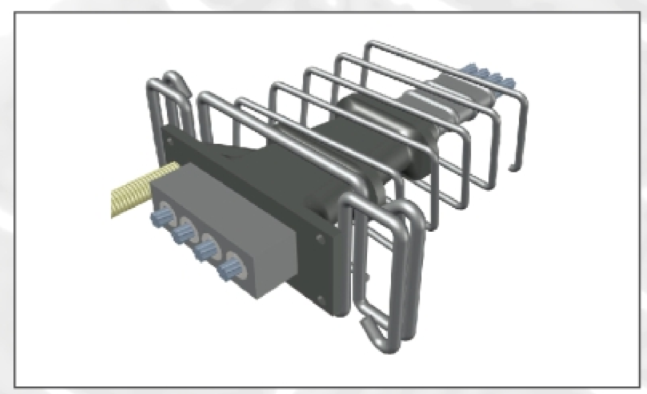
LMK MC - MOVABLE COUPLER - Fig. 6



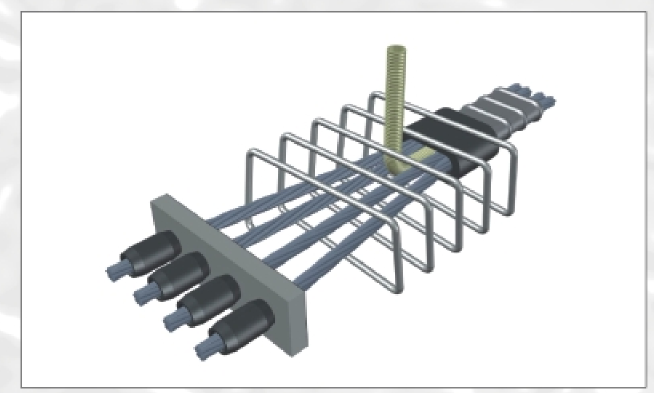
LMK FC - FIXED COUPLER - Fig. 7



LMK FFC - FIXED FLAT COUPLER - Fig. 8



LMK SFL - STRESSING FLAT - Fig. 9



LMK FFL - FIXED FLAT - Fig. 10

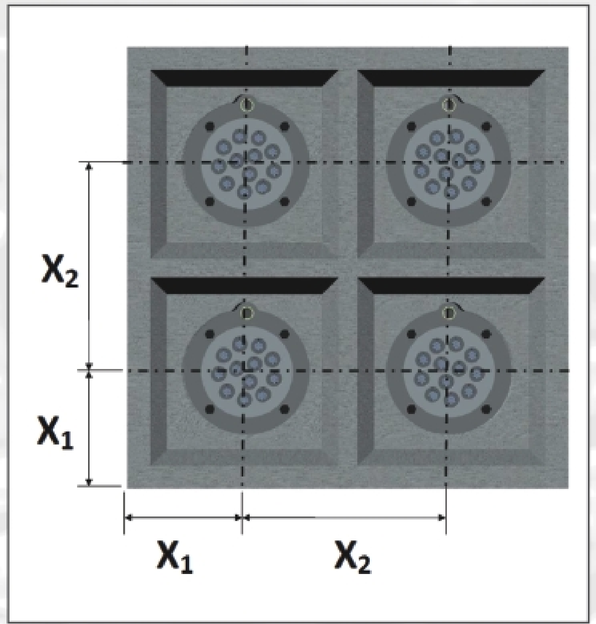
Block-out Dimensions & Reinforcement

MINIMUM CLEARANCE

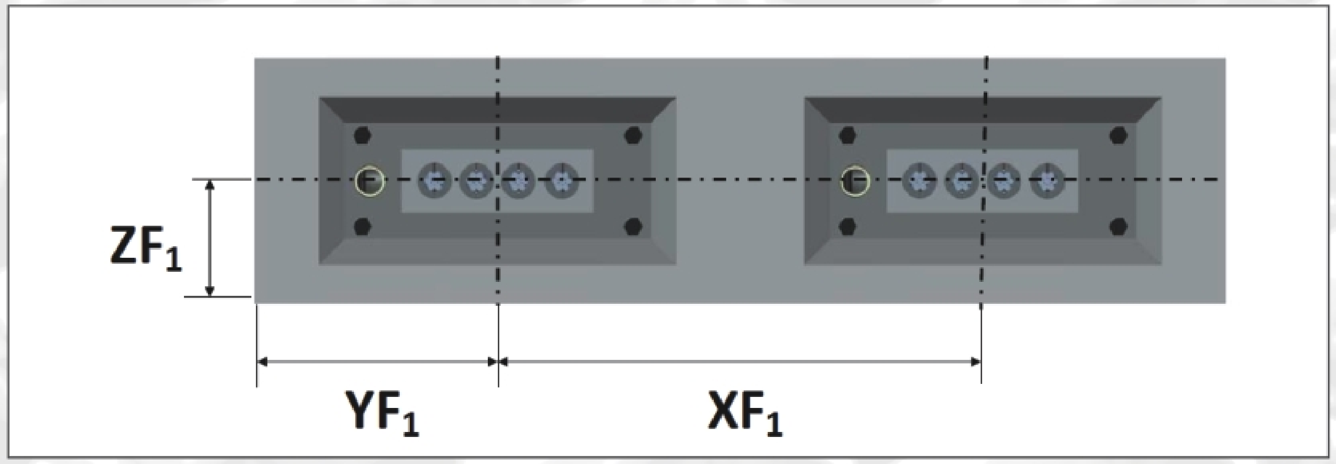
The technical cards of anchorages specify the characteristic anchorage spacings "X, Y & Z" for typical concrete classes, according to the characteristic strength at 28 days. For concrete of intermediate strength, additional data can be interpolated.

The minimum proposed distances as per below sketches, should not be considered when simultaneously stressing neighboring anchorages at ultimate strength condition. In such a case the appropriate distance X_2 must foreseen.

In addition to the reinforcement required by the design, supplementary reinforcement is suggested to be placed in the force distribution zone behind every anchorage. The spirals (yield strength > 420 N/mm^2) that are shown in the following anchorages technical cards can be replaced by an equivalent orthogonal reinforcement. Additional bursting reinforcement such as W and ☐ stirrups can be utilized as shown in the anchorages technical cards. Further details regarding the bursting reinforcement could be established by the site Engineer.



Round Bearing Plates - Fig. 11A



Flat Bearing Plates - Fig. 11B

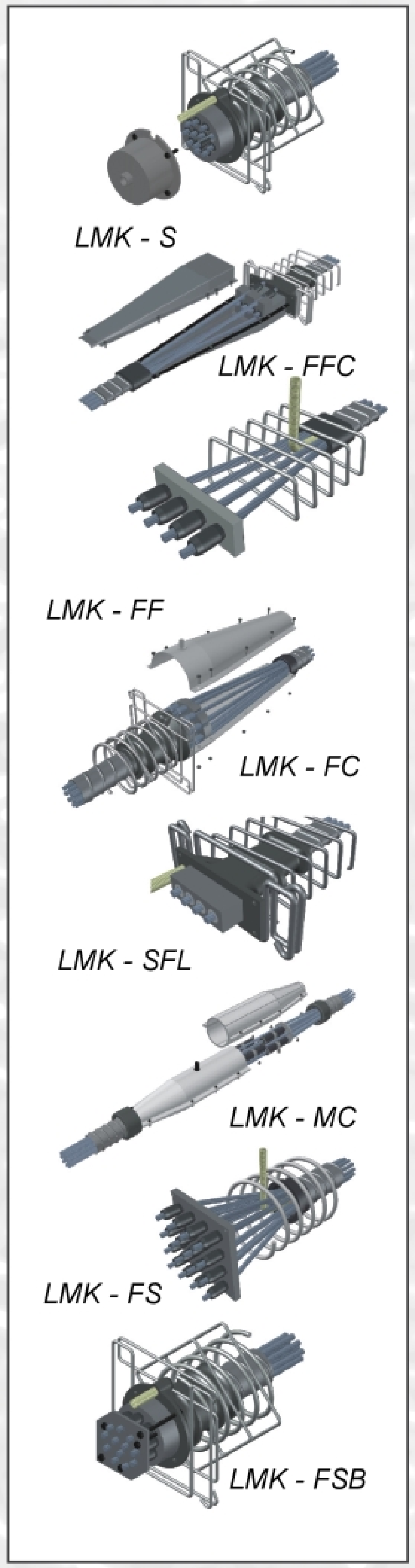
BEARING PLATES MIN RECOMMENDED ARRANGEMENT

Table 4

ROUND	min $X_{1(\#)}$	min X_2	min $X_{1(\#)}$	min X_2	min $X_{1(\#)}$	min X_2
	Concrete Class C30/37		Concrete Class C35/45		Concrete Class C40/50	
	mm	mm	mm	mm	mm	mm
2M15	120	180	115	180	110	180
3M15	125	185	120	180	115	180
4M15	130	210	125	195	120	185
5M15	150	240	145	240	140	240
6M15	165	260	155	240	150	240
7M15	170	280	160	260	155	240
8M15	185	335	180	335	175	335
9M15	190	340	185	340	180	340
10M15	195	345	190	345	185	345
11M15	205	350	195	350	190	350
12M15	210	365	200	355	195	355
13M15	225	380	220	365	200	365
14M15	230	395	225	375	215	370
15M15	235	405	230	380	220	375
16M15	250	420	235	400	225	400
17M15	265	435	245	405	235	405
18M15	270	445	250	410	240	410
19M15	275	455	255	425	245	415
20M15	280	470	260	440	250	440
21M15	285	480	265	445	255	445
22M15	290	490	270	455	260	450
23M15	310	505	290	480	275	480
24M15	315	515	295	485	280	485
25M15	320	525	300	490	285	490
26M15	325	535	305	495	290	495
27M15	330	545	310	505	295	500
28M15	335	555	315	530	300	530
29M15	340	565	320	535	305	535
30M15	345	575	325	540	310	540
31M15	350	585	330	545	315	545
32M15	355	595	335	575	320	575
33M15	360	600	340	580	325	580
34M15	365	610	345	585	330	585
35M15	370	620	350	590	335	590
36M15	375	630	355	595	340	595
37M15	380	635	360	600	345	600

FLAT	min XF_1	min $YF_{1(\#)}$	min $ZF_{1(\#)}$	min XF_1	min $YF_{1(\#)}$	min $ZF_{1(\#)}$
	Concrete Class C30/37			Concrete Class C35/45		
	mm	mm	mm	mm	mm	mm
2M15	340	115	75	330	110	70
3M15	360	135	80	350	130	75
4M15	390	170	95	380	165	90
5M15	410	185	100	400	180	95

(#) Concrete cover must be added to the above X_1, YF_1 & ZF_1 values depending on design requirements.

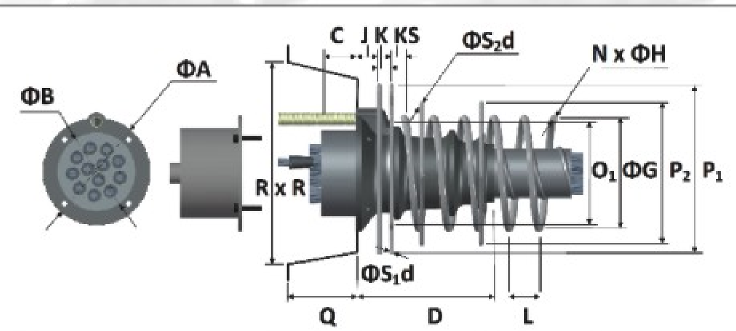


Technical Cards LMK-S STRESSING 15 (0,6")

Table 5A

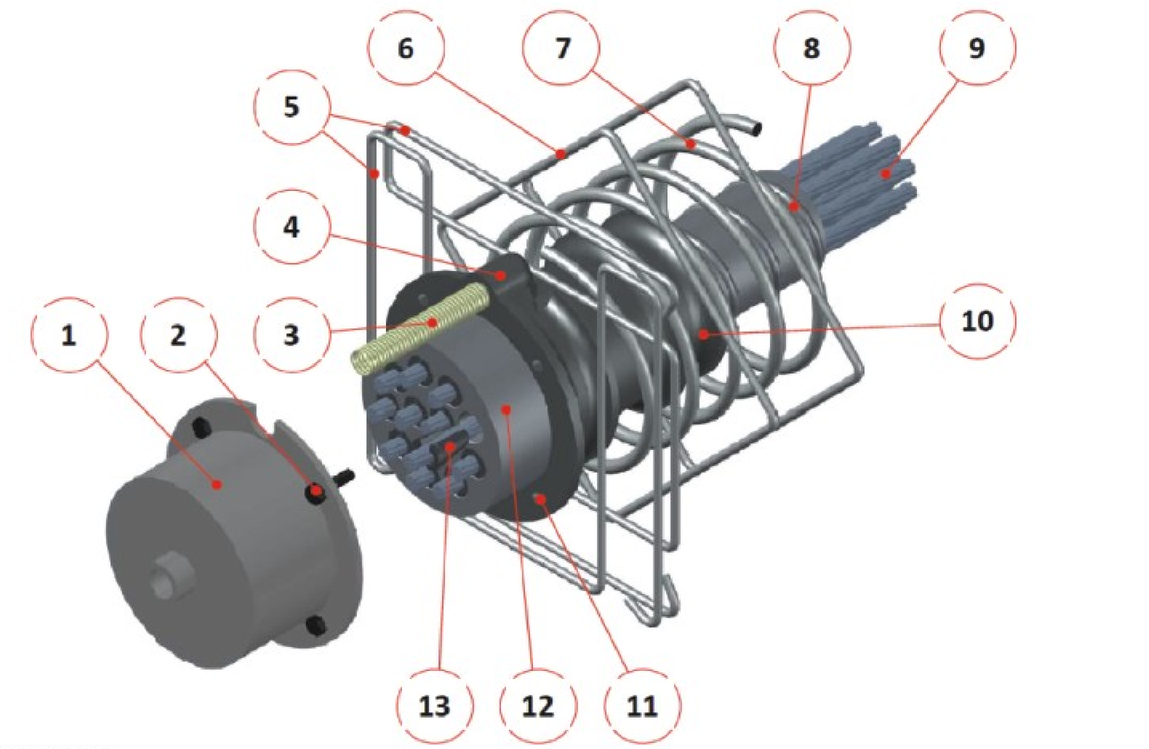
LMK - S	BEARING PLATE		ANCHOR HEAD		SPIRAL					W STIRRUPS						☐ STIRRUPS			RECESS	
	ΦA	D	ΦB	C	ΦG	N	ΦH	L	KS	P_1	O_1	$ΦS_{1d}$	J	N	K	P_2	$ΦS_{2d}$	N	R x R	Q
TYPE	mm	mm	mm	mm	mm	Nos	mm	mm	mm	mm	mm	mm	mm	Nos	mm	mm	mm	Nos	mm x mm	mm
1M15	--	--	50	48	140	5	10	50	20	--	--	--	--	--	--	--	--	--	165	90
2M15	140	125	86	50	140	5	10	50	20	155	120	6	50	1	--	--	--	--	220	90
3M15	140	125	91	50	180	5	10	50	20	160	125	6	50	1	--	--	--	--	270	90
4M15	140	125	102	50	210	5	10	50	25	165	125	6	50	1	--	--	--	--	270	90
5M15	180	170	115	50	230	6	10	50	25	200	160	8	70	1	--	--	--	--	330	90
6M15	180	170	126	52	260	6	10	50	25	220	160	8	70	1	--	--	--	--	330	120
7M15	180	170	126	53	280	6	10	50	25	220	160	8	70	1	--	--	--	--	360	120
8M15	225	230	146	55	300	6	12	60	25	260	195	8	70	2	30	--	--	--	360	120
9M15	225	230	146	55	320	6	12	60	25	265	195	8	70	2	30	--	--	--	395	120
10M15	225	230	166	58	330	6	12	60	25	290	195	8	70	2	30	--	--	--	395	120
11M15	225	230	166	58	350	6	12	60	30	300	195	8	70	2	30	--	--	--	395	120
12M15	225	230	166	60	370	8	12	60	30	310	195	8	70	2	30	--	--	--	420	130
13M15	255	290	176	63	380	8	12	60	30	330	200	10	90	2	30	--	--	--	420	130
14M15	255	290	176	65	400	8	12	60	30	340	200	10	90	2	30	--	--	--	470	130
15M15	255	290	186	68	400	8	14	60	30	340	200	10	90	2	30	--	--	--	470	140
16M15	280	235	196	70	410	8	14	60	30	370	215	12	100	2	30	--	--	--	485	140
17M15	280	235	196	73	430	8	14	60	30	375	215	12	100	2	30	--	--	--	485	140
18M15	280	325	206	75	440	8	14	60	30	380	215	12	100	2	30	--	--	--	500	140
19M15	280	325	206	75	450	9	14	60	30	385	215	12	100	2	30	--	--	--	500	140
20M15	310	325	226	80	450	9	16	60	30	410	255	12	100	2	30	--	--	--	500	150
21M15	310	325	226	80	450	9	16	60	30	415	255	12	100	2	30	--	--	--	545	150
22M15	310	325	226	80	460	10	16	60	30	420	255	12	100	2	30	400	8	2	545	150
23M15	340	430	244	82	460	10	16	60	35	450	275	14	135	2	30	400	8	2	575	150
24M15	340	430	244	82	470	10	16	60	35	455	275	14	135	2	30	400	8	2	575	150
25M15	340	430	244	85	470	10	16	60	35	460	275	14	135	2	30	400	8	2	575	150
26M15	340	430	244	85	480	10	16	60	35	465	275	14	135	2	30	400	8	2	575	150
27M15	340	430	244	85	480	11	16	60	35	470	275	14	135	2	30	450	10	3	620	150
28M15	360	415	260	88	490	11	16	60	35	500	315	14	130	2	35	450	10	3	620	150
29M15	360	415	260	88	490	11	16	60	35	510	315	14	130	2	35	450	10	3	620	150
30M15	360	415	260	90	500	11	16	60	35	515	315	14	130	2	35	450	10	3	630	150
31M15	360	415	260	90	500	12	16	60	35	515	315	14	130	2	35	450	12	3	630	150
32M15	405	510	296	95	510	12	16	60	40	540	350	16	160	2	40	500	12	4	700	170
33M15	405	510	296	95	510	12	16	60	40	545	350	16	160	2	40	500	12	4	700	170
34M15	405	510	296	95	510	12	16	60	40	550	350	16	160	2	40	500	12	4	700	170
35M15	405	510	296	100	520	12	18	60	40	555	350	16	160	2	40	500	12	4	700	170
36M15	405	510	296	100	520	12	18	60	40	560	350	16	160	2	40	500	12	4	700	170
37M15	405	510	296	100	520	12	18	60	40	565	350	16	160	2	40	500	12	4	700	170

Recommended values for Spiral, Stirrups & Recess



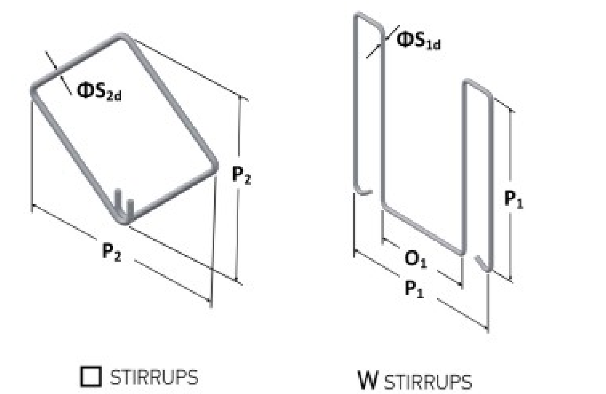
Side view - Fig. 12A

LMK - S - STRESSING ANCHORAGE-15



Axonometric View - Fig. 12B

BURSTING REINFORCEMENT



- Corrugated sheath diameter can be modified according to design requirements
- Ensure proper anchorage distance X_2 when simultaneously stressing
- Stirrups can be modified according to design requirements
- Additional ☐ stirrups distributed along the spiral length

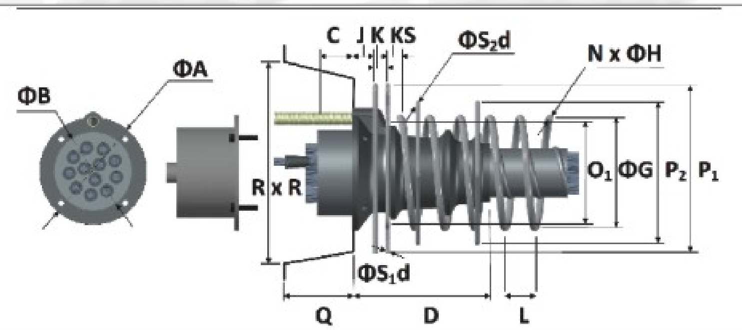
S/N	DESCRIPTION
1-	GROUTING CAP
2-	FIXING BOLTS
3-	GROUTING PIPE
4-	GROUTING PORT
5-	W STIRRUPS
6-	☐STIRRUPS
7-	SPIRAL REINFORCEMENT
8-	CORRUGATED SHEATH
9-	STRANDS
10-	BEARING PLATE
11-	FIXING HOLES
12-	ANCHOR HEAD
13-	WEDGES

Technical Cards LMK-S STRESSING-13 (0,5")

Table 5B

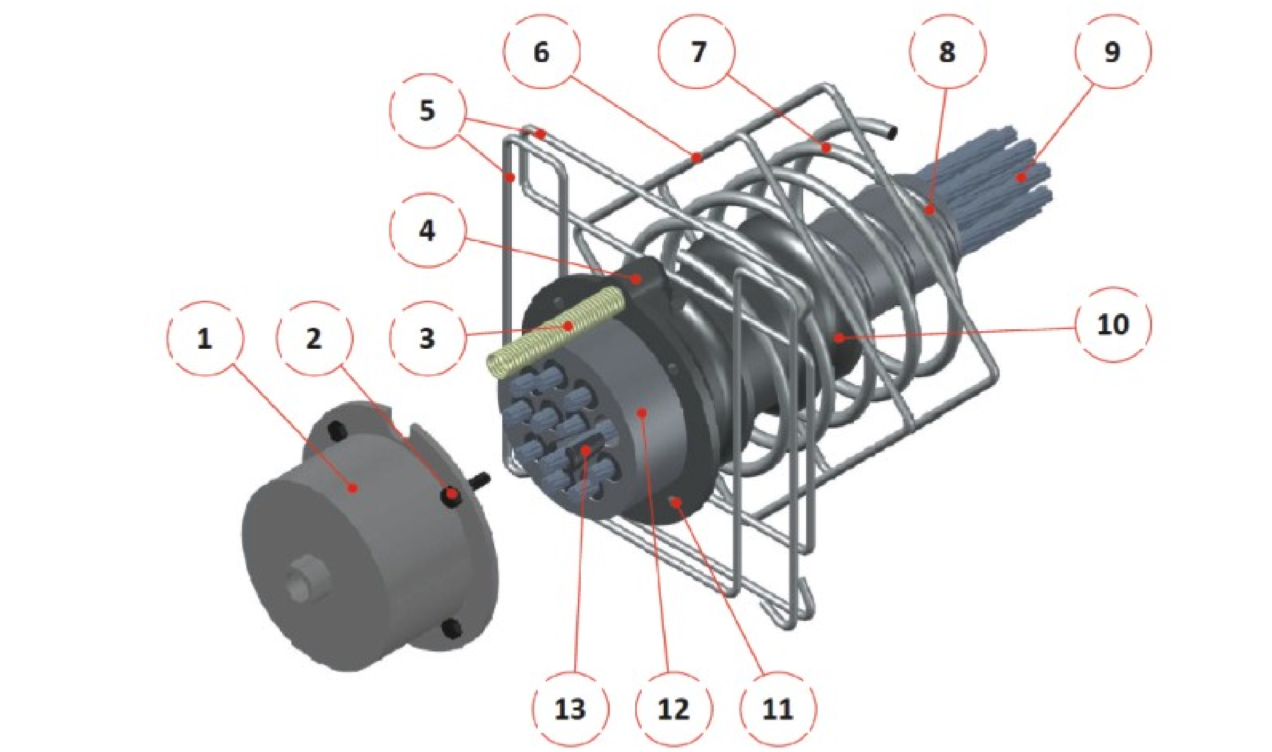
LMK - S	BEARING PLATE		ANCHOR HEAD		SPIRAL					W STIRRUPS						□ STIRRUPS			RECESS	
	ΦA	D	ΦB	C	ΦG	N	ΦH	L	KS	P_1	O_1	$ΦS_{1d}$	J	N	K	P_2	$ΦS_{2d}$	N	R x R	Q
TYPE	mm	mm	mm	mm	mm	Nos	mm	mm	mm	mm	mm	mm	mm	Nos	mm	mm	mm	Nos	mm x mm	mm
1M13	--	--	40	40	100	5	8	50	20	--	--	--	--	--	--	--	--	--	165	90
2M13	125	80	75	45	120	5	8	50	20	155	120	6	50	1	--	--	--	--	220	90
3M13	132	80	80	45	130	5	12	50	20	160	125	6	50	1	--	--	--	--	270	90
4M13	136	102	85	48	150	5	12	50	25	165	125	6	50	1	--	--	--	--	270	90
5M13	140	125	100	48	170	6	12	50	25	200	160	8	70	1	--	--	--	--	330	90
6M13	155	130	105	48	190	6	12	50	25	220	160	8	70	1	--	--	--	--	330	120
7M13	155	130	105	50	210	6	12	50	25	220	160	8	70	1	--	--	--	--	360	120
8M13	170	160	116	52	230	6	12	60	25	260	195	8	70	2	30	--	--	--	360	120
9M13	175	170	126	53	240	6	12	60	25	265	195	8	70	2	30	--	--	--	395	120
10M13	200	190	136	53	250	6	14	60	25	290	195	8	70	2	30	--	--	--	395	120
11M13	200	190	136	53	260	6	14	60	30	300	195	8	70	2	30	--	--	--	395	120
12M13	210	210	146	55	280	8	14	60	30	310	195	8	70	2	30	--	--	--	420	130
13M13	210	210	146	55	290	8	14	60	30	330	200	10	90	2	30	--	--	--	420	130
14M13	210	230	156	57	310	8	14	60	30	340	200	10	90	2	30	--	--	--	470	130
15M13	214	230	166	60	320	8	14	60	30	340	200	10	90	2	30	--	--	--	470	140
16M13	246	270	176	62	320	8	16	60	30	370	215	12	100	2	30	--	--	--	485	140
17M13	246	270	176	62	330	8	16	60	30	375	215	12	100	2	30	--	--	--	485	140
18M13	246	270	176	65	330	8	16	60	30	380	215	12	100	2	30	--	--	--	500	140
19M13	246	270	176	65	340	9	16	60	30	385	215	12	100	2	30	--	--	--	500	140
20M13	260	365	196	68	350	9	16	60	30	410	255	12	100	2	30	--	--	--	500	150
21M13	260	365	196	70	350	9	16	60	30	415	255	12	100	2	30	--	--	--	545	150
22M13	260	365	196	70	360	10	16	60	30	420	255	12	100	2	30	400	8	2	545	150
23M13	275	380	216	73	360	10	16	60	35	450	275	14	135	2	30	400	8	2	575	150
24M13	275	380	216	73	370	10	16	60	35	455	275	14	135	2	30	400	8	2	575	150
25M13	275	380	216	75	370	10	16	60	35	460	275	14	135	2	30	400	8	2	575	150
26M13	275	380	216	75	380	10	16	60	35	465	275	14	135	2	30	400	8	2	575	150
27M13	275	380	216	75	380	11	16	60	35	470	275	14	135	2	30	450	10	3	620	150
28M13	300	400	224	78	390	11	16	60	35	500	315	14	130	2	35	450	10	3	620	150
29M13	300	400	224	78	390	11	16	60	35	510	315	14	130	2	35	450	10	3	620	150
30M13	300	400	224	80	390	11	16	60	35	515	315	14	130	2	35	450	10	3	630	150
31M13	300	400	224	80	400	12	16	60	35	515	315	14	130	2	35	450	12	3	630	150
32M13	330	430	244	82	400	12	16	60	40	540	350	16	160	2	40	500	12	4	700	170
33M13	330	430	244	82	410	12	16	60	40	545	350	16	160	2	40	500	12	4	700	170
34M13	330	430	244	82	410	12	16	60	40	550	350	16	160	2	40	500	12	4	700	170
35M13	330	430	244	85	420	12	16	60	40	555	350	16	160	2	40	500	12	4	700	170
36M13	330	430	244	85	420	12	16	60	40	560	350	16	160	2	40	500	12	4	700	170
37M13	330	430	244	85	430	12	16	60	40	565	350	16	160	2	40	500	12	4	700	170

Recommended values for Spiral, Stirrups & Recess



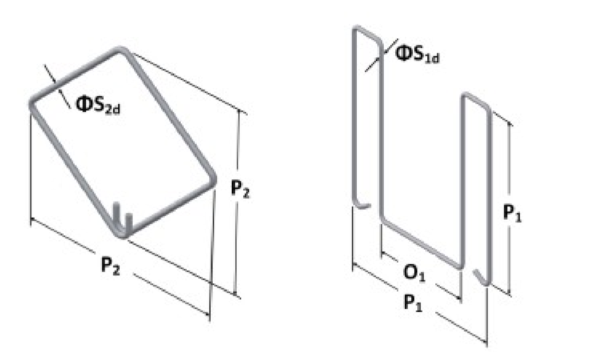
Side view - Fig. 12C

LMK - S - STRESSING ANCHORAGE-13



Axonometric View - Fig. 12D

BURSTING REINFORCEMENT



□ STIRRUPS W STIRRUPS

S/N	DESCRIPTION
1-	GROUTING CAP
2-	FIXING BOLTS
3-	GROUTING PIPE
4-	GROUTING PORT
5-	W STIRRUPS
6-	□STIRRUPS
7-	SPIRAL REINFORCEMENT
8-	CORRUGATED SHEATH
9-	STRANDS
10-	BEARING PLATE
11-	FIXING HOLES
12-	ANCHOR HEAD
13-	WEDGES

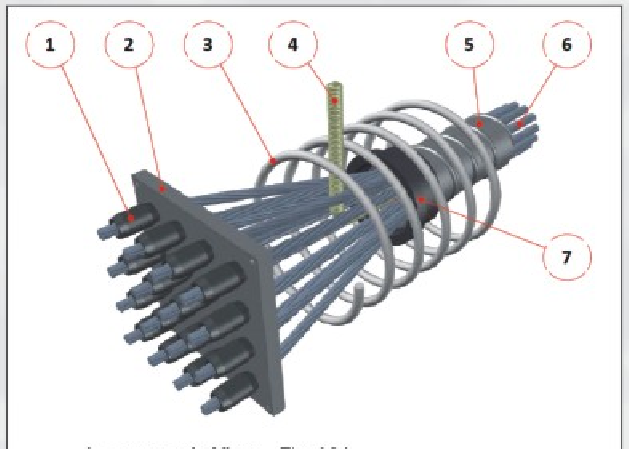
- Corrugated sheath diameter can be modified according to design requirements
- Ensure proper anchorage distance X_2 when simultaneously stressing
- Stirrups can be modified according to design requirements
- Additional □ stirrups distributed along the spiral length

Technical Cards LMK-FS FIXED SWAGED

Table 6

LMK-FS	Distance	Dimensions		Spiral			
TYPE	A x A'	B min	C	ΦG	N	ΦH	L
	mm	mm	mm	mm	Nos	mm	mm
2M15 (M13)	100 x 80 (90 x 70)	180 (120)	110 (85)	140 (120)	5 (5)	10 (8)	50 (50)
3M15 (M13)	120 x 120 (100 x 100)	180 (120)	110 (85)	180 (130)	5 (5)	10 (12)	50 (50)
4M15 (M13)	140 x 140 (120 x 120)	240 (180)	110 (110)	210 (150)	5 (5)	10 (12)	50 (50)
5M15 (M13)	155 x 155 (140 x 140)	300 (180)	110 (110)	230 (170)	6 (6)	10 (12)	50 (50)
6M15 (M13)	170 x 170 (150 x 150)	380 (300)	120 (110)	260 (190)	6 (6)	10 (12)	50 (50)
7M15 (M13)	185 x 185 (170 x 170)	380 (380)	120 (110)	280 (210)	6 (6)	10 (12)	50 (50)
8M15 (M13)	195 x 195 (170 x 170)	440 (380)	120 (110)	300 (230)	6 (6)	12 (12)	60 (60)
9M15 (M13)	210 x 210 (220 x 220)	440 (440)	120 (120)	320 (240)	6 (6)	12 (12)	60 (60)
10M15 (M13)	220 x 220 (220 x 220)	500 (440)	135 (120)	330 (250)	6 (6)	12 (14)	60 (60)
11M15 (M13)	230 x 230 (220 x 220)	500 (440)	135 (120)	350 (260)	6 (6)	12 (14)	60 (60)
12M15 (M13)	240 x 240 (220 x 220)	500 (440)	135 (120)	370 (280)	8 (8)	12 (14)	60 (60)
13M15 (M13)	250 x 250 (250 x 250)	500 (500)	135 (135)	380 (290)	8 (8)	12 (14)	60 (60)
14~15M15 (M13)	260 x 260 (250 x 250)	560 (500)	135 (135)	400 (320)	8 (8)	12 (14)	60 (60)
16M15 (M13)	260 x 260 (250 x 250)	560 (500)	135 (135)	410 (320)	8 (8)	14 (16)	60 (60)
17M15 (M13)	285 x 285 (250 x 250)	720 (500)	135 (135)	430 (330)	8 (8)	14 (16)	60 (60)
8~19M15 (M13)	300 x 300 (250 x 250)	720 (500)	135 (135)	450 (340)	9 (9)	14 (16)	60 (60)
20~22M15	325 x 325	900	135	460	10	16	60
23~27M15	350 x 350	1000	135	480	11	16	60
28~31M15	380 x 380	1100	135	500	12	16	60
32~34M15	400 x 400	1100	135	510	12	16	60
35~37M15	420 x 420	1200	135	520	12	18	60

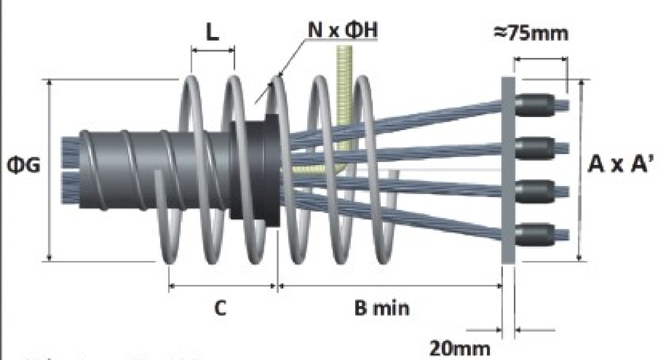
Recommended values for Spiral
Values in parenthesis for type M13



Axonometric View - Fig. 13A

- Corrugated sheath diameter can be modified according to design requirements

S/N	DESCRIPTION
1-	SWAGES
2-	ANCHOR HEAD
3-	SPIRAL REINFORCEMENT
4-	GROUTING TUBE
5-	CORRUGATED SHEATH
6-	STRANDS
7-	COLLAR



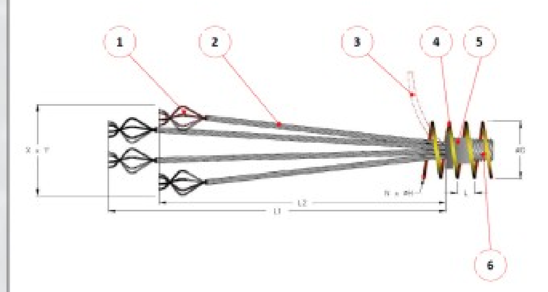
Side view - Fig. 13B

Technical Cards LMK-FB FIXED BULB

Table 6A

LMK-FB	Bulb Configuration			Spiral			
TYPE	X x Y	L1	L2	ΦG	N	ΦH	L
	mm	mm	mm	mm	Nos	mm	mm
1-4M15 (M13)	190 x 210 (190 x 210)	900 (900)	--	210 (150)	5 (5)	10 (12)	50 (50)
5-8M15 (M13)	250 x 270 (250 x 270)	1000 (1000)	850 (850)	300 (230)	6 (6)	12 (12)	60 (60)
9-12M15 (M13)	280 x 420 (280 x 420)	1100 (1100)	950 (950)	370 (280)	8 (8)	12 (14)	60 (60)
13-16M15 (M13)	380 x 390 (380 x 390)	1100 (1100)	950 (950)	410 (320)	8 (8)	14 (16)	60 (60)
17-19M15 (M13)	380 x 490 (380 x 490)	1200 (1200)	1050 (1050)	450 (340)	9 (9)	14 (16)	60 (60)
20-23M15 (M13)	470 x 470 (470 x 470)	1300 (1300)	1150 (1150)	460 (360)	10 (10)	16 (16)	60 (60)
24-27M15 (M13)	560 x 470 (560 x 470)	1400 (1400)	1250 (1250)	480 (380)	11 (11)	16 (16)	60 (60)
28-31M15 (M13)	510 x 570 (510 x 570)	1500 (1500)	1350 (1350)	500 (400)	12 (12)	16 (16)	60 (60)
32-35M15 (M13)	600 x 650 (600 x 650)	1600 (1600)	1450 (1450)	520 (420)	12 (12)	18 (16)	60 (60)
36-37M15 (M13)	600 x 650 (600 x 650)	1600 (1600)	1450 (1450)	520 (430)	12 (12)	18 (16)	60 (60)

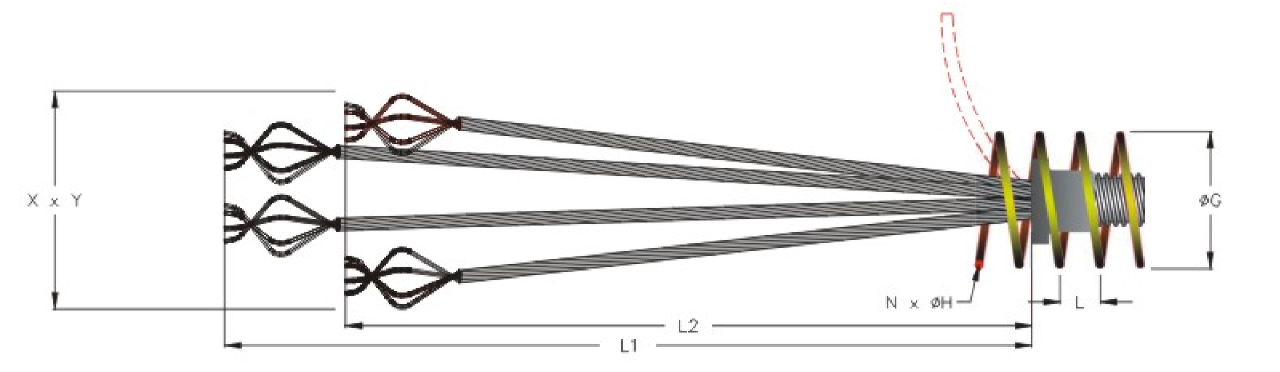
Recommended values for Spiral
Values in parenthesis for type M13



Axonometric View - Fig. 13C

- Corrugated sheath diameter can be modified according to design requirements

S/N	DESCRIPTION
1-	BULBS
2-	STRANDS
3-	GROUTING TUBE
4-	SPIRAL REINFORCEMENT
5-	COLLAR
6-	CORRUGATED SHEATH



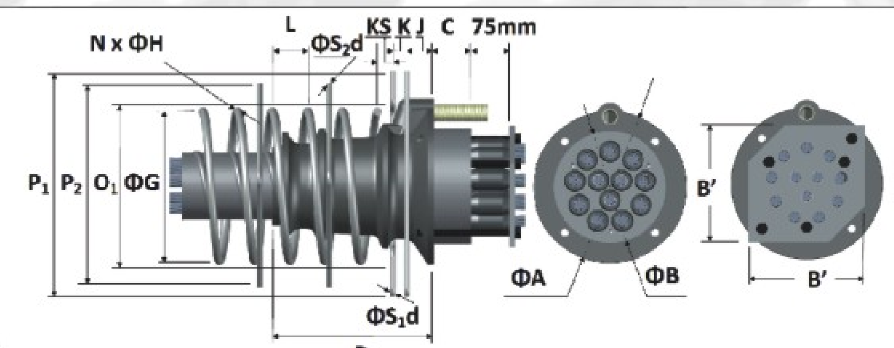
Side view – Fig. 13D

Technical Cards LMK-FSB FIXED SWAGED BEARING

Table 7

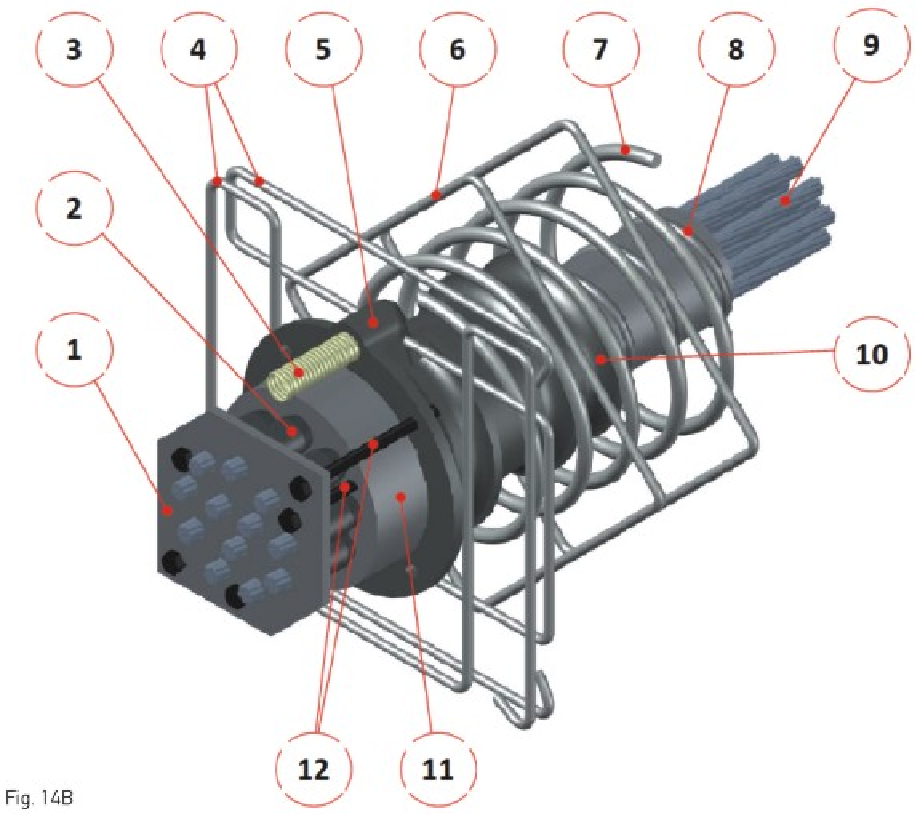
LMK - FSB	BEARING PLATE		ANCHOR HEAD		PRESSING BOARD		SPIRAL					W STIRRUPS						☐ STIRRUPS		
	ΦA	D	ΦB	C	B' x B'	t	ΦG	N	ΦH	L	KS	P_1	O_1	$ΦS_{1d}$	J	N	K	P_2	$ΦS_{2d}$	N
TYPE	mm	mm	mm	mm	mm x mm	mm	mm	Nos	mm	mm	mm	mm	mm	mm	mm	Nos	mm	mm	mm	Nos
3M15	140	125	91	35.5	135	8	180	5	10	50	20	160	125	6	50	1	--	--	--	--
4M15	140	125	102	35.5	150	8	210	5	10	50	25	165	125	6	50	1	--	--	--	--
5M15	180	130	117	40	170	8	230	6	10	50	25	200	160	8	70	1	--	--	--	--
6M15	180	170	126	45	180	8	260	6	10	50	25	220	160	8	70	1	--	--	--	--
7M15	180	170	126	45	180	8	280	6	10	50	25	220	160	8	70	1	--	--	--	--
8M15	210	190	136	50.5	195	8	300	6	12	60	25	260	195	8	70	2	30	--	--	--
9M15	210	190	146	50.5	215	8	320	6	12	60	25	265	195	8	70	2	30	--	--	--
10M15	225	230	156	50.5	230	8	330	6	12	60	25	290	195	8	70	2	30	--	--	--
11M15	225	230	166	55	240	8	350	6	12	60	30	300	195	8	70	2	30	--	--	--
12M15	225	230	166	55	240	8	370	8	12	60	30	310	195	8	70	2	30	--	--	--
13M15	255	250	170	60	245	8	380	8	12	60	30	330	200	10	90	2	30	--	--	--
14M15	255	250	176	60	250	8	400	8	12	60	30	340	200	10	90	2	30	--	--	--
15M15	255	250	186	60	255	8	400	8	14	60	30	340	200	10	90	2	30	--	--	--
16M15	280	325	196	60	265	8	410	8	14	60	30	370	215	12	100	2	30	--	--	--
17M15	280	325	196	60	265	8	430	8	14	60	30	375	215	12	100	2	30	--	--	--
18M15	280	325	206	60	270	8	440	8	14	60	30	380	215	12	100	2	30	--	--	--
19M15	280	325	206	60	270	8	450	9	14	60	30	385	215	12	100	2	30	--	--	--
20M15	310	325	226	60	300	8	450	9	16	60	30	410	255	12	100	2	30	--	--	--
21M15	310	325	226	60	300	8	450	9	16	60	30	415	255	12	100	2	30	--	--	--
22M15	310	325	226	60	300	8	460	10	16	60	30	420	255	12	100	2	30	400	8	2
23M15	340	325	244	70	315	8	460	10	16	60	35	450	275	14	135	2	30	400	8	2
24M15	340	325	244	70	315	8	470	10	16	60	35	455	275	14	135	2	30	400	8	2
25M15	340	325	244	75	315	8	470	10	16	60	35	460	275	14	135	2	30	400	8	2
26M15	340	325	244	75	315	8	480	10	16	60	35	465	275	14	135	2	30	400	8	2
27M15	340	325	244	80	315	8	480	11	16	60	35	470	275	14	135	2	30	450	10	3
28M15	360	400	260	80	330	8	490	11	16	60	35	500	315	14	130	2	35	450	10	3
29M15	360	400	260	80	330	8	490	11	16	60	35	510	315	14	130	2	35	450	10	3
30M15	360	400	260	80	330	8	500	11	16	60	35	515	315	14	130	2	35	450	10	3
31M15	360	400	260	80	330	8	500	12	16	60	35	515	315	14	130	2	35	450	12	3
32M15	405	450	296	95	440	8	510	12	16	60	40	540	350	16	160	2	40	500	12	4
33M15	405	450	296	95	440	8	510	12	16	60	40	545	350	16	160	2	40	500	12	4
34M15	405	450	296	95	440	8	510	12	16	60	40	550	350	16	160	2	40	500	12	4
35M15	405	450	296	100	440	8	520	12	18	60	40	555	350	16	160	2	40	500	12	4
36M15	405	450	296	100	440	8	520	12	18	60	40	560	350	16	160	2	40	500	12	4
37M15	405	450	296	100	440	8	520	12	18	60	40	565	350	16	160	2	40	500	12	4

Recommended values for Spiral & Stirrups Please refer to Table 5B for type M13



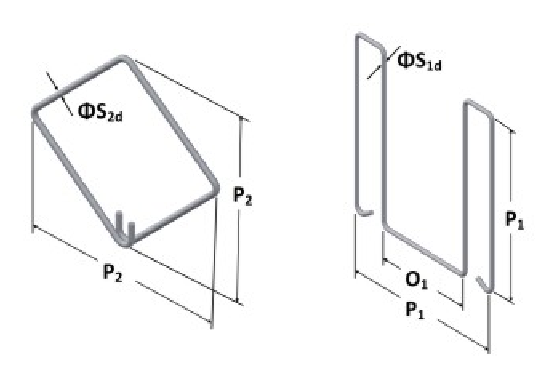
Side view - Fig. 14A

LMK - FSB - FIXED SWAGED WITH BEARING PLATE ANCHORAGE



Axonometric View - Fig. 14B

BURSTING REINFORCEMENT



☐ STIRRUPS W STIRRUPS

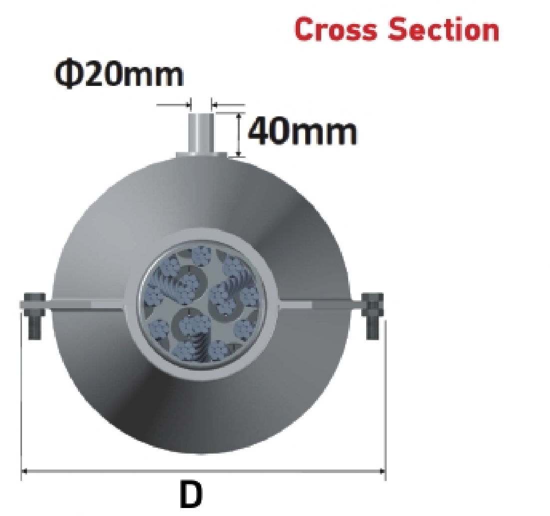
S/N	DESCRIPTION
1-	PRESSING BOARD
2-	SWAGES
3-	GROUTING TUBE
4-	W STIRRUPS
5-	GROUTING PORT
6-	☐STIRRUPS
7-	SPIRAL REINFORCEMENT
8-	CORRUGATED SHEATH
9-	STRANDS
10-	BEARING PLATE
11-	ANCHOR HEAD
12-	CONNECTING BOLTS

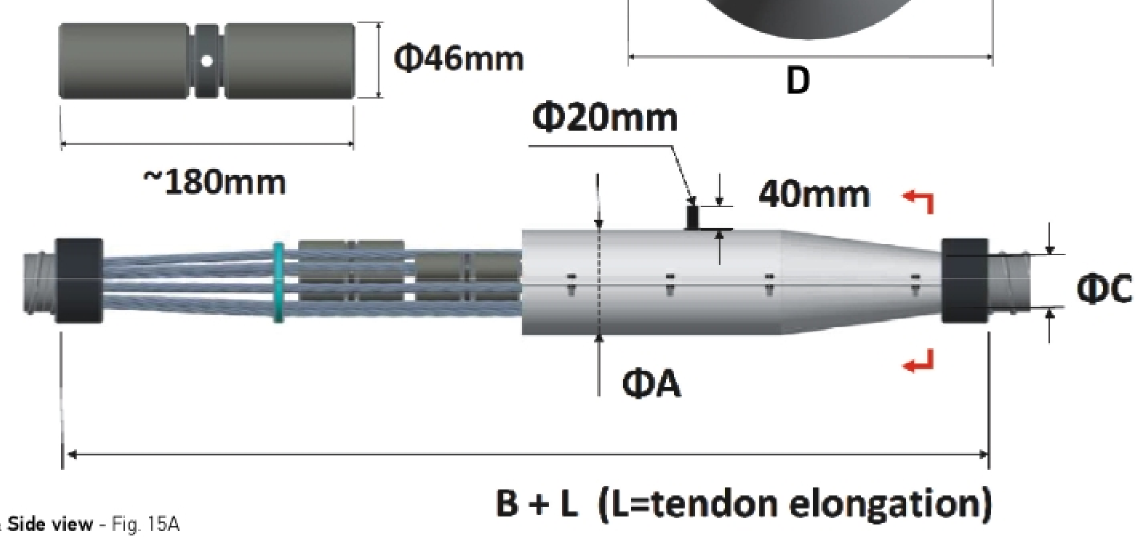
- Corrugated sheath diameter can be modified according to design requirements
- Stirrups can be modified according to design requirements
- Additional ☐ stirrups distributed along the spiral length

Technical Cards LMK-MC MOVABLE COUPLER

Table 8

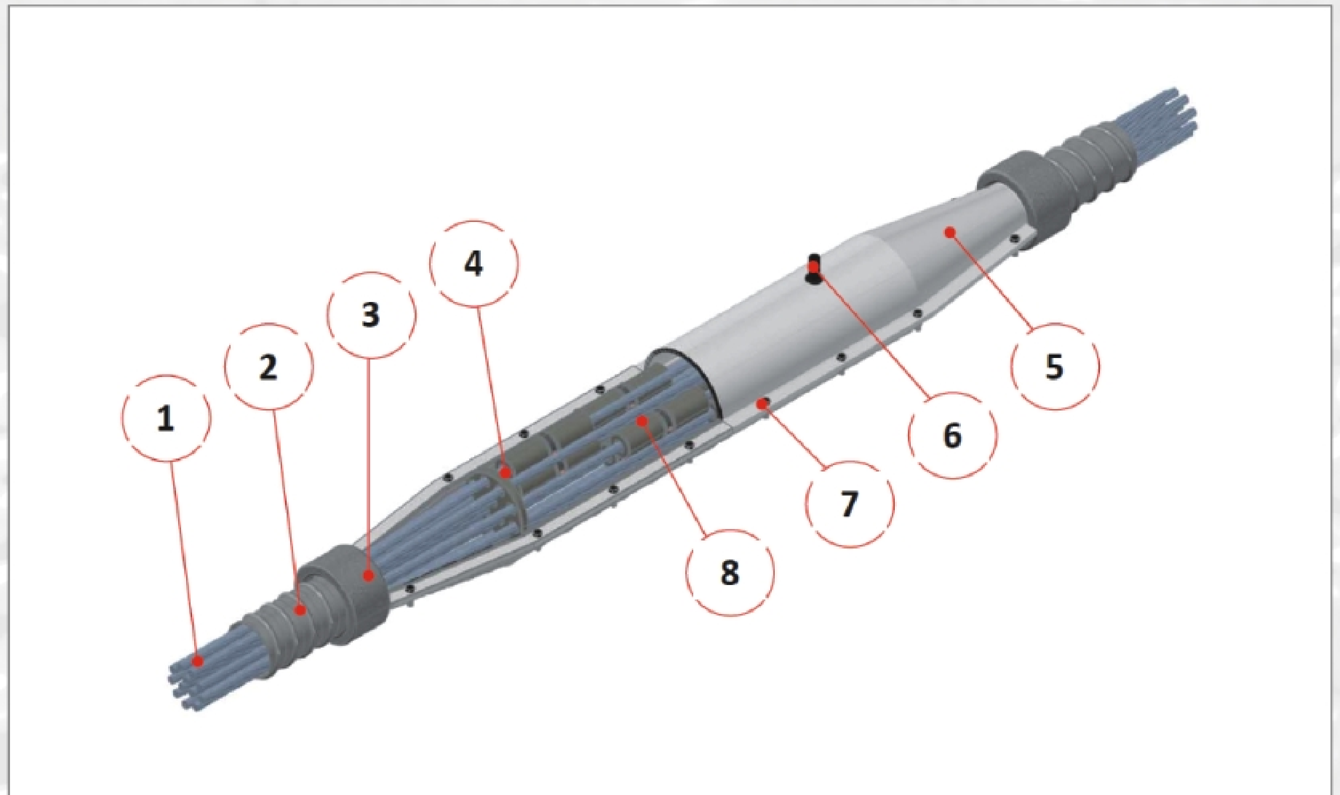
LMK - MC	PROTECTIVE COVER			
TYPE	ΦA mm	B mm	C mm	D mm
2~3M15	101	965	62	169
4M15	112	1205	62	180
5M15	125	1260	62	193
6~7M15	136	1300	76	204
8~9M15	156	1380	86	224
10~12M15	177	1430	96	245
13~14M15	187	1540	106	255
15M15	197	1570	106	265
16~19M15	217	1635	106	285
20~22M15	237	1705	106	305
23~27M15	256	1840	126	324
28~31M15	272	1855	136	340
32~37M15	308	2070	140	376



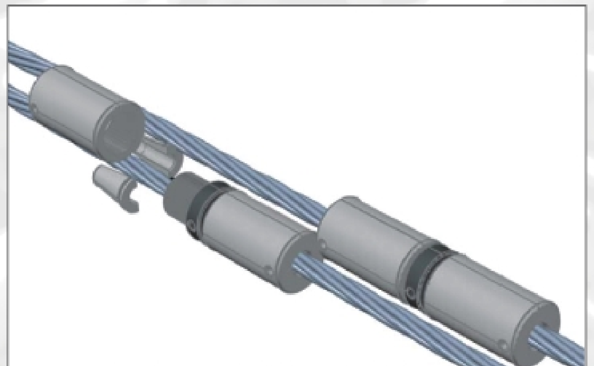


Mono-coupler & Side view - Fig. 15A

LMK - MC - MOVABLE COUPLER



Axonometric view - Fig. 15-B



Mono-coupler Axonometric View - Fig. 15C

S/N	DESCRIPTION
1-	STRANDS
2-	CORRUGATED SHEATH
3-	COLLAR
4-	SPREADING BOARD
5-	PROTECTIVE UPPER & LOWER COVER
6-	GROUTING PORT
7-	CONNECTION BOLTS & NUTS
8-	STRAND MONO-COUPLER

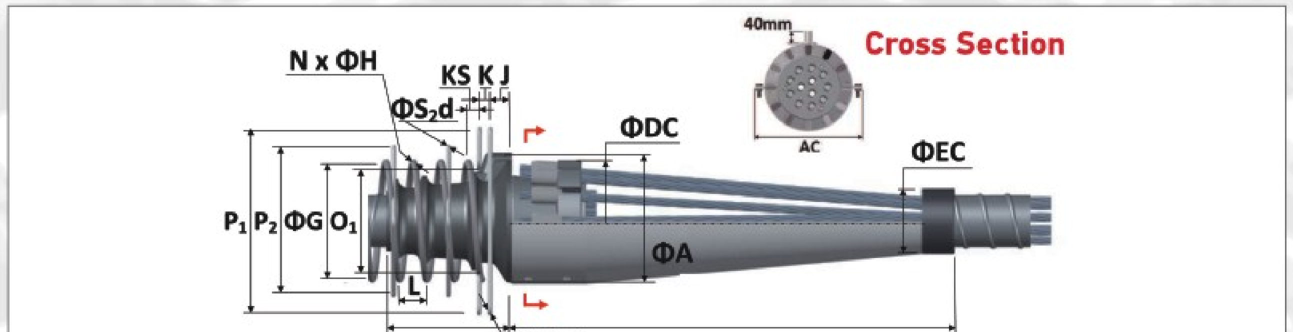
- Corrugated sheath diameter can be modified according to design requirements

Technical Cards LMK-FC FIXED COUPLER

Table 9

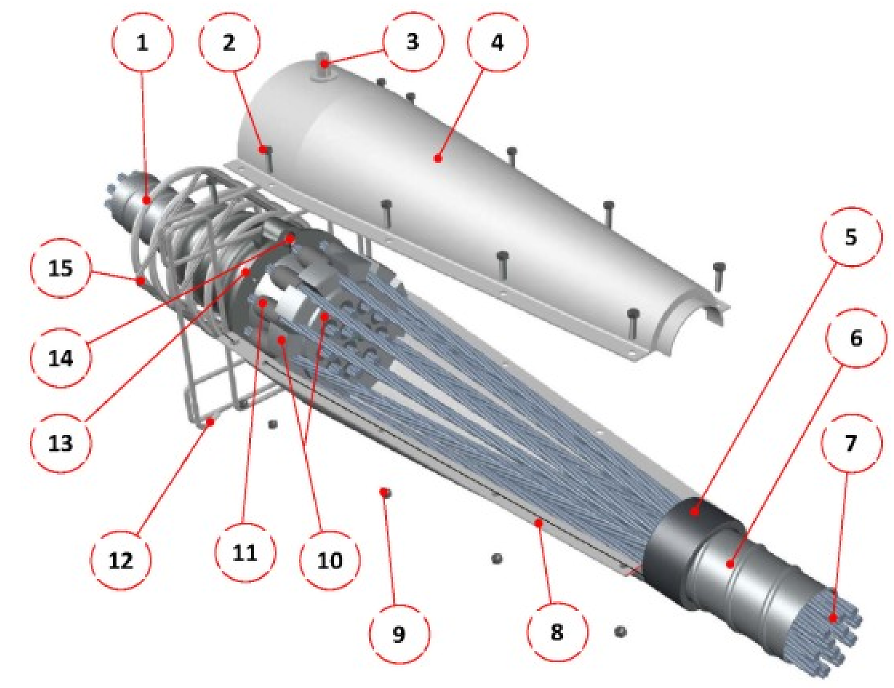
LMK - FC	BEARING PLATE		COUPLER BEARING PLATE & PROTECTIVE COVER				SPIRAL					W STIRRUPS						☐ STIRRUPS		
	ΦA	D	AC	BC	ΦDC	ΦEC	ΦG	N	ΦH	L	KS	P1	O1	ΦS1d	J	N	K	P2	ΦS2d	N
TYPE	mm	mm	mm	mm	mm	mm	mm	Nos	mm	mm	mm	mm	mm	mm	mm	Nos	mm	mm	mm	Nos
2M15	140	125	216	590	140	80	140	5	10	50	20	155	120	6	50	1	--	--	--	--
3M15	140	125	220	590	140	80	180	5	10	50	20	160	125	6	50	1	--	--	--	--
4M15	140	125	232	660	155	85	210	5	10	50	25	165	125	6	50	1	--	--	--	--
5M15	180	170	244	722	170	96	230	6	10	50	25	200	160	8	70	1	--	--	--	--
6M15	180	170	258	722	183	100	260	6	10	50	25	220	160	8	70	1	--	--	--	--
7M15	180	170	258	722	183	100	280	6	10	50	25	220	160	8	70	1	--	--	--	--
8M15	225	230	266	739	198	116	300	6	10	60	25	260	195	8	70	2	30	--	--	--
9M15	225	230	276	783	207	116	320	6	12	60	25	265	195	8	70	2	30	--	--	--
10M15	225	230	288	809	223	120	330	6	12	60	25	290	195	8	70	2	30	--	--	--
11M15	225	230	298	809	223	120	350	6	12	60	30	300	195	8	70	2	30	--	--	--
12M15	225	230	298	809	223	120	370	8	12	60	30	310	195	8	70	2	30	--	--	--
13M15	255	290	302	809	223	140	380	8	12	60	30	330	200	10	90	2	30	--	--	--
14M15	255	290	308	809	233	140	400	8	12	60	30	340	200	10	90	2	30	--	--	--
15M15	255	290	320	915	255	140	400	8	14	60	30	340	200	10	90	2	30	--	--	--
16M15	280	235	330	915	255	140	410	8	14	60	30	370	215	12	100	2	30	--	--	--
17M15	280	235	330	915	255	140	430	8	14	60	30	375	215	12	100	2	30	--	--	--
18M15	280	325	336	932	260	140	440	8	14	60	30	380	215	12	100	2	30	--	--	--
19M15	280	325	336	932	260	140	450	9	14	60	30	385	215	12	100	2	30	--	--	--
20M15	310	325	356	1020	280	166	450	9	16	60	30	410	255	12	100	2	30	--	--	--
21M15	310	325	356	1020	280	166	450	9	16	60	30	415	255	12	100	2	30	--	--	--
22M15	310	325	356	1020	280	166	460	10	16	60	30	420	255	12	100	2	30	400	8	2
23M15	340	430	386	1074	310	180	460	10	16	60	35	450	275	14	135	2	30	400	8	2
24M15	340	430	386	1074	310	180	470	10	16	60	35	455	275	14	135	2	30	400	8	2
25M15	340	430	386	1074	310	180	470	10	16	60	35	460	275	14	135	2	30	400	8	2
26M15	340	430	386	1074	310	180	480	10	16	60	35	465	275	14	135	2	30	400	8	2
27M15	340	430	386	1074	310	180	480	11	16	60	35	470	275	14	135	2	30	450	10	3
28M15	360	415	434	1241	358	180	490	11	16	60	35	500	315	14	130	2	35	450	10	3
29M15	360	415	434	1241	358	180	490	11	16	60	35	510	315	14	130	2	35	450	10	3
30M15	360	415	434	1241	358	180	500	11	16	60	35	515	315	14	130	2	35	450	10	3
31M15	360	415	434	1241	358	180	500	12	16	60	35	515	315	14	130	2	35	450	12	3

Recommended values for Spiral & Stirrups

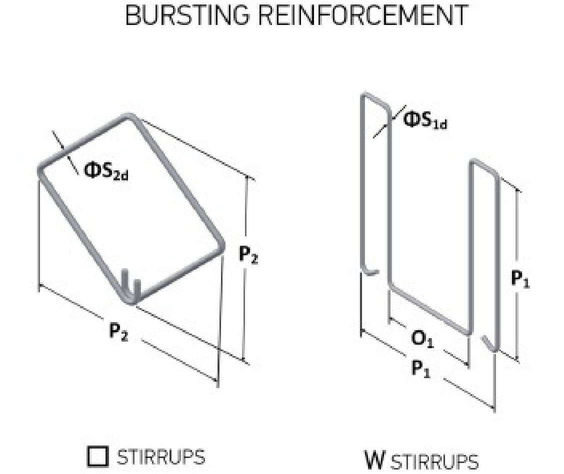


Side view - Fig. 16A

LMK - FC - FIXED COUPLER



Axonometric View - Fig. 16B



S/N	DESCRIPTION
1-	SPIRAL REINFORCEMENT
2-	CONNECTION BOLTS
3-	GROUTING PORT
4-	UPPER PROTECTIVE COVER
5-	COLLAR
6-	CORRUGATED SHEATH
7-	STRANDS
8-	LOWER PROTECTIVE COVER
9-	NUTS
10-	COUPLING HEAD & WEDGES
11-	SWAGES
12-	W STIRRUPS
13-	BEARING PLATE
14-	GROUTING PORT
15-	☐STIRRUPS

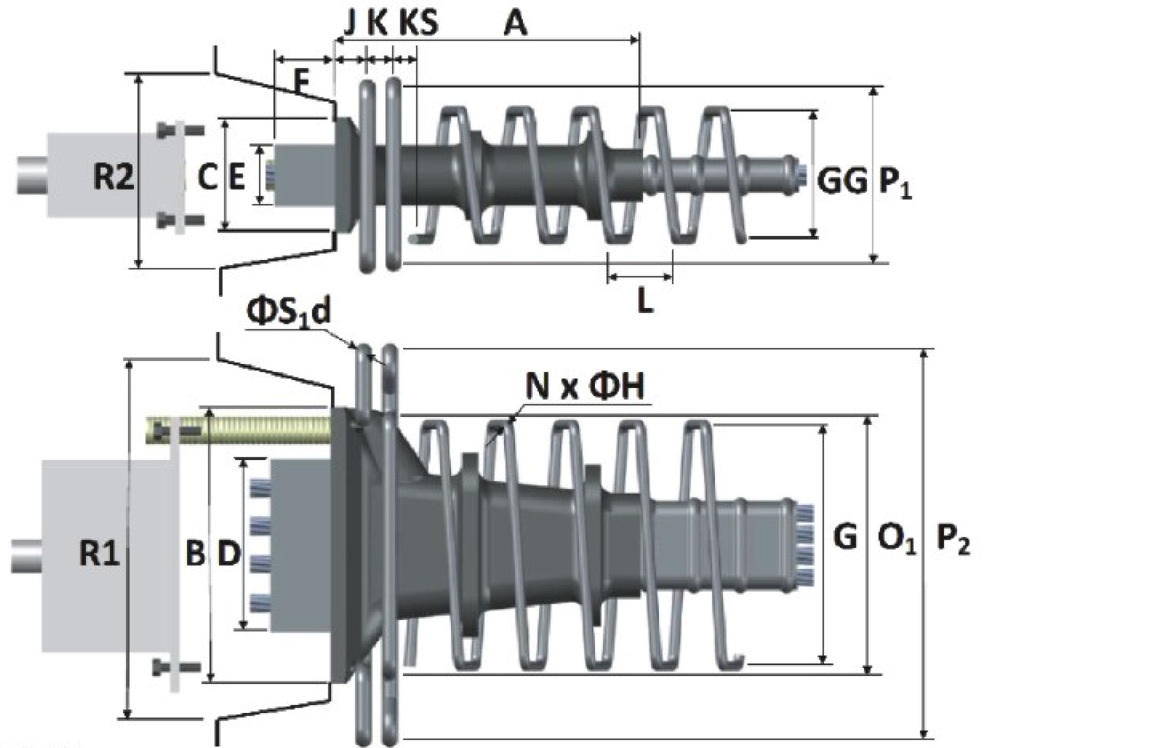
- Corrugated sheath diameter can be modified according to design requirements
- Ensure proper anchorage distance X_2 when simultaneously stressing
- Stirrups can be modified according to design requirements
- Additional ☐ stirrups distributed along the spiral length

Technical Cards LMK-SFL STRESSING FLAT

Table 10

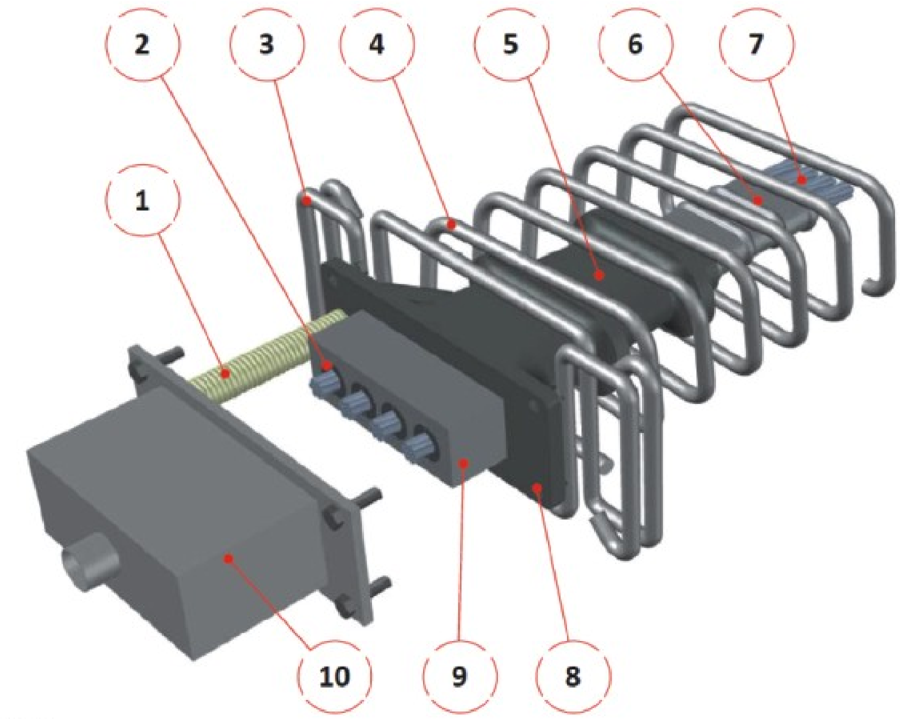
LMK - SFL	BEARING PLATE			ANCHOR HEAD			SPIRAL						W STIRRUPS							RECESS	
	A	B	C	D	E	F	G	GG	N	ΦH	L	KS	P1	P2	O1	ΦS_1d	J	N	K	R_1	R_2
TYPE	mm	mm	mm	mm	mm	mm	mm	mm	Nos	mm	mm	mm	mm	mm	mm	mm	mm	Nos	mm	mm	mm
2M15	150	160	90	80	48	50	150	120	5	12	50	20	95	300	170	8	35	2	20	170	90
2M13	120	150	70	80	48	50	150	120	5	10	50	20	95	300	170	8	35	2	20	150	90
3M15	190	200	90	115	48	50	190	120	5	12	50	20	95	300	190	8	60	2	20	210	90
3M13	150	180	70	115	48	50	190	120	5	10	50	20	95	300	190	8	60	2	20	170	90
4M15	235	240	90	150	48	50	230	120	6	12	50	25	120	350	200	12	80	2	20	250	90
4M13	210	220	70	150	48	50	230	120	6	10	50	25	120	350	200	12	80	2	20	230	90
5M15	270	270	90	185	48	50	260	120	6	14	50	25	120	350	240	12	90	2	20	280	90
5M13	250	260	70	185	48	50	260	120	6	12	50	25	120	350	240	12	90	2	20	260	90

Recommended values for Spiral, Stirrups & Recess



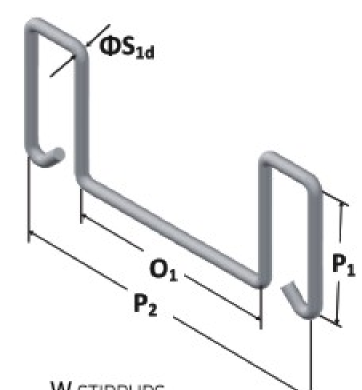
Side view - Fig. 17A

LMK - SFL - STRESSING FLAT ANCHORAGE



Axonometric View - Fig. 17B

BURSTING REINFORCEMENT



W STIRRUPS

S/N	DESCRIPTION
1-	GROUTING TUBE
2-	WEDGES
3-	W STIRRUPS
4-	SPIRAL REINFORCEMENT
5-	BEARING PLATE
6-	CORRUGATED SHEATH
7-	STRANDS
8-	CONNECTION HOLES
9-	ANCHOR HEAD
10-	GROUTING CAP

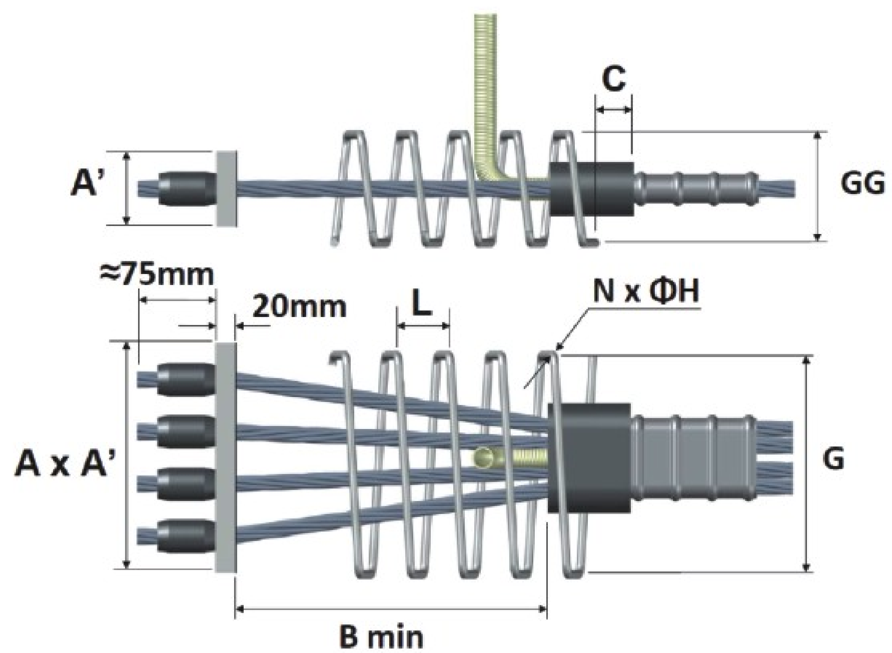
- Corrugated sheath diameter can be modified according to design requirements
- Stirrups can be modified according to design requirements

Technical Cards LMK-FFL FIXED SWAGED FLAT

Table 11

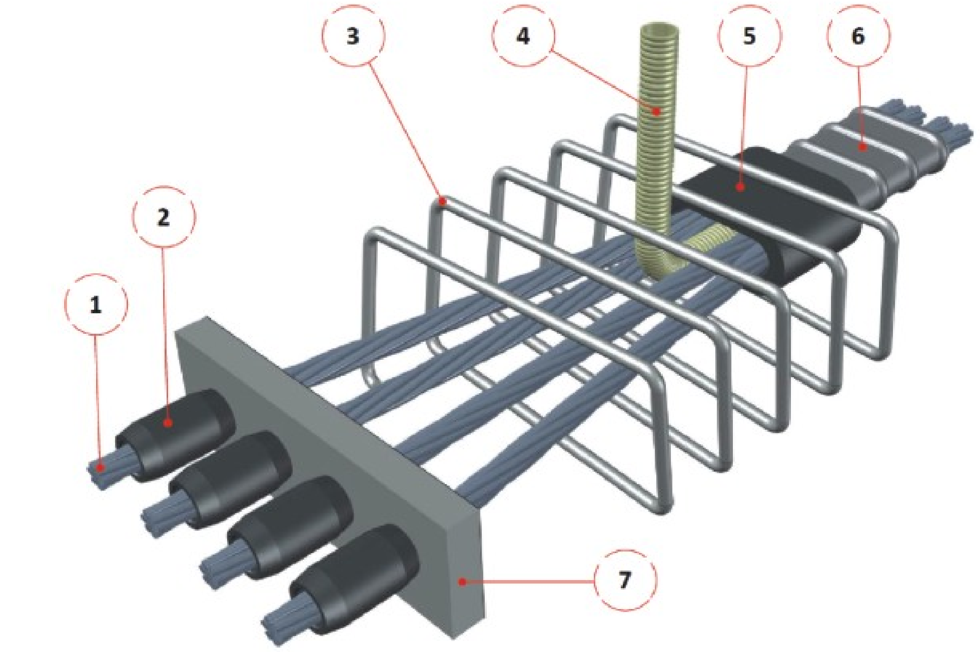
LMK - FFL	ANCHOR HEAD		SPIRAL					DIMENSIONS	
	A	A'	G	GG	N	ΦH	L	Bmin	C
TYPE	mm	mm	mm	mm	Nos	mm	mm	mm	mm
2M13/15	140	70	130	100	5	12	50	190	50
3M13/15	180	70	170	100	5	12	50	250	50
4M13/15	220	70	210	100	6	12	50	320	50
5M13/15	260	70	250	100	6	14	50	400	50

Recommended values for Spiral



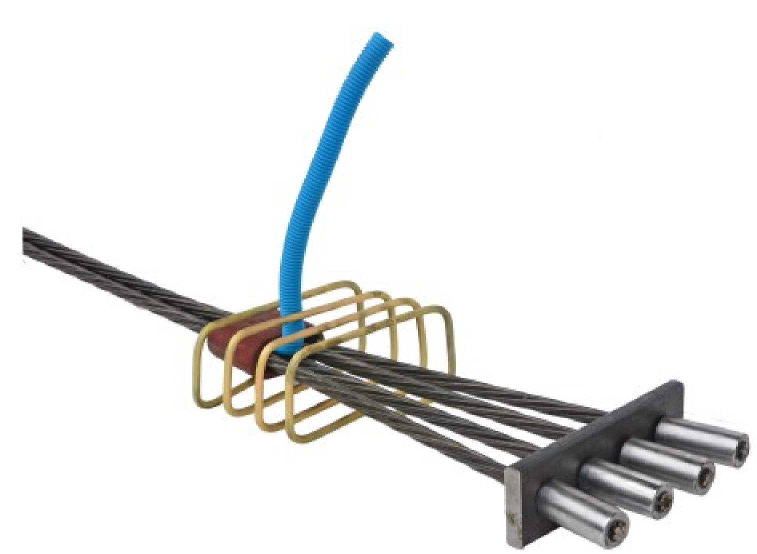
Side view - Fig. 18A

LMK - FFL - FIXED SWAGED FLAT ANCHORAGE



Axonometric View - Fig. 18B

- Corrugated sheath diameter can be modified according to design requirements



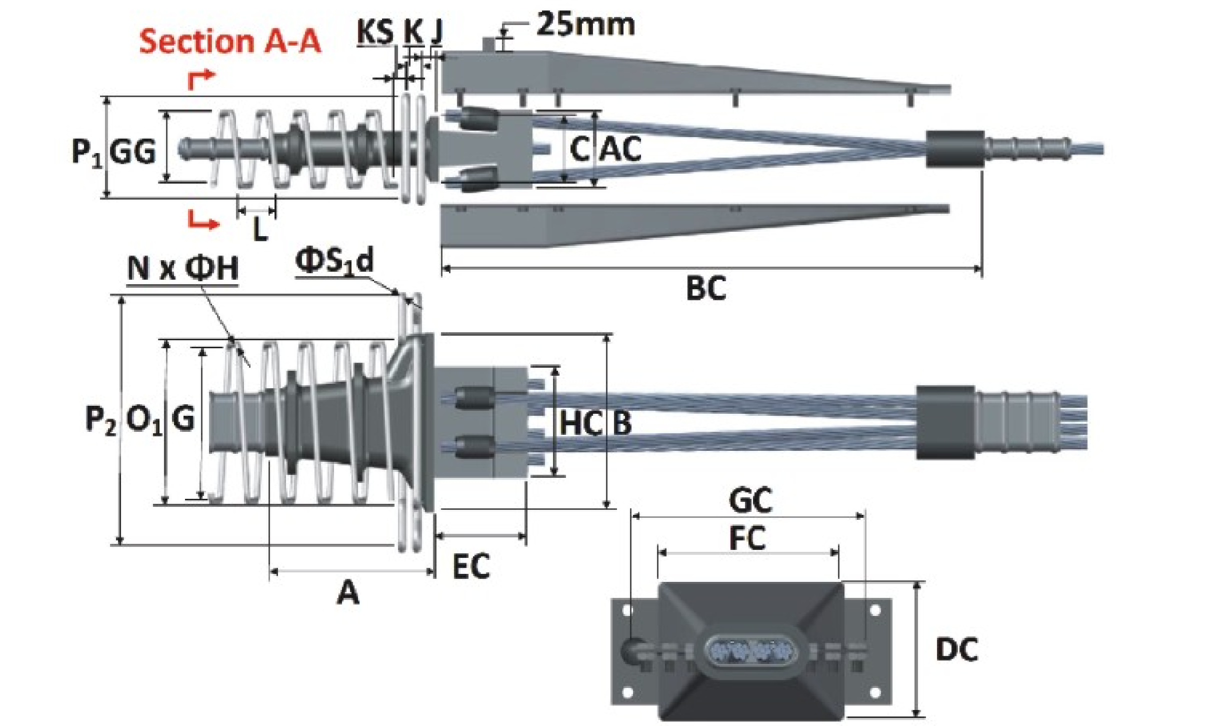
S/N	DESCRIPTION
1-	STRANDS
2-	SWAGES
3-	SPIRAL REINFORCEMENT
4-	GROUTING TUBE
5-	COLLAR
6-	CORRUGATED SHEATH
7-	ANCHOR HEAD

Technical Cards LMK-FFC FIXED FLAT COUPLER

Table 12

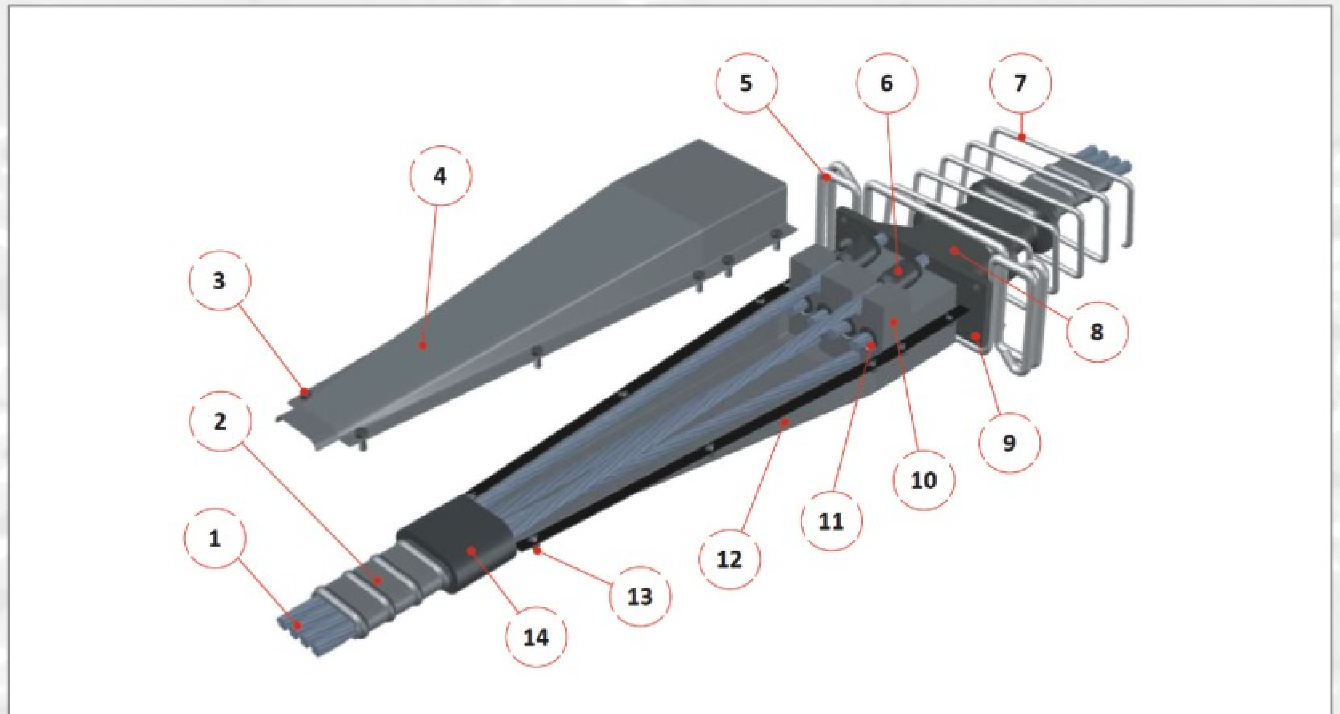
LMK - FFC	BEARING PLATE			COUPLING HEAD & PROTECTIVE COVER							SPIRAL						W STIRRUPS						
	A	B	C	AC	BC	DC	EC	FC	GC	HC	G	GG	N	ΦH	L	KS	P1	P2	O1	$\Phi S_1 d$	J	N	K
TYPE	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	Nos	mm	mm	mm	mm	mm	mm	mm	mm	Nos	mm
2M15	150	160	90	100	700	118	135	90	130	80	150	120	5	12	50	20	95	300	170	8	35	2	20
2M13	120	150	70	100	700	118	135	90	130	80	150	120	5	10	50	20	95	300	170	8	35	2	20
3M15	190	200	90	100	700	118	135	125	165	115	190	120	5	12	50	20	95	300	190	8	60	2	20
3M13	150	180	70	100	700	118	135	125	165	115	190	120	5	10	50	20	95	300	190	8	60	2	20
4M15	235	240	90	100	750	118	135	160	200	150	230	120	6	12	50	25	120	350	200	12	80	2	20
4M13	210	220	70	100	750	118	135	160	200	150	230	120	6	10	50	25	120	350	200	12	80	2	20
5M15	270	270	90	100	750	118	135	195	235	185	260	120	6	14	50	25	120	350	240	12	90	2	20
5M13	250	260	70	100	750	118	135	195	235	185	260	120	6	12	50	25	120	350	240	12	90	2	20

Recommended values for Spiral & Stirrups

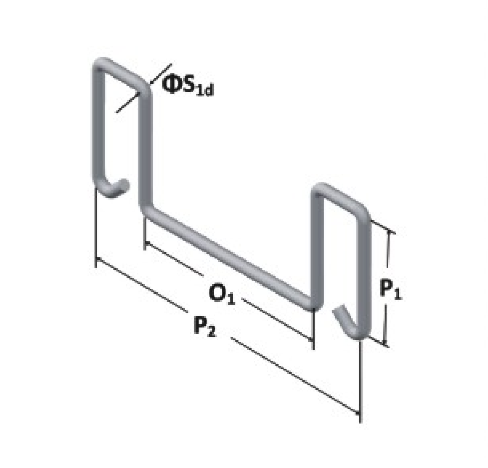


Side view - Fig. 19A

LMK - FFC - FIXED FLAT COUPLER



Axonometric View - Fig. 19B



- Corrugated sheath diameter can be modified according to design requirements
- Stirrups can be modified according to design requirements

S/N	DESCRIPTION
1-	STRANDS
2-	CORRUGATED SHEATH
3-	CONNECTION BOLTS
4-	UPPER PROTECTIVE COVER
5-	W STIRRUPS
6-	SWAGES
7-	SPIRAL REINFORCEMENT
8-	BEARING PLATE
9-	CONNECTION HOLES
10-	COUPLING HEAD
11-	WEDGES
12-	LOWER PROTECTIVE COVER
13-	NUTS
14-	COLLAR

Stressing Equipment

TENSIONING JACKS

The post tensioning jacks and pumps are especially studied and manufactured in order to reduce their weight and their volume for an easier handling and a practical use/operation. Pumps have high pressure capacity and flow rate so as to promptly respond when using jacks of big capacity and long piston stroke.

The bundle of strands passes through the jack and the applied pressure on each strand is the same at the entire group of strands. Depending on the type of jacks (front or rear locking), stressing heads, rings and spacers are used for tensioning.

When the required elongation and load are reached, the pressure is released and thus the load is transferred to the anchor head through wedges achieving the same wedge draw-in to all strands. The tensioning can be accomplished in more than one steps depending on the required elongation and piston stroke capacity.

Upon requirement, one by one tensioned stands can be released using a proper releasing device (mono-strand jack).

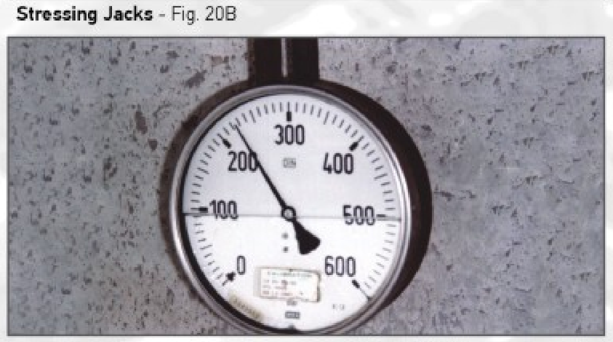
The swaged fixed anchorages are greeping the swaged head onto the strand edge by cold extruding process.

Each jack is connected through a system of high pressure hoses to a pump. The developed pressure is monitored during stressing operation using pressure gauges.

All pressure gauges are calibrated at LMK's facilities and certified by a master gauge determining the pressure-load calibration table. The maintenance and repair of hydraulic equipment is following a strict and frequent routine inspection schedule.

Front Locking Jack - Fig. 20A

Stressing Jacks - Fig. 20B



Pressure Gauge - Fig. 20C

Stressing Jacks

TECHNICAL CHARACTERISTICS & CLEARANCE REQUIREMENTS

The selection of jack type depends on the required by the design stressing load per tendon and the clearance on the spot. The below Table 13 considers indicative maximum applied load per strand not exceeding 240KN.

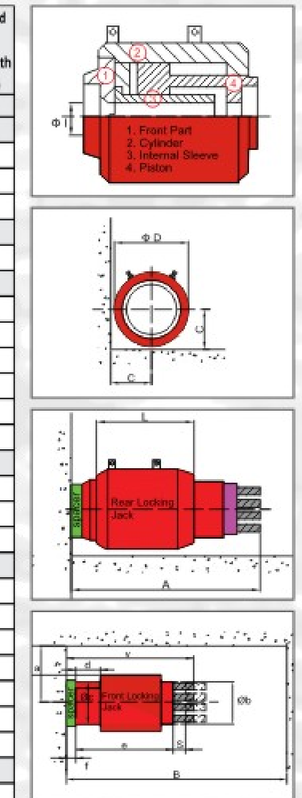
FRONT & REAR LOCKING JACKS

Table 13

Jack Type	Front or Rear Locking	Nominal Stressing Force	Strand Diameter	Nos. of strands	Nominal Pressure	Piston area	Back piston area	Back pressure	Internal Sleeve Diameter ΦI	Stroke (S)	Overall Dimensions L x ΦD (Φb x e)	Weight	Required Clearance B x C (a-Φc-d-f-B)	Required Strand Overlength A or (v)
		KN	mm	Nos	Mpa	m²	m²	Mpa	mm	mm	mmxmm	Kg	mm x mm	mm
ETS1.6/1	F	240	15.2 / 15.7	1	46	0.2383×10^{-2}	--	--	--	195	(Φ98x645)	16	(--)	(450)
YCD260Q-200	R	264	15.2 / 15.7	1	48	5.498×10^{-3}	1.413×10^{-3}	<25	19	200	540×Φ115	23	700x90	450
YCW60C	R	600	15.2 / 15.7	2	52	1.154×10^{-2}	0.408×10^{-2}	<25	58	200	356×Φ168	40	1270x120	590
L4.6/4	F	900	15.2 / 15.7	4	58	1.5892×10^{-2}	--	--	--	125	(Φ175x434)	55	(90-Φ140-155-75)	(450)
YCW100C	R	992	15.2 / 15.7	3-4	52	1.908×10^{-2}	0.777×10^{-2}	<25	78	200	353×Φ216	65	1220x150	570
YCW150C	R	1512	15.2 / 15.7	5-6	50	3.024×10^{-2}	1.610×10^{-2}	<25	102	200	369×Φ280	110	1250x190	570
L7.6/7	F	1570	15.2 / 15.7	7	64	2.5239×10^{-2}	--	--	--	125	(Φ220x447)	80	(110-Φ175-155-75)	(460)
YCW150C	R	1512	15.2	7	50	3.024×10^{-2}	1.610×10^{-2}	<25	102	200	369×Φ280	110	1250x190	570
YCW200C	R	1960	15.7	7	52	3.769×10^{-2}	1.845×10^{-2}	<25	118	200	372×Φ310	140	1270x210	590
YCW200C	R	1960	15.2 / 15.7	8	52	3.769×10^{-2}	1.845×10^{-2}	<25	118	200	372×Φ310	140	1270x210	590
YCW200C	R	1960	15.2	9	52	3.769×10^{-2}	1.845×10^{-2}	<25	118	200	372×Φ310	140	1270x210	590
YCW250C	R	2480	15.7	9	54	4.594×10^{-2}	2.804×10^{-2}	<25	140	200	371×Φ345	165	1270x220	590
YCW250C	R	2480	15.2 / 15.7	10-11	54	4.594×10^{-2}	2.804×10^{-2}	<25	140	200	371×Φ345	165	1270x220	590
L12.6/12	F	2700	15.2 / 15.7	12	63.5	4.3749×10^{-2}	--	--	--	125	(Φ285x468)	180	(130-Φ220-160-85)	(490)
YCW300C	R	2990	15.2 / 15.7	12-13	54	5.537×10^{-2}	3.024×10^{-2}	<25	140	200	375×Φ370	200	1320x250	620
YCW300C	R	2990	15.2	14	54	5.537×10^{-2}	3.024×10^{-2}	<25	140	200	375×Φ370	200	1320x250	620
YCW350C	R	3460	15.7	14	51	6.785×10^{-2}	4.311×10^{-2}	<25	165	200	389×Φ416	235	1354x255	620
L15.6/15	F	3400	15.2 / 15.7	15	63.5	5.4902×10^{-2}	--	--	--	125	(Φ320x497)	200	(150-Φ250-165-90)	(520)
YCW350C	R	3460	15.2 / 15.7	15	51	6.785×10^{-2}	4.311×10^{-2}	<25	165	200	389×Φ416	235	1354x255	620
YCW350C	R	3460	15.2	16	51	6.785×10^{-2}	4.311×10^{-2}	<25	165	200	389×Φ416	235	1354x255	620
YCW400C	R	3957	15.7	16	52	7.611×10^{-2}	4.595×10^{-2}	<25	175	200	389×Φ435	277	1320x265	620
YCW400C	R	3957	15.2 / 15.7	17	52	7.611×10^{-2}	4.595×10^{-2}	<25	175	200	389×Φ435	277	1320x265	620
YCW400C	R	3957	15.2	18-19	52	7.611×10^{-2}	4.595×10^{-2}	<25	175	200	389×Φ435	277	1320x265	620
YCW450C	R	4428	15.7	18-19	54	8.199×10^{-2}	5.183×10^{-2}	<25	175	200	389×Φ450	300	1320x275	620
L19.6/19	F	4300	15.2 / 15.7	19	63.5	7.0720×10^{-2}	--	--	--	125	(Φ360x490)	255	(160-Φ270-160-100)	(540)
YCW450C	R	4428	15.2 / 15.7	20	54	8.199×10^{-2}	5.183×10^{-2}	<25	175	200	389×Φ450	300	1320x275	620
YCW450C	R	4428	15.2	21	54	8.199×10^{-2}	5.183×10^{-2}	<25	175	200	389×Φ450	300	1320x275	620
YCW500C	R	4926	15.7	21	49	10.053×10^{-2}	4.775×10^{-2}	<25	196	200	430×Φ495	430	1484x295	620
L22.6/22	F	5000	15.2 / 15.7	22	63.5	7.9171×10^{-2}	--	--	--	125	(Φ385x525)	320	(180-Φ295-180-100)	(580)
YCW500C	R	4926	15.2 / 15.7	22	49	10.053×10^{-2}	4.775×10^{-2}	<25	196	200	430×Φ495	430	1484x295	620
YCW500C	R	4926	15.2	23	49	10.053×10^{-2}	4.775×10^{-2}	<25	196	200	430×Φ495	430	1484x295	620
YCW600C	R	5929	15.7	23	49	12.1×10^{-2}	6.825×10^{-2}	<25	196	200	430×Φ525	480	2000x330	850
YCW600C	R	5929	15.2 / 15.7	24-25-26	49	12.1×10^{-2}	6.825×10^{-2}	<25	196	200	430×Φ525	480	2000x330	850
YCW600C	R	5929	15.2	27-28	49	12.1×10^{-2}	6.825×10^{-2}	<25	196	200	430×Φ525	480	2000x330	850
YCW650C	R	6590	15.7	27-28	50	13.18×10^{-2}	6.754×10^{-2}	<25	220	200	450×Φ570	650	2050x355	900
YCW650C	R	6590	15.2 / 15.7	29	50	13.18×10^{-2}	6.754×10^{-2}	<25	220	200	450×Φ570	650	2050x355	900
YCW650C	R	6590	15.2	30	50	13.18×10^{-2}	6.754×10^{-2}	<25	220	200	450×Φ570	650	2050x355	900
YCW700C	R	6975	15.7	30	50	13.95×10^{-2}	7.516×10^{-2}	<25	220	200	450×Φ580	660	2050x365	900
L31.6/31	F	6950	15.2 / 15.7	31	63.5	11.1872×10^{-2}	--	--	--	125	(Φ455x552)	480	(200-Φ340-180-120)	(650)
YCW700C	R	6975	15.2 / 15.7	31	50	13.95×10^{-2}	7.516×10^{-2}	<25	220	200	450×Φ580	660	2050x365	900
YCW700C	R	6975	15.2	32-33	50	13.95×10^{-2}	7.516×10^{-2}	<25	220	200	450×Φ580	660	2050x365	900
YCW800C	R	8150	15.7	32-33	50	16.3×10^{-2}	7×10^{-2}	<25	250	200	510×Φ650	930	2200x430	1000
YCW800C	R	8150	15.2 / 15.7	34-35	50	16.3×10^{-2}	7×10^{-2}	<25	250	200	510×Φ650	930	2200x430	1000
YCW800C	R	8150	15.2	36-37	50	16.3×10^{-2}	7×10^{-2}	<25	250	200	510×Φ650	930	2200x430	1000
YCW900C	R	9190	15.7	36-37	50	18.38×10^{-2}	7×10^{-2}	<25	280	200	510×Φ690	980	2200x450	1000

Table 14 - Swaged Jack

Nos. of Strands	Extrusion Force	Internal Sleeve Diameter	Overall Dimensions	Extrusion Distance
1	F (KN)	Ø I (mm)	L x ØD (mm x mm)	(mm)
Swaged jack	503	30	565 x 150	150

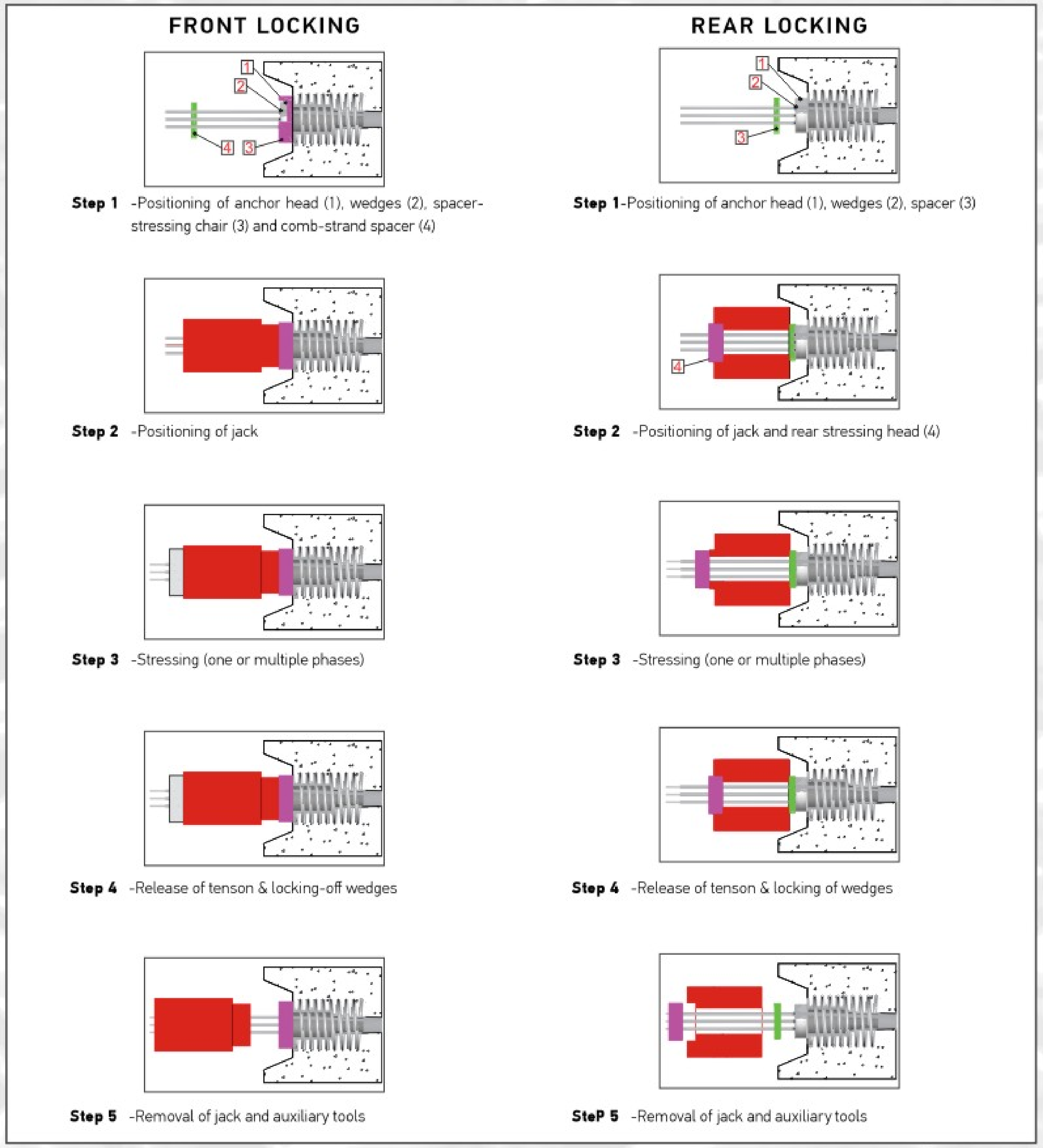


Required Jacks Clearance - Fig. 21

Stressing Operation

TENSIONING PROCEDURE

The technical cards of anchorages specify the recommended concrete clearance required for the proper installation of all types of jacks depending on the types of anchorages. When using hollow type jacks (rear locking) or front locking jacks the following typical procedure is applied.



Tensioning Procedure - Fig. 22

Tendon Force Losses

IN BRIEF

The effective stressing force differs from the initial stressing force for various reasons. Significant factors include:

Short Term -Friction losses in the anchorage and due to curvature of tendons
-Concrete elastic deformation
-Wedges draw-in

Long Term -Shrinkage & creep of concrete
-Relaxation of strand

The friction losses in the anchorage due to adjustment of the anchor head on the bearing plate and the curvature and friction of the strand in the wedges contribute usually to a value up to 4% of the jacking force depending on the type of anchorage and tendon.

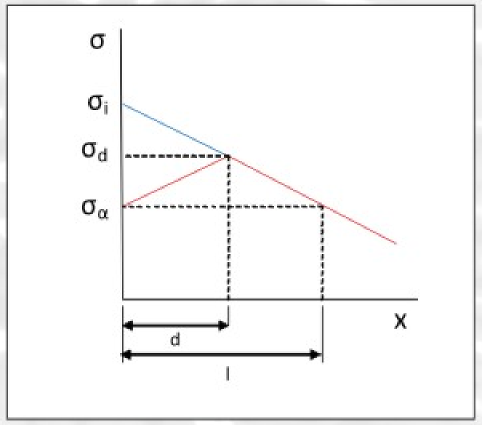
After the wedges are finally locked, they slightly recede into the anchor head causing a loss of tension at the back of the anchorage. This tension loss should be taken into account to the calculations, especially in tendons of short length (<15m) and can be completely or partially compensated with over-stressing. The compensation of the wedge draw-in should be mentioned in the tensioning protocol. The wedge draw-in is 4~5 mm.

For calculating the losses due to shrinkage and creep of the concrete, reference should be made to the technical literature and the standards applicable to project.

All tendons in a section commonly are not stressed simultaneously, therefore there are losses of prestress due to elastic shortening of the concrete caused by the progressive tendons stress application.

The relaxation of the strands depends primarily upon the type of steel (relaxation class), the magnitude of the prestress and the temperature. For low relaxation class strands, the max losses are about 2,5% after 1000h @ 20°C and an initial stress of about 70% of the nominal tensile strength. Further information can be obtained in the relevant steel strands technical literature.

Where:
r = wedge draw-in
l = tendon length where we know the tension
(the cable length can be used)
σ_l = the tension at distance l from the anchorage
σ_i = the tension at the jack
E = Elasticity modulus of strand
(where E ≈ 195 GPa-KN/mm^2)
d = the affected tendon length by the wedge draw-in
σ_a = the tension of the tendon after the wedge draw-in
σ_d = the tension of the tendon at distance d from the anchor



$$d = \sqrt{\frac{r * E * l}{\sigma_i - \sigma_l}} \qquad \sigma_a = \sigma_i - \frac{2 * r * E}{d} \qquad \sigma_d = \frac{\sigma_i + \sigma_a}{2}$$

Losses Graph - Fig. 23

Friction Losses along the Tendon

BASIC CALCULATIONS

To calculate the tension σ in the section X at distance x from the nearest stressing anchorage, the following formula can be utilized:

$$\sigma_x = \sigma_i e^{-\mu(\alpha+\kappa x)}$$

where:

σ_i = tension at the anchorage

x = cable length (m) from the anchorage to section X

α = the total angle of the deviation (rad) between the anchorage and section X.

μ = friction coefficient between strand and sheath (rad^{-1}).

κ = coefficient of unintentional angular deviation (rad / m).

The friction coefficient μ depends on various factors such as strand and sheath nature and contact surfaces conditions, number of strands, bending radius, tensioning force, type of stressing (external-internal), duct stiffness, lubrication of strands etc.

The coefficient of unintentional angular deviation κ depends on the way to install the cables, the sheath stiffness, the distance between stirrups supports etc.

The following values may be assumed for design:

For bare non-lubricated strands:

Steel ducts:	μ = 0,20 rad^{-1}	κ = 0,009 rad/m
Plastic ducts:	μ = 0,14 rad^{-1}	κ = 0,006 rad/m

For un-bonded strands:

μ = 0,06 rad^{-1} κ = 0,01 rad/m

Finally the tendon's elongation Δx is given by the formula:

$$\Delta x = \int_0^x \frac{\sigma_x}{E} dx$$

Elongation Recording

Grouting

PROCESS

The quality of the produced grout complies with Int'l standards and specifications, since every grout composition is tested to LMK's facilities prior to site application. Duct grout shall be a mixture of Portland cement and water and may contain admixtures such as expanding grout and water reducing/plasticisers subject to approval. The grout shall be free from chlorides, nitrates or other chemicals causing steel corrosion.

Tendons are grouted immediately after sealing the recess in the anchorage zone with concrete or using grouting caps, but not earlier than 12 hours after the stressing operation. The grout will flow from the lowest to highest elevation point of tendon's geometry.

Prior to grouting, it is recommended to check the tendons for possibly blockage using compressed air. Water is not recommended in order to avoid strand corrosion in case of a blocked tendon. When fixed type couplers are used, the grouting of the previous tendon section will be preceded the tensioning of the next in line section.

The grouting equipment has to produce grout that fulfils the requirements of the projects. The grouted tendon will remain under pressure of 5 bar for at least one minute, having all its grouting ports closed/sealed, in order to assure the tightness of the tendon. The specially designed grouting vents with caps and valves assure the proper accomplishment of the procedure.

Grouting & Venting Tubes/Valves at Anchorages Zone

Grout Mix Design

FORMULA

The water to cement ratio (w/c) will be as low as possible, thus providing a grout with low bleeding and volume change and a fluidity allowing to fill through the tendon. Grout temperature must be kept between 10°C and 25°C and fluidity has to be within 14~19 sec. Testing is carried out using a special fluidity cone. If the value is out of this range, the batch should not be used and a new water/cement ratio has to be defined so as to obtain a satisfactory fluidity.

The grout quantity per lt/m can be given by the formula:

$$\frac{\pi * (\frac{\Phi i}{2})^2 - A * n}{1000}$$

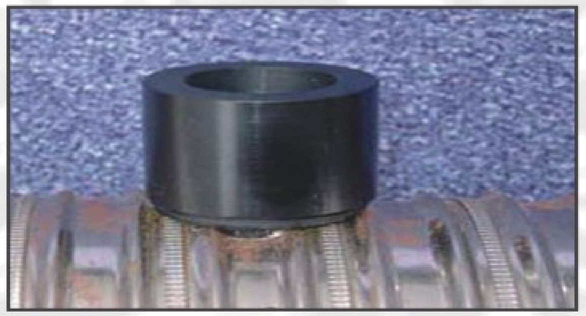
Where:

Φi (mm) = inner diameter of the sheath
A (mm^2) = one strand area
n = number of strands inside the tendon

Water is batched through accurately weigthing devices, in order to secure the stability of the produced grout.
Usually with 36~38lt of water and 100kg of cement we could produce 72~74lt of grout.
In case vacuum grouting is required a vacuum grouting pump should be used.


Grouting Vents, Saddles & Tubes at Steel Sheaths


Close View of a Grouted Tendon


Grouting Port in Steel Sheath

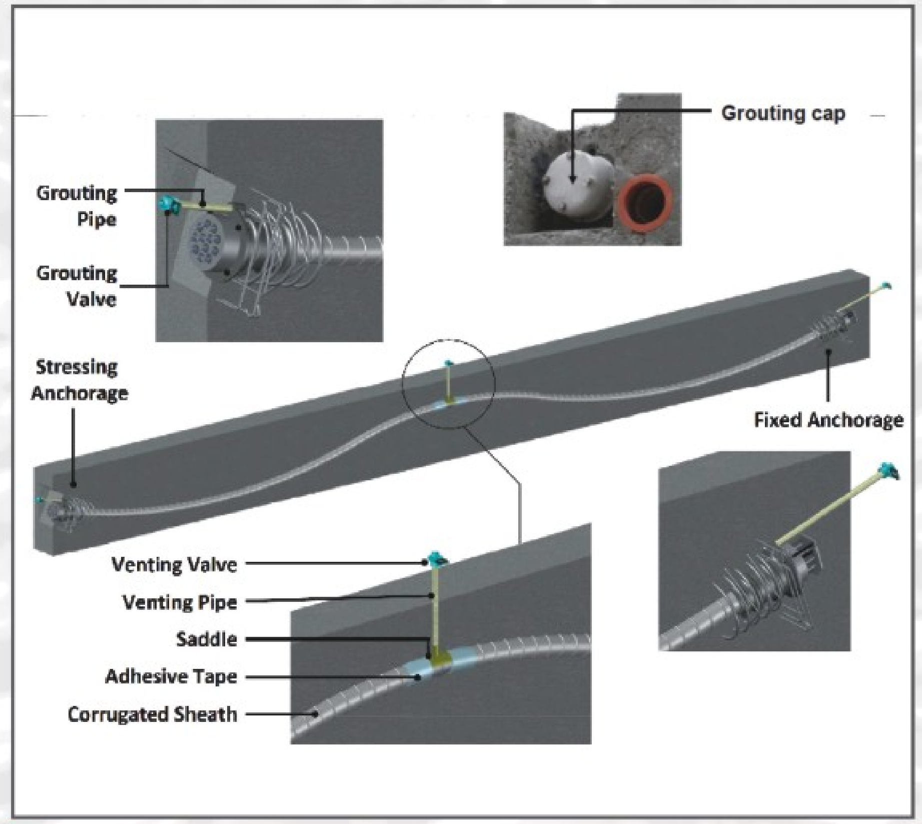

Grouting Port in Plastic Sheath


Fluidity Cone Test


Bleeding Test

Equipment & Ancillaries

Grouting Equipment consists of a high speed mixer, an agitator, a grout-pump and a hydraulic power unit, capable of continuous mechanical mixing which will produce a grout free of lumps and undispersed cement.



Breakthrough in Technology

SERVICES & TECHNICAL SUPPORT

Provision of complete package solutions including projects preliminary & final designs, supply of PT materials, equipment/machinery, alternative proposals and PT installation-planning-stressing-grouting and supervision services.

Study and evaluation of special demands for stressing forces and losses, lengths and type of tendons (internal - external post-tenioning), number and type of strands, sizes of anchorages, stirrups and grout mix designs and trials by providing customized solutions for all types of structures. Further details about PT applications upon contact with our Technical Dept.

This leaflet contains selectively the most characteristic products related with PT technology and general information for design and construction as well. Depending on projects requirements **HERCULES LMK's** anchorages can be modified accordingly.

HERCULES

CUM MANU ET CORDE

LMK Post Tensioning System

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